THE FRESHWATER MOLLUSCS OF THE NORTH-EAST SCOTLAND, WITH PARTICULAR REFERENCE TO THE FAMILY SPHAERIIDAE (MOLLUSCA, BIVALVIA, HETERODONTA, VENEROIDA)

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M.Sc. Geology (University of Perugia, 1992)

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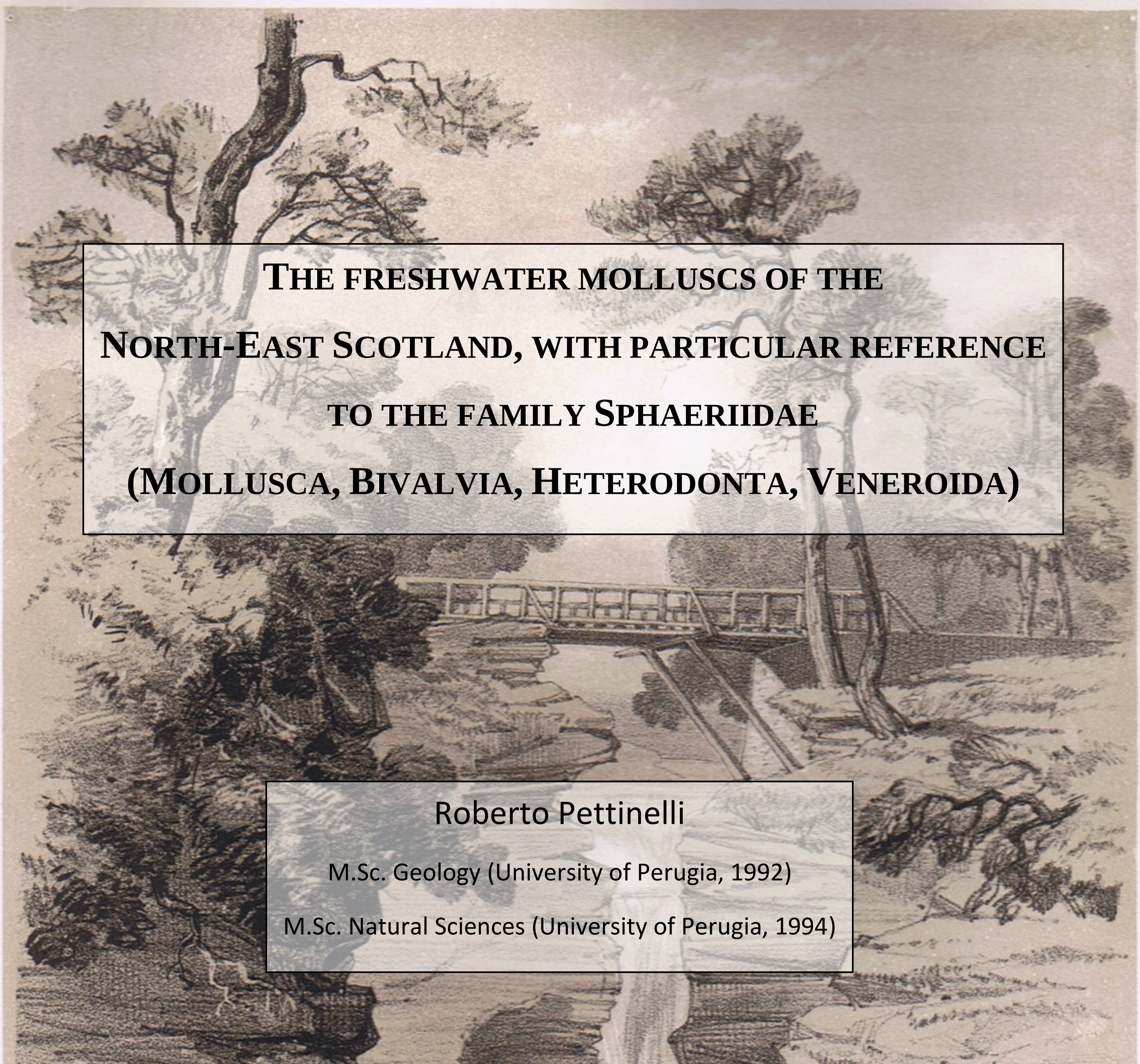

Linn of Dee: Gibb A., Hay J. M., 1884 - The scenery of the Dee, with pen and pencil. Gibb & Hay, Draughtsmen and Lithographers to Her Majesty, Aberdeen

LINN OF DEE.

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This research is the result of two years of field sampling and three years of laboratory activities. The important conclusions concerning the ecology and the zoogeography of the freshwater mollusc populations living in North-East Scotland have been achieved only through the continuous support of my first Tutor Dr. Mark Richard Young. Mark significantly contributed to the research planning and steering, giving me the necessary motivation to perform and complete this ambitious task.
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ABSTRACT

This research deals with a hydrobiological investigation performed in the North-East of Scotland, covering 5 vice counties: Angus (90), Kincardineshire (91), South Aberdeenshire (92), North Aberdeenshire (93) and Banffshire (94).

A total of 334 sampling stations have been located in the study area, with the aim to sample virtually every ecotope occurring within this research perimeter.

Systematic sampling performed over a vast area generated a huge number of sediment samples which were carefully examined under the stereoscopic microscope (ca. 500 kg in total), allowing counts and separation of a large number of molluscs.

Original site descriptions available in the literature have been carefully analysed and most places re-visited during field work.

Distribution maps for every taxon have been generated, integrating historical with new data, allowing an accurate reconstruction of the effective presence of a specific organism within the study area.

The total number of freshwater molluscs identified during this study amounts to 20 gastropods and 12 bivalves of which 10 are sphaeriids, whilst the complete fauna believed to inhabit the area consists of 21 gastropods (*Anisus leucostoma* presence here was not confirmed) and 14 bivalves (*Pisidium pulchellum* and *P. amnicum* were not found).

Detailed scanning electron microscope (SEM) observations have been carried out on selected specimens, primarily Sphaeriidae, which showed typical specific characters or clear anomalies in the shell. Teratological specimens among the Sphaeriidae are quite frequent, such as those affected by hinge reversal or by ventral-posterior repairs (diphyoidy).

The standardised sampling technique, coupled with measurements of chemico-physical parameters, allowed the data to be investigated following statistical approaches such as bivariate and multivariate analyses.

The hydrographic longitudinal gradient appears to be the most important ecological factor determining the genetic origin of an ecotope, considering that the water speed and consequently the sediment load are positively related to the thalweg inclination.

It appears that a negative relationship exists between altitude and conductivity, which is related to increase of the suspended and dissolved fractions of the stream load. Altitude and pH show a similar negative trend, in relation to the organic matter increase due to progressive

establishment of macrophyte communities and algal biomass proceeding towards the lowlands.

A classification analysis was carried out using cluster analysis on two different data matrices: 'stations vs all mollusc species occurrences' (Matrix-1) and 'stations vs all sphaeriid species occurrences' (Matrix-2).

Matrix-1 provided a dendrogram defining 11 groups of ecotopes (groups 1-11) at the fifth dichotomous level and a second dendrogram identifying 6 groups of species (groups A-F) at the third dichotomous level.

The results of this cluster analysis demonstrated the existence of groups of ecotopes which can be distinguished on the basis of the molluscan preferences, suggesting these groups share common ecological features.

It is notable that the persistence of mollusc assemblages is in those ecotopes where their ecological requirements are met.

For instance Group-C *(P. casertanum, P. personatum, Potamopyrgus antipodarum, Radix balthica* and *Ancylus fluviatilis)* is a recurrent assemblage, frequently found along the coastal stream system.

Matrix-2 (stations vs sphaeriids) splits 6 groups of ecotopes (groups 1bis-6bis) at the third dichotomous level and 3 groups of species (groups Abis-Cbis) plus *Musculium lacustre* at the third dichotomous level.

Group-Abis is represented by the generalist species *Pisidium personatum* and *P. casertanum.* These two sphaeriids occur in the vast majority of the ecotopes together with a variety of other molluscs, but where they are found alone is usually because they inhabit hostile environments such as river headwaters or coastal stream systems.

Similarly specific faunistic assemblages are frequently found in comparable habitats, demonstrating the direct relation between ecological parameters and species distribution. This phenomenon is nicely described in the river continuum concept (Vannote *et al.*, 1980), which explains that every species is adapted to specific environmental conditions, and where these are met the organism has the maximum probability of occurring.

Multiple linear regression (MLR) was run on Matrix-3 (mollusc species abundances vs ecological parameters) and Matrix-4 (sphaeriid species abundances vs ecological parameters) in order to test the significance of the ecological variables measured in the field in explaining molluscan abundance and diversity. Six out of twelve ecological variables were identified as significant to explain the dependent variable in Matrix-3, among which altitude, temperature and pH ranked as most important explanatory factors.

The same exercise performed on Matrix-4 drove to similar conclusion, with seven out of twelve explanatory variables retained in the model, with temperature, pH and current speed ranked as most important environmental factors.

In both cases the null hypothesis H_0, stating that no dependency exists between mollusc diversity/abundance and ecological variables, was rejected.

MLR allowed defining a new set of matrices: Matrix-5 (stations vs 6 ecological variables) for all mollusc species and Matrix-6 (stations vs 7 ecological variables) for sphaeriid-only species.

The multivariate analysis (CCA) performed on Matrix-1/Matrix-5 and Matrix-2/Matrix-6 proved to be a helpful tool for identifying some species affinities and establishing ecological gradients. The results obtained in Matrix-1/Matrix-5 and Matrix-2/Matrix-6 show some leading ecological variables such as conductivity and altitude to explain molluscan association distributions along a hydrographic longitudinal gradient (Axis-2). Similarly pH, temperature and current speed vectors define a trophic gradient along Axis-1.

The molluscan associations previously identified through cluster analysis are fairly well defined on the ordination cross-plots, confirming that the results already obtained are not by chance.

Finally, the longitudinal distribution of molluscs along rivers systems and the colonization of remote ecotopes located within the highland sector, suggest a possible role for Amphibia in passive transportation, particularly for the Sphaeriidae.

Different dispersal mechanisms are presented here and discussed in order to compare the specific effectiveness of each vector in relation to the mollusc morphological characteristics.

Key words: Great Britain, Scotland, Grampian, Cairngorm, Mollusca, Sphaeriidae, Hydrobiidae, cluster analysis, ordination analysis, multivariate analysis, CCA, glaciations, Loch Lomond Stadial, immigration, zoogeography, ecology, passive dispersal, teratology, diphyoidy.

1

INTRODUCTION

This research deals with freshwater mollusc populations inhabiting in North-east of Scotland, identifying distribution patterns and establishing relationships with those ecological parameters most influencing communities dynamic.

The study area roughly corresponds to the Grampians, a region still requiring detailed field investigations to better define distribution areas of freshwater invertebrate populations. The many records and observations performed over the past two centuries are also difficult to interpret today and their integration into the most recent ArcGIS-based repositories is complex and most of the times subjective.

For this reason it was decided to start this project with the aim of collating the most complete data set yet covering the whole Grampian Area. Standardised sampling techniques and accurate habitat description with the acquisition of key ecological parameters, allowed the building of a set of data matrixes used for bivariate and multivariate analysis.

This type of approach represents a classic and consolidated technique widely used among hydro-biologists to correlate ecological parameters versus species habitat requirements.

Molluscan distribution is closely related to ecological parameters, particularly for those species that have specific habitat requirements, defined as 'specialists' (Sturm, 2007). One of the most important factors directly impacting on chemico-physical parameters is the topographic gradient, which regulates water speed and sediment load (and consequently the majority of the ecological aspects). Also the distance to the sea influences the water chemistry of coastal hydrographic systems, constantly affected by tidal currents and exposed to sea spray (Bruyndoncx *et al.,* 2000). Additionally a number of other local factors, such as the geological nature of the substratum, may lead to the formation of microhabitats, as water composition changes according to the enrichment of ions. Fine examples of these local habitats can be seen across the mountain range of the Cairngorms, as in Loch Vrotachan, a cirque lake holding a highly diverse mollusc community. This peculiar environment is related to the presence of carbonate-rich rocks that provide significant amounts of calcium to the water, required for mollusc shell development.

Considering that the majority of the studied area falls in a hill-mountain range, with huge plateaux higher than 500 m AMSL, all extensively explored and sampled during field activities, the present research provides a significant contribution to understand mollusc requirements in such extreme environments.

Particular care has been given to analysis of historical data, in order to integrate work performed by other malacologists into an updated database which represents the best knowledge to date of the studied area. All the project datasets will be transferred to the Conchological Society of Great Britain & Ireland to update the national mapping scheme and to the NBN Gateway data collection scheme for their direct incorporation into the national online repository.

The first section of this chapter describes the project background and the aims of the research, fixing specific targets to be achieved during the project.

The second section provides a general introduction to the Grampian area, focusing on the main geomorphological features, starting from the highest peaks of the Cairngorms mountain range and concluding with a description of the articulated coastal fringe.

The third section deals with a historical excursion through the history of malacological recording, with particular emphasis on Scotland.

The fourth section is a literature review starting with the first studies dealing with mollusc ecological requirements followed by more recent multivariate analyses experiences performed by several authors over the last forty years.

1.1. AIMS OF THE RESEARCH

The North-East of Scotland is an under-recorded area for a wide range of invertebrates and particularly for molluscs. This because the majority of field researches have been performed in England, where the majority of malacologists have been active during the last three centuries.

Nevertheless the relatively high number of data records available for this region is primarily due to the work of occasional collectors, who sporadically submitted their material to the Conchological Society for taxonomic attribution validation. These verified records were reported in a specific section organised by county of the Journal of Conchology named ‘Recorder's report’.

The present field research conducted over a period of two years (2002-2003) deals with the freshwater molluscs inhabiting the North-East of Scotland. For the first time a systematic field collection targeting freshwater molluscs has covered the Grampian Area, examining a large variety of habitats ranging from brackish waters to mountain lakes.

This is an important step forward in freshwater mollusc ecology, as bivariate and multivariate analyses have been systematically applied to identify dependencies among ecological parameters and taxa preferences.

Considering the large variability of the studied environments, a standardized sampling technique has been regularly used in order to acquire data suitable for statistical analysis and numerical comparison. The results of this study have been compared with similar analyses performed in other areas by other authors, in order to identify convergence of ecological requirements within different co-specific populations.

Furthermore the consistency among the ecological and zoogeographical identified patterns, and the classic theories developed to justify benthic invertebrate distribution mechanisms, has been carefully analysed and discussed. Particularly the River Continuum theory (Vannote *et al.,* 1980) and the river longitudinal zonation scheme (Illies & Botosaneanu, 1963) have been critically reviewed and the mechanisms driving the invertebrate longitudinal distribution cautiously examined.

For the first time in the Grampian Area updated species mapping has been extended to the Cairngorms, a mountainous area poorly investigated, allowing distribution patterns to be related to interacting sets of different parameters.

Because of the recent origin of the British fauna, molluscan distribution patterns are mostly related to the ecological parameters of the surface waters; for this reason this study tries to identify the most important factors playing in the taxon-habitat equilibrium. Expanding the river continuum concept expressed by Vannote *et al.* in 1980 to all aquatic habitats, biological strategies and dynamics of molluscan communities adapt to a number of ecological and physical parameters, eventually establishing a dynamic equilibrium. The comparison with similar studies performed in various geographic areas, sometimes considering different species, allows establishment of the primary role of certain parameters in species survival in a defined habitat (e.g. trophic level, calcium concentration, etc.).

Moreover, despite recent faunal immigration, some patterns reflect a chorological contraction of the distribution area of some species considered as cold relicts from the last glacial event (Devensian Glaciation).

Discovery of Holarctic and Palaearctic relict populations of molluscs, mainly located within the mountainous range, are important in reconstructing the complex post-glacial evolution of the area. Major climatic changes have occurred during the last 10,000 years, defining the current drainage network and forcing an upstream migration of species less tolerant to the generalized warming (Kuiper *et al.*, 1989).

The large amount of field data collected during the survey phase, allows a satisfactory reconstruction of molluscan distribution, clearly identifying the main geographical patterns. Therefore it was possible to identify the most successful species, perfectly in equilibrium with present day environmental conditions, which are currently under expansion in the area. On the other hand relict species are sporadically found within the study area and only survive in ancient sites. This survey greatly increased the number of known stations, identifying the existence of valuable biotopes as well as better defining the ecological requirements of declining species.

This project comes 170 years after the first malacological monograph published in 1843 by emeritus professor William Macgillivray, King's College, Aberdeen. His book, 'A history of the molluscous animals of the counties of Aberdeen, Kincardine, and Banff; to which is appended an account of the cirripedal animals of the same district', still represents a fundamental work for the continental mollusc fauna of the North-East of Scotland. It is worth pointing out that already in the mid 19th century the general structure of the aquatic mollusc fauna living in the region was nearly identified, totalling 13 gastropod and 9 bivalve taxa, compared to the 21 gastropods and 14 bivalves known today. Despite the high number of malacological records collected during the 19th and 20th centuries all over Scotland, very little has been done to describe the habitats where these molluscs live.

One of the scopes of this project is to fill this gap, providing a more exhaustive ecological background concerning the freshwater molluscs living in the area, focusing on habitat requirements and identifying the main factors influencing the taxon-habitat dynamic equilibrium.

The main objectives of this study can be summarized as follows:

- Mollusc species distribution
  - Collate a complete set of references relevant to the area malacological records.
  - Produce an updated freshwater mollusc list for the Grampian Area.
  - Generate a set of distribution maps for every taxon identified.

- Taxonomy
  - Document specific variability among the Sphaeriidae family.
  - Investigate whether any conchological character, (such as internal micropores), has any relation to ecological conditions.

- Mollusc ecology
  - Test the null hypothesis H_0 that no dependency exists between mollusc diversity/abundance and ecological variables.
  - Establish which are the main explanatory ecological variables affecting molluscan abundance and diversity.
  - Ascertain which are the key ecological variables that most limit the spread of molluscs along the altitude gradient.
  - Verify if surface geology has any impact to molluscan diversity and abundance.
  - Relate the current molluscan population distributions to passive dispersal means.

Finally, this faunistic survey represents a useful tool for the conservation organizations that operate in the area, hopefully helping them to identify endangered populations and prevent damage to vulnerable habitats.

1.2. The Grampian Area

The general morphology of the Grampian region consists of a high plateau that rises from the coast to the mountainous area of the Cairngorms, and of wide lowland which follows the North Sea coast (Fig. 1). The Cairngorms mountain range is mainly characterised by broad summits, separated by impressive U-shaped valleys excavated by massive glaciers developed since the Devensian (Fig. 2). The River Dee drains a vast area of the Cairngorms attaining a length of about 140 km before opening in the North Sea through a wide estuary, currently occupied by Aberdeen harbour. On the southern side of the Dee Valley another broad plateau is found: Lochnagar. This massif consists of a set of peaks, which bound the northern side of Loch Muick, an elongated glacial lake that occupies the median sector of the Glen Muick valley. Southern Deeside is bounded by other considerable summits such as Mount Keen and Mount Battock, before gently descending towards the North Sea. The northern Deeside belt is characterised by a smaller hill range, which gradually descends from Ben Avon, the eastern main massif of the Cairngorms. Mount Morven is the last significant culmination that interrupts this lower hill range before entering in a vast lowland area, which extends down to the sea. Hill of Fare is the largest hill found in this area, separating the River Dee by another wide depression occupied by a rounded shallow lake: Loch of Skene.

Proceeding northwards the relatively broad River Don valley, mainly west-east oriented, is bounded on two sides by a gentle hills belt, rising to an average elevation of 700-800 m AMSL in the very upper sector, north-eastwards from Ben Avon. Some isolated hills occur along the northern range such as: Hill of Three Stones, The Buck, Correen Hills and Bennachie. These areas represent isolated highland environments within a landscape mainly dominated by lowlands. Continuing northward the area is mainly characterised by lowlands, extensively cultivated and occupied by a number of small to medium urban settlements. Only the upper sector of the River Deveron still belongs to a mountainous environment, sharing the watershed with the Don catchment area. The River Deveron is generally sinuous, being formed by at least two north-south and two west-east segments, before entering into the North Sea near Banff. The coast between the Spey mouth and the village of Fraserburgh is very indented: a variety of bays of different sizes are found intercalated between high cliffs and pronounced ridges.

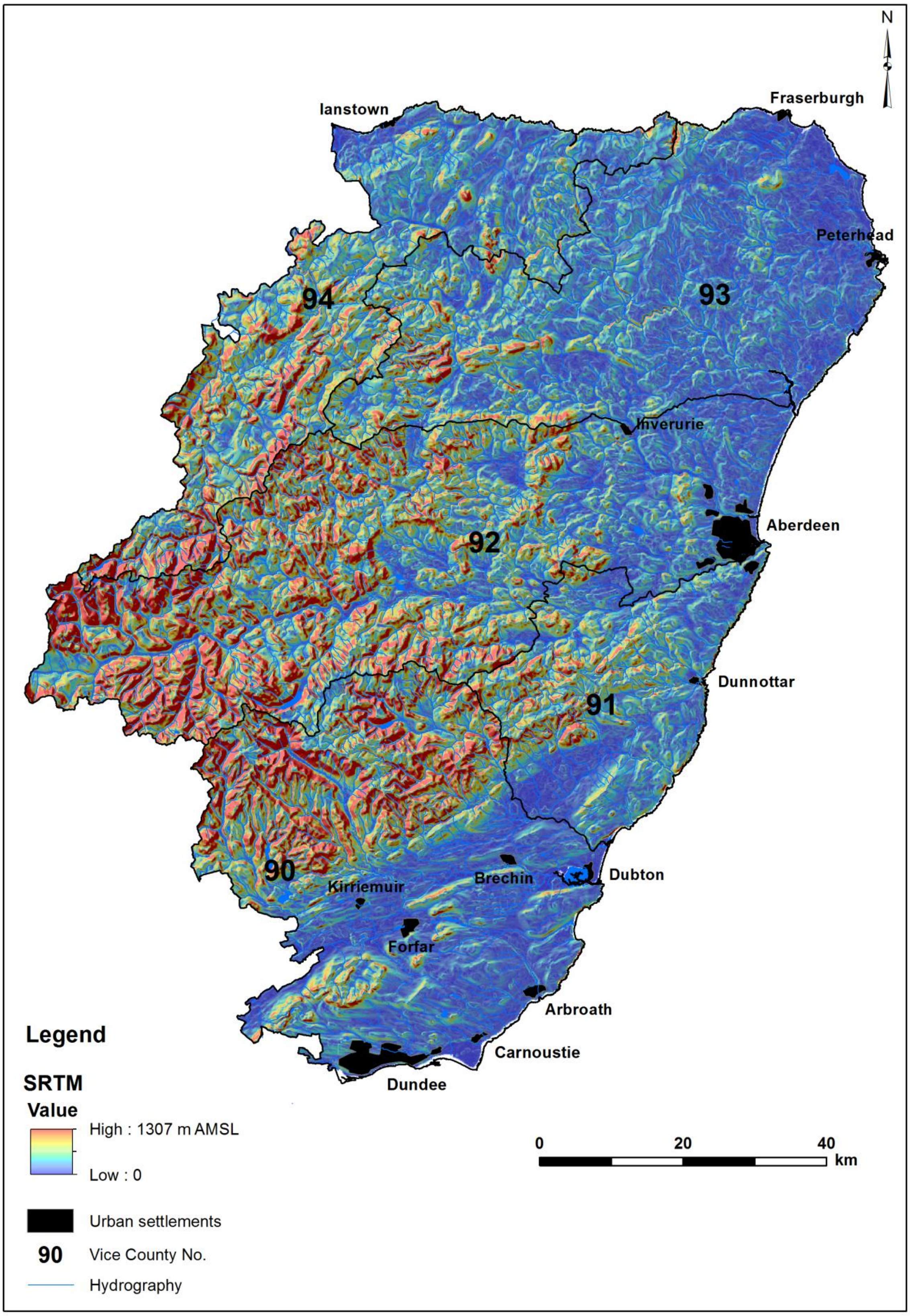

Fig. 1. Study area SRTM (Shuttle Radar Topography Mission) digital elevation model. This map clearly identifies the Cairngorms Area with the highest altitude (in red).

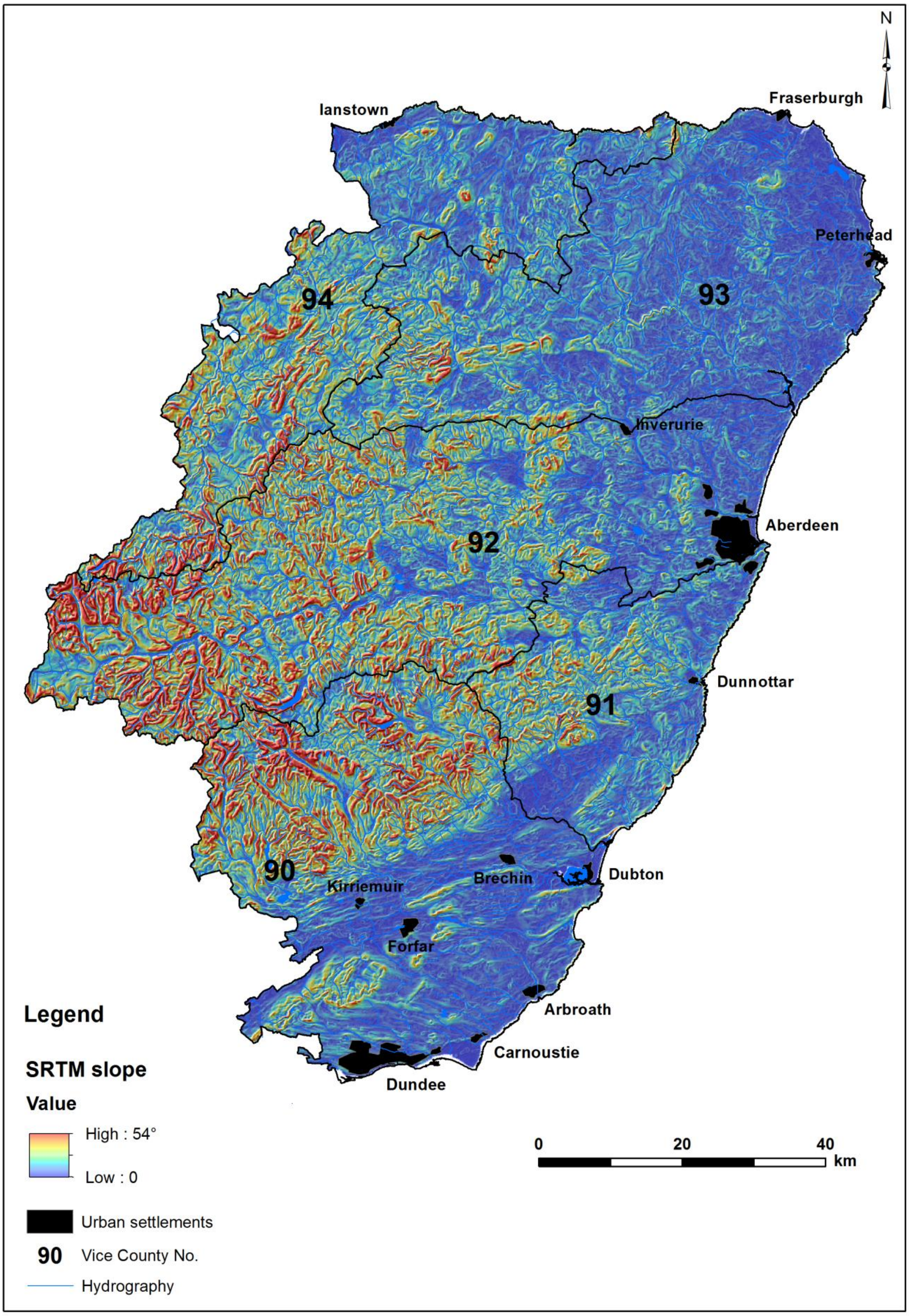

Fig. 2. Study area SRTM (Shuttle Radar Topography Mission) slope map.
This map shows the distribution of slope gradients from steep (red) to flat (blue).

The coast then gradually rises eastward, attaining a maximum elevation at Troup Head (112 m AMSL), near Pennan. Several north-south short streams flow toward this coast, mainly draining cultivated areas. Once passed the Fraserburgh cape a long low coast is found down to Peterhead. The Loch of Strathbeg is located along this sector, behind a well-developed dune belt system, which guarantees an efficient separation from sea water invasion. Near Peterhead the River Ugie terminates its west-east run into the North Sea, after having drained a large area between the villages of Towie and Maud.

Moving southwards the Buchan area is characterised by a high coast intensively carved by marine caves and sink-holes formed by structural collapse. In the past the area underwent intensive quarrying to extract valuable granite. The quarries abandonment resulted in the formation of a number of deep small pools fed by field waters, which represent an unusual environment for this area. Apart from the Cruden Bay area the rest of the coast down to Collieston is characterised by a medium-high cliff, dissected by very short streams, constantly fed by ground waters. The River Ythan is the third longest river of the Grampian Area (111 km), even if it flows exclusively on lowlands. Its course is very sinuous, being characterised by four main meanders, generating many abrupt direction changes at about a right angle. The Ythan mouth is a vast tidal flat, which allows a deep ingression of sea water through its river channel. The tidal influence is clearly visible up to the Kirkton of Logie Buchan Bridge, at a distance of about 7 km from the sea. From the Ythan mouth down to the town of Aberdeen there is an uninterrupted long beach, where a number of short streams find their way to the sea. The last portion of these channels is nearly parallel to the coast, being continuously pushed inland by sand dune migration driven by strong winds. To the south of Aberdeen the coast becomes high again, being characterised by an articulated cliff system, only interrupted by small bays. In the proximity of Crawton, the cliff is represented by a continuous rock wall higher than 40 metres before gradually degrading towards Inverbervie, where a low rocky coast, widely exposed during low tides, is located. A number of short-medium streams flow across this coastal tract, coming from the hill range situated immediately to the west. The Cowie, Carron and Bervie waters are examples of this type of stream. Finally the River Esk basin delimits the southwards extent of the study area, with the estuary located close to St Cyrus village. From here down to Montrose bay another long beach characterises the landscape. The River Esk upper sector is located to the south of Mount Keen, in an area dominated by hills of about 800 m AMSL. Before the confluence with Glen Mark (its left tributary) the valley opens widely, producing an elongated loch which occupies the bottom of an U-shaped section: the Loch Lee. The River Esk then flows through a low range of hill, where it has cut a deep gorge known as 'The Rock of Solitude'.

With respect to land use, the area shows a high percentage of lowlands, where the effects of anthropogenic activities are dominant among the other ecological factors, apart from the narrow strip of coastal sand dunes environments protected by the creation of natural reserves (Fig. 3).

Loch of Strathbeg and the Sands of Forvie are examples of this type of habitat, where the generally dry habitat of the sand dune belt is interrupted by the presence of streams flowing into the North Sea.

The most frequent plant association found at the back of the dune systems includes the following species: marram grass *(Ammophila arenaria),* red fescue *(Festuca rubra),* crowberry *(Empetrum nigrum),* cross-leaved heath *(Erica tetralix),* common sedge *(Carex nigra),* marsh pennywort *(Hydrocotyle vulgaris)* and the invasive creeping willow *(Salix repens argentea).*

The lowland sector of the Grampian Area is extensively cultivated, with crops mainly represented by barley, wheat, oilseed rape, potato and turnip. Clearly most of these cultivations are related to livestock farming, which requires a consistent amount of fodder for animal consumption. Crops appear to be the commonest land use feature of the North-East of Scotland (Fig. 3).

Lowland acid grassland occurs in nutrient-poor soils, characterised by pH values ranging between 4 and 5.5 as defined in the UK Biodiversity action Plan, prepared by the UK BAP Steering Group in 2008.

This vegetation cover is characterised by a number of plants, most commonly represented by heath bedstraw *(Galium saxatile),* sheep's fescue *(Festuca ovina),* common bent *(Agrostis capillaris),* sheep's sorrel *(Rumex acetosella),* sand sedge *(Carex arenaria),* wavy hair-grass *(Deschampsia flexuosa),* bristle bent *(Agrostis curtisii)* and common tormentil *(Potentilla erecta).*

Moving towards the hill range, particularly on the most sheltered slopes, the dominant vegetation cover is represented by moorland with dwarf shrubs such as heather *(Calluna vulgaris),* bilberry *(Vaccinium myrtillus),* cowberry *(Vaccinium vitis-idaea)* and bearberry *(Arctostaphylos* spp.). On wind-exposed summits this association is replaced by carpets of woolly fringe-moss *(Racomitrium lanuginosum)*, liverworts and lichen heaths.

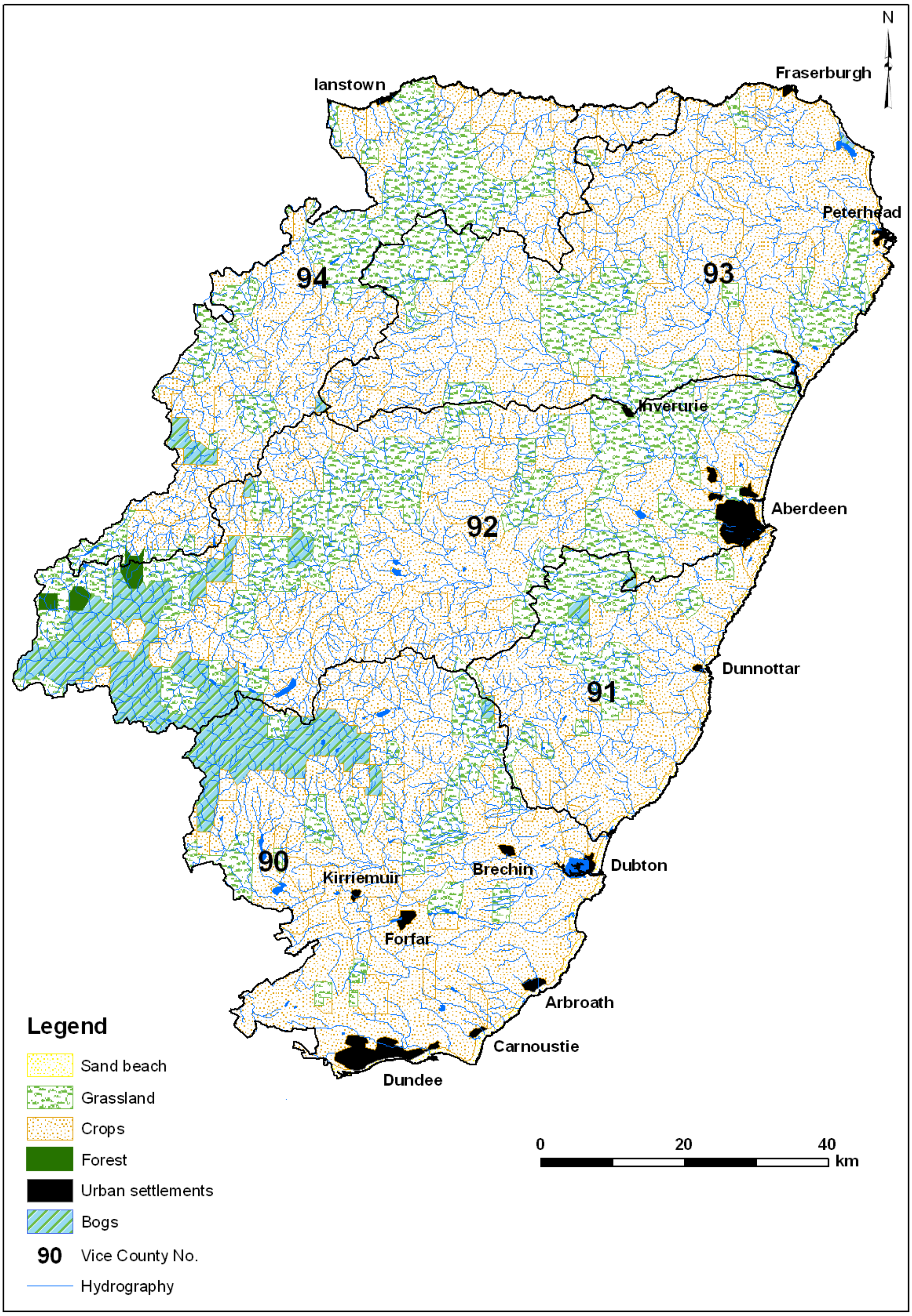

Fig. 3. Study area land use map.

The blanket bog is a peatland habitat typically associated with cool wet climates, under a direct maritime influence. It is one of the most widespread semi-natural habitats found in upland Britain, particularly in the Highlands of Scotland. The most frequent vegetation association characterising the blanket bogs is represented by heather *(Calluna vulgaris),* cross-leaved heath *(Erica tetralix),* deer-grass *(Scirpus cespitosus),* cotton-grass *(Eriophorum* spp.) and several species of *Sphagnum* moss (Cosgrove, 2002). In the studied area blanket bogs develop mainly in the uplands, which are located to the western side of the vice counties 90 (Angus) and 92 (Aberdeenshire South).

Forest patches occur sparsely in the Cairngorms area, representing remnants of a more extensive woodland cover known as the Caledonian Forest, which used to blanket much of the Scottish Highlands (O'Sullivan, 1977). These ancient woodlands are primarily formed by the native Scots pine *(Pinus sylvestris),* often associated with the pioneer colonist silver birch *(Betula pendula)* and other broadleaved trees, with the juniper *(Juniper communis)* as the main under-storey species.

The progressive expansion of the Caledonian Forest during the Flandrian Post-Glacial follows the general increase of temperature, which reached the thermal maximum during the Middle Flandrian sub-stage at around 6,000 years BP (Davis *et al.*, 2003). From this period onwards the climate became cooler and moister, causing development of blanket bogs, heath and grasslands on the Cairngorms massifs, with consequent withdrawal of the tree-line.

The occurrence of pine stumps in peat scours above the present tree-line, indicates that during the Early and Middle Flandrian sub-stages (10,000–5,000 years ago) the forest limit was about 200 m higher than today.

1.3. PREVIOUS MALACOLOGICAL STUDIES

This chapter discusses the composition of the Scottish freshwater malacofauna, with particular emphasis on the study area.

A general overview of the history of malacological research since its inception is given. The Grampian area is one of the less explored regions in Great Britain, despite hundreds of papers and short notes mostly written during the last 150 years. I have attempted to identify old localities in the current cartographic framework, and to compare historical records with new ones. The total number of malacological records retrieved from the literature amounts to 426 (original observations are reported in Appendix-I).

First indirect mention of the Scottish freshwater molluscs from the historical literature is given by the early Latin writers, who commented on British pearls two thousand years ago, at the dawn of the Christian era.

The Roman historian *Caii Suetoni Tranquilli (Suetonius,* ca. 69/75 - after 130 AD) in his biography of *Iulius Caesar,* the first of a set of twelve volumes written in 120 AD known as *'De Vita Caesarum',* stated that *Caesar* really admired the pearls that occurred in Britain and that they probably inspired the *Caesar* expedition to Britain in 55 BC[1].

Caii Plinii Secundi (Pliny the Elder, 23-79 AD) in his *'Naturalis Historia'* published circa 77-79 AD briefly refers in the IXth volume (probably published in 77 AD) to British pearls, which are small with a hue not comparable to the oriental specimens and that also *Iulius Caesar* dedicated a cuirass made of British pearls to Venus Mother[2].

Caii Cornelii Taciti (Tacitus, ca. 56 - ca. 117 AD) in his *'De vita et moribus Iulii Agricolae'* published in circa 98 AD comments that pearls (probably sea pearls) from Britain are dusky or brownish[3].

The Venerable *Baedae* (Bede, ca. 673-735), the ecclesiastic writer, in the first book of his best-known work '*Historiam ecclesiasticam gentis Anglorum'* completed in 731 AD, mentions the several colours observed among pearls from mussels of Britain's natural life[4].

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[1] XLVII. *Britanniam petisse spe margaritarum, quarum amplitudinem conferentem interdum sua manu exegisse pondus.*

[2] *In Britannia parvos atque decolores nasci certum est, quoniam Divus Iulius thoracem, quem Veneri Genetrici in templo eius dicavit, ex Britannicis margaritis factum voluerit intellegi.*

[3] *Fert Britannia aurum et argentum et alia metalla, pretium victoriae: gignit et oceanus margarita, sed subfusca ac liventia.*

[4] *Capiuntur autem saepissime et uituli marini, et delphines, nec non et balenae; exceptis uariorum generibus concyliorum; in quibus sunt et musculae quibus inclusam saepe margaritam omnis quidem coloris optimam inueniunt, id est et rubicundi, et purpurei, et iacintini, et prasini, sed maxime candidi.*

In ca. 1070 *Marbodi Redonensis (Marbodus,* Bishop of Rennes, ca. 1035-1123), referred in his *'Liber de Gemmis'* to British pearls, comparing their beauty to those of Persia and India.

During the twelfth century a Scottish pearls market was held in Europe, where they were valued less than those from Orient (Kunz & Stevenson, 1908).

In 1527 the Scottish historian and humanist *Hector Boethii* (or *Boecius,* 1465-1536), provided a detailed description of the fishing techniques used by pearl fishers to gather pearls from the waters of the rivers Dee and Don.

British pearls are mentioned again in 1560, when fine large pearls although not quite good as the oriental ones, were sent from Scotland to Antwerp (Macpherson, 1805).

In 1586 the first edition of *'Britannia'* appeared, a topographical and historical survey of all Great Britain and Ireland written by William Camden (1551-1623), which was considerably enlarged in subsequent revisions, particularly in the 1610 edition, the first English translation from the Latin by Philemon Holland. In *'Britannia'* it is mentioned that British and Irish pearls are peculiar to rapid and stony rivers in Wales, North of England, Scotland and some parts of Ireland.

In 1596 the historian John Lesley (or Jhone Leslie, 1527-1596), Bishop of Ross [=Rosse] in his 'The Historie of Scotland', reported some information concerning the commercial value of Scottish pearls and their abundance in the Laudien Land (Lothian), particularly those from freshwater[5].

In 1620 a great pearl was found in the Water of Kelly, at the junction with the River Ythan in Aberdeenshire (Manson, 1845).

In 1621 the Privy Council of Scotland proclaimed that every pearl found within the realm belonged to the crown and pearl fishing conservators were appointed in several counties including Aberdeenshire (Kunz & Stevenson, 1908).

Afterwards British pearls are mentioned again in a letter addressed to James VI in 1622 by the Earl of Melrose. In this letter it is reported that pearls are found in many river catchments across Britain, including the River Ythan, where a large pearl was granted to Mr. Buchan of Auchmacoy (Stewart, 1909).

[5] In Laudien Land farther, and lykwyse in vthir prouinces with ws ar funde Gemis, thir, to wit: the Turques, the adamant, the Rubie, and the Margarite in gret number, bot the Turques, and the Rubie ar verie rare and few to be funde, bot the adamant ar in gretter number, than thay ar deir: bot the Margarite is baith welthie and of a noble price. Thay indeid schawe a schyneng brichtnes, notwithstanding mair obscuir than thay quhilkes ar brocht in frome the Eist. In freshe water buckies nocht pleisand to the mouth, na lesse than in salt water buckies growis the Margarite.

In 1684 Sir Robert Sibbald, physician to Charles II of England, praised the great beauty of a Scottish pearl necklace in the third volume of his '*Scotia illustrata sive Prodromus Historiae Naturalis'*.

In 1688 Robert Redding in a note communicated by Dr. Martin Lister in 1693 accurately described the fishing techniques used by local people in North Ireland to secure the molluscs, using either their toes, or wooden tongs or even thrusting sharpened sticks directly into the valves.

About 1750 Mr. Tower of Aberdeen received £100 from a London jeweller 'for a quantity of pearls, which were taken out of the mussels that were found in the Ythan' (Keith, 1811).

In 1771 the eminent conchologist Pennant cited the Ythen [=Ythan] as a productive river of the pearl mussel. He also reported in his British Zoology (Pennant, 1777) that this species, noted for producing quantities of pearls (up to sixteen pearls were found in a single specimen), is widely distributed within the great rivers flowing through the mountainous parts of Great Britain. Pennant also mentioned that 'muscles are also much used for bait, and many boats loads are brought for that purpose from the mouth of the Ythen', statement frequently quoted by later authors (e.g. G. J., 1829; Johnston, 1850).

In 1861 a German merchant named Unger, who travelled across the districts of Tay, Doon and Don, bought up all the Scottish pearls he could obtain with the aim of selling them on European markets such as in Paris, raising an extremely good profit (A.W.C.H., 1890).

In 1867 the Rev. James Brodie from Monimail, Fife, wrote an article on the pearls of the River Ythan with particular reference to a famous pearl found in this river and later sold to the king.

The exploitation of the pearl mussels in Scottish rivers and streams caused a rapid decline of populations; the climax of destruction came in 1913, after a series of intensive campaigns carried out by two well-equipped bands of fishers (Ritchie, 1920)

With the second half of the 19th century the freshwater malacology of Scotland becomes an important research field, after the publishing of fundamental standard works such as Forbes & Hanley (1853a-d), Jeffreys (1862, 1863, 1865, 1867, 1869) and Taylor (1894-1900, 1902-1907, 1906-1914, 1916-1921). These monographs also include a reference to the Scottish fauna, which begins to be considered and studied, following the frantic description of the English fauna carried out during the first quarter of the 20th century. During this period a number of clubs and societies devoted to Natural Sciences flourished in Scotland; their members actively collected material over their areas of residence and started to compile the first species distribution lists. Many records were validated by the most authoritative exponents of the malacological world at that time such as William Denison Roebuck, Henry Coates and William Evans. The zoological nomenclature used at that time is today not longer valid in the majority of the cases, having been continuously revised especially for problematic groups such as the Sphaeriidae. Therefore, for certain easily identified species, these 150-years-old records still remain valid, and are a valuable source of information for comparison to current taxa distribution maps. As a consequence it has been possible to reconstruct distribution changes of certain species, demonstrating the progressive expansion of alien taxa (e.g. *Potamopyrgus antipodarum)* or the decline of some native species *(Margaritifera margaritifera).*

The first malacological monograph for Aberdeenshire was published by Macgillivray in 1843, describing a total number of 13 species of freshwater gastropods and 9 bivalves. This work provided a significant contribution to the characterization of Scottish malacofauna. As much as two thirds of the species identified today (consisting of 21 gastropods and 14 bivalves) were reported by this early author. In 1855, a year after his death, another monograph by Macgillivray mainly focused on the Deeside area, was published posthumously, adding a few other taxa to the existing list. These two works represent the first reference to sphaeriids in the North-East of Scotland. Today the validity of these records lacks taxonomic meaning because some of the cited taxa such as *Pisidium Joannis, P. Jenynsii* and *P. pusillum* have been synonymised with other species. In addition some common sphaeriids such as *Pisidium personatum*, *P. subtruncatum*, *P. lilljeborgii* and *P. hibernicum* had not yet been described at that time and some older records may be referred to these taxa.

Another significant impetus to the growth of Scottish malacology was foundation of the 'Perthshire Society of Natural Science' and the consequent publishing of magazines such as 'The Transactions and Proceedings of the Perthshire Society of Natural Science' (1867-1954, afterwards published as 'Journal of the Perthshire Society of Natural Science') and the 'Scottish Naturalist' (1871-date with which is incorporated 'The Annals of Scottish Natural History' for the period 1892-1911 and the 'Western Naturalist' for the period 1972-1982). These magazines represented the most authoritative knowledge available to researchers during the 19th century, where a number of important works on Scottish molluscs were published. The most important Scottish Malacologists of that time such as Francis Buchanan White (first President of the Perthshire Society of Natural Science) and Henry Coates wrote their contributions (mainly relevant to the Perthshire area) in these periodicals, opening a flourishing period for the development of British natural science during late Victorian times.

In 1870 another important malacological list appeared for Aberdeenshire and Banffshire, compiled by Dawson and dealing mainly with marine molluscs.

In 1874 the Conchological Society of Great Britain and Ireland was constituted, publishing a magazine called 'The Quarterly Journal of Conchology'. Subsequently in 1879 this periodical changed its name to 'Journal of Conchology', which survives today 134 years later.

In 1880 Rimmer published an illustrated manual 'Land and freshwater shells of the British Isles', which included references to the Scottish fauna.

In 1885 the series of the 'Census of the authenticated distribution of British land and freshwater Mollusca' commenced; a periodical publication of the 'Conchological Society of Great Britain and Ireland', originally published in the Journal of Conchology. The first issue was edited by Taylor & Roebuck (1885), who also took care of the second edition published in the monograph on land and freshwater shells edited by Williams in 1889 (Taylor & Roebuck, 1889).

In 1886 Coates accomplished its first attempt to catalogue all the historical references available for the Aberdeen, Kincardine, Forfar, Fife, Kinross and Perth vice counties.

In 1891 Roebuck started an independent 'Census of Scottish land and fresh-water Mollusca' published in the 'Proceedings of the Royal Physical Society of Edinburgh' (Roebuck 1891a). This was an effort to improve the number of Scottish malacological records, a place physically affected by the lack of resident malacologists. This work was followed by six updates published during 1891-1895 in 'The Scottish Naturalist' and in the 'Annals of Scottish Natural History', mainly dealing with additional records for the western vice counties (Roebuck 1891b, 1892a-b, 1893, 1894, 1895).

Between 1890 and 1899 Scott wrote nine contributions called 'The invertebrate fauna of the inland waters of Scotland', published in the periodical 'Annual Reports Fishery Board for Scotland' of Edinburgh, providing a significant contribution defining the Scottish fauna (Scott, 1890, 1891, 1893, 1894, 1895, 1896, 1899). Contributions No. 7 (1897) and No. 8 (1898) were performed with the contribution of Duthie.

The third edition of the Conchological Society's Census by Taylor & Roebuck appeared as an independent chapter in 'The collector's manual of British land and freshwater shells' published by Adams in 1896.

The fourth edition of the census edited by Taylor & Roebuck appeared once again in the third edition of the 'Land and freshwater shells' booklet edited by Williams in 1901.

A year later (1902) Adams compiled the fifth edition of the Census, this time published in the Journal of Conchology.

Stewart (1909) reports a number of British drainage basins where *Margaritifera margaritifera* is found, including the North Esk, the Dee and the Don in Aberdeenshire.

In 1910 the first volume of 'The Book of Buchan' (Tocher ed.) was released; a monograph collating several works of natural science and history, including an interesting contribution (Simpson, 1910) on pearl fishing and general matters concerning *Margaritifera margaritifera*. In this paper it is stated that the chief sources of pearl mussels in the Buchan area are the rivers Ythan and Ugie, where the mussels are commonly seen throughout the lower reaches.

Significant progress in defining the malacological fauna of Aberdeenshire and Kincardineshire was achieved after the publication of three distinct contributions by Booth, appeared in 1913 in 'The Scottish Naturalist' (Booth, 1913a-c).

In the same year (1913) Woodward published an impressive monograph on British Sphaeriidae, mainly based on meticulous analysis of the historical collections stored in the Natural History Museum of London and on accurate bibliographic research.

In 1917 Roebuck published in 'The Scottish Naturalist' a couple of short notes dealing with materials from Banffshire provided by Gowan (Roebuck, 1917a-b).

In 1917 there appeared for the first time in the Journal of Conchology a section entitled 'Census authentications', which became an important tool for collating and validating British malacological records. This section later changed its name to the 'Recorder's Report', still regularly published in the Journal of Conchology today.

In 1921 the sixth edition of the Census was published in the Journal of Conchology, edited by Roebuck.

A year later (1922), another version of Coates' report of bibliographic references dealing with land and freshwater molluscs of Perthshire and adjacent areas appeared in the 'Transactions of the Perthshire Society of Natural Science' (Coates, 1922b).

The first edition of the 'British Snail' by Ellis was published in 1926, a fundamental standard work with reference to the distribution of species within the British Isles (including Scotland).

In the same year Gowan published a significant work for the Banffshire area, and in 1929 Waterston added more data to the historically neglected county of Kincardineshire.

In 1940 Ellis started to publish the first of three contributions dealing with the British bivalve fauna. This first work specifically addressed the *Pisidium* species, followed in 1946 by a second contribution on *Corbicula, Sphaerium, Dreissena,* and finally (1947) by a third part dealing with the Unionacea. All these works report general information regarding species occurrences in Scotland.

The seventh edition of the Census edited by Ellis appeared in the Journal of Conchology in 1951.

In 1952 the first ecological study on Scottish molluscs at high altitudes was delivered by Stelfox, followed in 1956 by another similar contribution by Hunter & Hunter.

In 1959 Richter tried to clarify the status of the expansion of the New Zealander invader *Potamopyrgus jenkinsi* (i.e. *Potamopyrgus antipodarum)* in the North-East Scotland, providing notes about its preferred ecological parameters.

In 1962 the first edition of the fundamental work on the 'British freshwater bivalve Mollusca' was published by Ellis. This work discusses the zoological characters distinguishing different sphaeriid species and varieties, providing a comprehensive set of area distributions and vertical ranges.

In 1966 Kerney contributed a supplement to the seventh edition of the Census, once again published in the Journal of Conchology.

A year later (1967) Kerney wrote the fundamentals of procedures for mapping the land and freshwater molluscs in the British Isles, methodology still applied today in field work.

In 1971 Anderson performed an ecological study concerning the *Hydrobia [=Peringia] ulvae* population living in the Ythan estuary.

In 1973 an important monograph relevant to the Loch of Strathbeg was disclosed by Bourne *et al*. This work is an important attempt to identify its invertebrate fauna with notes on the ecology of its habitats.

In 1976 Kerney compiled the first version of the 'Atlas of the non-marine Mollusca of the British Isles', a vanguard work, which maintained its validity for more than twenty years. During the same period a series of studies sponsored by Aberdeen University commenced, to investigate aquatic habitats and characterise the freshwater invertebrate communities (Young, unpublished data; Bwathondi, 1976; Davidson, 1977; Forteath, 1977, etc.).

In 1977 Bishop published an interesting paper dealing with the molluscan habitats within an area in the central highlands of Scotland. This work provided useful information regarding the vertical distribution of the molluscs in a high altitude area, attempting to identify relationships between the nature of the soils, water chemistry and species distribution patterns.

In 1980 Davidson & Young performed an important study for the Nature Conservancy Council regarding the invertebrate fauna of the River Dee and its main tributaries.

In 1982 Kerney managed the eighth edition of the Census and the year after the IUCN red data book (Wells *et al.,* 1983) was published: the first important work focused on conservation issues of endangered species.

In 1983 a number of studies dealing with *Margaritifera margaritifera* commenced, led by the Aberdeen University researchers (Young & Williams, 1983a-b, 1984; Young, 1984).

In 1985 a multidisciplinary team, studying the area from different perspectives, accomplished another important monograph on the Deeside edited by Jenkins.

In 1991 the British red data book no. 3, relevant to invertebrates other than insects (Bratton ed., 1991) appeared.

The last significant study focused on the vertical distribution of molluscs in Scotland was performed by Marriot & Marriot in 1992, who carried out detailed field samplings in the Ben Lawers area, Perthshire.

In 1994 Woodward wrote a book dealing with the history of Scottish pearls, where he tried to trace the origin of the pearl fishery and the reasons for the global decline of *Margaritifera margaritifera*.

It appears that the last report on the status of this bivalve was prepared for the Scottish Natural Heritage by Cosgrove & Young (1998).

In 1999 Kerney completed his latest version of the 'Atlas of the land and freshwater molluscs of Britain and Ireland', a standard work which summarises and discusses all the historical records for each single species occurring in the British Isles (Kerney, 1999b). The latest monograph on British bivalves was published by Killeen *et al.* (2004), who provided an accurate description with an adequate number of plates illustrating shell variability and taxonomical characters for all the British species. Distribution areas are also discussed in relation to habitat requirements and human pollution.

1.4. Ecology of freshwater molluscs: a historical perspective

Many authors concentrated their studies on multivariate analysis in various parts of the world, trying to establish general rules behind the molluscan zoogeographic patterns. The role of calcium in freshwater mollusc proliferation was already invoked in 19^{th} century as the most effective of the environmental factors considered.

Boycott (1921, 1936) following the observations of Roebuck (1921) in his Scottish census clearly stated the importance of calcium content in controlling the molluscan distribution and population size. Boycott (1936) also stated that among British freshwater molluscs there are no real calcifuge species, but species who can live in soft waters such as *Limnaea peregra [=Radix balthica]* and *Ancylus fluviatilis* among gastropods, and *U. margaritifera [=Margaritifera margaritifera], P. cinereum [=P. casertanum], P. hibernicum, P. lilljeborgii* and *P. nitidum* among bivalves. Boycott defined the calcium concentration of 20 mg/l as a critical figure below which a number of calciphile species seldom or never occur. Calcium content plays also a determinant role in the development of aquatic vegetation which inevitably creates more shelter, humus production, etc. Consequently it becomes quite difficult to establish the real role of calcium in the growth of molluscan communities as it is tightly interrelated with other dependents ecological factors.

Altitude is another fundamental parameter limiting molluscan distribution, being directly related to temperature and consequently to the risk of freezing.

The importance of calcium supply was also highlighted by Hubendick (1947) for the limnophile gastropod fauna inhabiting the lakes of Northern Europe. He also concluded that a rich mollusc fauna is on average associated with deciduous forest, cultivated land, clay soils, calcareous areas, abundant vegetation and more generally to eutrophic conditions.

Macan (1950) explored a large number of water-bodies in a small, geologically uniform area located in the Lake District (England). Three main types of water-body were recognised: lakes, tarns and pools. During this study he collected 12 species of gastropods and 15 species of bivalves, including 11 species of *Pisidium;* calcium content, alkalinity and electrical conductivity were also measured. Molluscan distributions were also compared to water surface and botanical stages. The results of this study show a good correlation between calcium content (and electrical conductivity) and species distribution. This evidence demonstrates once again the importance of calcium concentration for mollusc populations. *R. balthica* for instance, a species well adapted to live in a wide range of waters, was hardly found in habitats with a minimum calcium content below 3 mg/l. Macan also noticed that a low calcium concentration may be compensated by the large size of the water body, the same conclusion reached by Boycott in 1936. The role of altitude on the austerity of the mountain environment and consequently on the capability of molluscs to survive in extreme environments was also confirmed.

In 1971 Green performed Multiple Discriminant Analysis (MDA) on 10 bivalve mollusc species (out of 22 residing species) identified from a total of 382 samples collected from 37 lakes in Central Canada. Nine ecological parameters were chosen and measured: pH, total alkalinity, calcium, total hardness (less calcium hardness), sodium chloride, depth, mean sediment particle size, percentage loss on ignition and sorting coefficient of sediment. Green's conclusions stated that a real separation exists among the 10 bivalve species defined in ecological spaces. Four discriminant functions depending on some of the 9 ecological parameters were considered in this study: calcium and total alkalinity (DF I), depth and sediment particle size (DF II), particle size and organic content (DF III) and NaCl relative to other non-Ca salts (DF IV). This approach demonstrated to be valid as ecological niches for some of the analysed species living in different lakes were nicely defined on the DF cross-plots.

Dussart (1976) with the aim to establish whether the direct relationships between water hardness and field distribution applies to British freshwater molluscs, performed forward stepwise multiple regression analysis using 12 hydrological factors: bicarbonate alkalinity, calcium, total hardness, magnesium, nitrate, phosphate, sodium, potassium, temperature, pH, chloride and dissolved oxygen. Among thirteen sites sampled in North-West England, Calcium hardness, total hardness and pH were identified as significant factors affecting the distribution of 9 mollusc species (P < 5%). *Planorbis planorbis, Pisidium* spp. *Lymnaea peregra, Bithynia tentaculata, Potamopyrgus jenkinsi [=P. antipodarum]* and *Sphaerium corneum* were found more abundant in harder waters, *Planorbis albus* and *Ancylus fluviatilis* were most abundant in soft waters while *Physa fontinalis* was more frequent in medium hardness waters. Another forward stepwise multiple regression analysis applied to the same sampling stations was performed by Dussart in 1979, using the same hydrological factors (plus mud substratum size, rock substratum size and number of molluscs per month) but focussing on distribution and growth patterns of 4 gastropod species over a year period: *Bithynia tentaculata, Gyraulus albus, Planorbis planorbis* and *Lymnaea peregra* (Dussart, 1979a). Surprisingly potassium, nitrate and rock substratum were all significant physico-chemical factors for *B. tentaculata* but not calcium. Furthermore mud substratum, nitrate, phosphate and dissolved oxygen revealed to be significant factors for *G. albus*. Major factors for *P. planorbis* were rock substratum, calcium and total hardness. Finally magnesium, calcium, phosphate and mud substratum, were all significant variables for *L. Peregra*. Dussart (1979b) also performed forward stepwise multiple regression analysis on a reduced subset of 11 sites of the original field campaign (Dussart, 1979a), sampled over a year period, with the aim to establish more detailed physico-chemical requirements (same factors as before) for *Sphaerium corneum* and *Pisidium* spp. The results showed the following variables to be highly significant ($P < 0.01$): bicarbonate alkalinity, potassium, calcium and magnesium for *S. corneum* and phosphate, magnesium, mud substratum and oxygen percentage saturation for *Pisidium* spp. These factors are clearly not independent and may be interrelated, for example, phosphate-rich waters support plant growth, which in turn may favour sedimentation of silting (mud substratum).

Aho *et al.* (1981) studied 363 sample sites from a total of 72 lakes located in southern and western Finland. Twenty gastropods species were identified and three ecological niches (lake area, total hardness and colour of water) defined and used to run a similarity dendrogram able to group species in clusters. The conclusion was that the three species clusters identified are formed on the basis of physical environments, with the total hardness considered as the most significant ecological factor. The role of submerged vegetation in molluscan distribution was also confirmed (as initially highlighted by Boycott in 1936) as some species such as *Physa fontinalis* live exclusively on macrophytes.

In 1985 Davidson *et al.* assessed the invertebrate distribution along the River Dee using TWINSPAN and DECORANA analyses, trying to subdivide the system into homogeneous sectors. The TWINSPAN analysis performed on the sites/species matrix produced a subdivision into ten groups of sites with ecological affinities and twelve groups of species with similar preferences. The dichotomous divisive process was arrested in both cases at the fourth divisive level. The group affinities to the sites indicated a higher grouping level allowing the combination into two major categories: main river and middle tributaries sites. This high level site association was nicely confirmed by the DECORANA analysis, where a clear distinction between main river & upper tributaries and lower & middle tributaries emerged in the ordination plot.

In 1986 Pip surveyed a total of 38 species of molluscs in more than 400 aquatic habitats located in the central Canadian region and examined a number of ecological parameters: water body type, sediment type, gastropod community diversity, submerged macrophyte diversity, surface water pH, total dissolved solids, total alkalinity, chloride, sulphate, nitrate/nitrite and soluble reactive phosphorus. Cluster analysis was used to show similarities between ponds and distribution type for the molluscs occurring in the study area. Calcium hardness, total alkalinity and pH were recognized as key parameters, controlling molluscan distribution. Macrophyte communities were also identified as indicative of the water quality. Pip also noticed that species which could tolerate high water chemistry parameters values tend to have wide tolerance ranges. Consequently this ecological adaptability would be expected to be advantageous in that the capacity to colonise a new habitat would be enhanced.

Hornbach & Cox (1987) attempted to relate life history traits of ten *Pisidium casertanum* populations from a range of environments (both lentic and lotic) located in Virginia (USA), together with other sites known from literature, with habitat typology. Principal Component Analysis (PCA) was conducted using the following demographic data: maximum shell length, maximum life span, number of generations per year, age at first reproduction, maximum number of embryos per parent and maximum embryo size. The study suggested that factors such as habitat predictability (i.e. more stable conditions) and habitat favourability (e.g. temporary ponds versus littoral lakes) play a fundamental role in conditioning population dynamics, driving successful colonisation.

Pip (1988), studying the freshwater gastropod occurrence (36 species) in 430 sites located in central North America with respect to six ecological parameters (total alkalinity, total dissolved solids, chloride, sulphate, phosphorus, and dissolved organic matter), defined some ecological niches applying cluster and principal component analyses. Cluster analysis between gastropod species and niche congruency showed clear grouping of taxa owning different tolerances for inorganic parameters, but in general all taxa occupied a broad spectrum of chemical niches.

PCA distinguished six groups of taxa, occurring in different habitats: groups A and B included species living in water characterised by low total dissolved solids (generally located in the Precambrian Shield), whilst Group-C mostly preferred ponds and small lakes with intermediate water chemistry values. Group-D was mostly represented by taxa inhabiting lakes, and Group-E linked together tolerant species widespread in a variety of water chemistry types. Finally species belonging to Group-F generally occurred in waters falling at the extreme ranges of water chemistry, ecological conditions frequently met in ponds.

In 1988 Bailey ran PCA on forty-one sites in Inner Long Point Bay, Lake Erie (Canada), inhabited by a rich molluscan community characterised by nine gastropods and twenty-four bivalves species. The following were the environmental data used for this analysis: alkalinity, calcium, pH, depth, % sand and LOI (loss on ignition). The author identified a strong negative correlation between the macrophyte and fingernail clam species richness with exposure or turbulence in the benthic habitat. Macrophyte richness appeared to be negatively correlated with exposure, whilst fingernail clam richness was found to be positively correlated.

Kilgour & Mackie (1988) running stepwise multiple regressions, found a direct correlation between the total sphaeriid density and abundance of twelve species of *Pisidium* in Britannia Bay on the Ottawa River (Canada) and some ecological parameters such as: sediment particle size, organic matter content, algal biomass and depth. These parameters were considered to be the main factors affecting the population dynamics. More in detail a unimodal distribution of the sphaeriid mean diversity versus mean particle size was observed, with an optimum at 0.18 mm, suggesting that finer or coarser sediment sizes may disadvantage sphaeriid proliferation (i.e. low oxygen content in fine or high energy in coarse sediments).

In 1991 Kilgour & Mackie performed multivariate analyses (PCA) on 17 populations of *Pisidium casertanum* in Ontario (USA), trying to relate population demographics (abundance, productivity, biomass, number of shelled larvae per adult, adults length at which develop shelled larvae, lifespan and maximum adult size) to environmental conditions (mean particle size, loss on ignition of fine sediments, loss on ignition of coarse sediments, dissolved oxygen, temperature, pH, conductivity, alkalinity, calcium hardness, sulphate and organic seston). The demographic patterns were mainly related to water chemistry (specifically buffering variables and sulphate levels) and temperature.

Benzie *et al.* (1991) applied multivariate analysis to 7 major North-East Scotland rivers using a chemico-physical data base available from the North-East River Purification Board. PCA was run using the following parameters: conductivity, BOD, suspended solid, alkalinity, pH, NH, NO, total oxidised nitrogen, orthophosphate, orthosilicate, chloride, oxygen concentration, oxygen saturation and temperature. PCA plots highlighted clear parameter patterns, suggesting strong dependency on conductivity and ion content, discriminating between highland (e.g. Spey and Dee rivers) and lowland rivers (e.g. North Ugie, South Ugie and Ythan rivers). Low values of pH and oxygen content also identify rivers such as the Lossie, which behave differently from the other intermediate highland systems. This is related to the non-calcareous nature of sedimentary rocks outcropping in the catchment as well as to coniferous woodland. A third consistent pattern resulting from PCA is the clear increasing trend of temperature and alkalinity from source to mouth, notably detectable in large rivers such as the Don.

In 1994 Malmqvist & Maki performed a TWINSPAN classification followed by Canonical Correspondence Analysis (CCA) on benthic macroinvertebrate assemblages and environmental variables from 60 riffle stream sites located in northern Sweden. Eight groups were defined after the third dichotomous subdivision of the sites-by-species matrix using TWINSPAN analysis. Twenty-seven environmental variables were measured and analysed; PCA was used to select the most significant variables with highest loadings: size of drainage area, elevation, water quality (in terms of alkalinity), water colour, phosphates and macrophytes. CCA was run on the species-by-environmental variables matrix (six independent variables after PCA) and the results compared with the eight groups previously defined. Species richness was mainly conditioned to the size of drainage area and to a lesser degree, to organic matter and discharge.

In 1999 Mouthon using multivariate statistical methods examined 272 river stations located in five major French catchments: the Rhône, the Rhine, the Seine, the Loire and the Garonne. The scope of this work was to model a theoretical French river based on correspondence analysis, Hierarchical Ascending Classification (HAC) and plots of inertia ellipses. Following HAC 11 groups of stations were defined together with 9 malacotypes (i.e. mollusc communities associated with the station groups) from the 52 identified species of mollusc. This study clearly demonstrated the longitudinal zonation of the malacotypes starting from classes 1-2 within the crenon, 3-6 in the rhithron and 7-9 in the potamon. Species richness increases regularly moving downstream, with a peak in malacotype 8 (potamon). Mollusc densities are maximal among malacotypes 5-7 (rhithron-potamon) once the effect of *Potamopyrgus antipodarum* is removed, a species generally forming huge colonies in the upper zone of plain rivers (malacotypes 3, rhithron).

Horsák & Hájek in 2003 investigated 48 spring fens situated in the borderland between the Czech Republic and Slovakia, collecting a total of 57 terrestrial and aquatic molluscs. Using cluster analysis the authors identified 5 groups of sites: mineral-rich fens with tufa formation, brown-moss mineral-rich fens without tufa formation, brown-moss mineral-rich fens with very low inclination, both mineral-rich and mineral-poor *Sphagnum*-fens and mineral-poor *Sphagnum*-fens. Detrended Correspondence Analysis (DCA) was run on the species by sample matrices for both terrestrial and aquatic molluscs, leading to a good accordance with the results of the cluster analysis. Water Chemistry (Ca, Mg, Fe, K, Na, Si, SO_4, Cl, pH, conductivity and redox) and vegetation were the environmental parameters considered for the CCA, which established the main molluscan trends. A linear correlation between species richness and water calcium concentration (but also Mg, Na, pH, conductivity) was seen in mineral-poor fens, whilst in the mineral-rich fens the same correlation was not found; species richness was dependant on other abiotic and biotic variables such as Fe concentration and water regime. Generally vegetation appeared to be more important than water chemistry for explaining mollusc species diversification. Eventually in hostile environments, such as mineral-poor fens, only stress-tolerant species (i.e. generalist) such as *Pisidium casertanum* can be found, gradually replacing species with higher habitat requirements.

Watson & Ormerod in 2005 addressed an ordination analysis using CCA and classification by TWINSPAN on 106 ditches located in British grazing marshlands inhabited by rare sphaeriids and snail species. In the surveyed sites a total of 34 environmental parameters were measured, whilst the mollusc species amounted to 8 bivalves and 10 gastropods. The parameters considered in the CCA were the following: depth, width, open water, % of ditch choked, emergent cover (vegetation), floating cover, submerged cover, chlorophyll-*a*, alkalinity, calcium, conductivity, BOD, gastropod diversity and bivalve diversity. Two bivalve assemblages were determined by TWINSPAN: Assemblage-1 *(P. pseudosphaerium, Sphaerium corneum, Musculium lacustre* and *P. obtusale)* typically associated with shallower, narrower ditches with a greater cover of floating and emergent vegetation and Assemblage-2 *(P. nitidum, P. milium, P. hibernicum, P. henslowanum* and *P. personatum)* occurring in wider, deeper, less calcareous ditches with lower BOD and chlorophyll-*a* concentrations.

In 2006 Lewin & Smoliński made a survey of clay pit ponds located in the Ciechanowska Upland (Central Poland). Nine sites were investigated and nine biological, physical and chemical parameters (gastropod density, number of species, chlorides, alkalinity, area, calcium, sulphates, phosphates and nitrates) recorded and assessed through PCA. Twenty-three gastropod species (of which 4 were prosobranchs and 19 pulmonates) were identified in the study area. Gastropod density was found positively correlated to nitrates, alkalinity and chlorides, whereas among pulmonates *Gyraulus albus* only showed a statistically significant positive association with a sand and clay bottom, perhaps due to algae film presence. Furthermore gastropod density was found considerably high on dolomite sediment bottoms, confirming the strong dependency between molluscs and calcium concentration.

In 2006 Füreder *et al.* conducted a study on 55 lakes located in three different regions of the Alps: Maggiore Lake drainage basin (Italy-Switzerland), South Tyrol (Italy) and North-East Tyrol (Austria). Six environmental variables (bare rocks, nitrate, potassium, alkalinity, ammonia and peat bog) were measured and 144 taxa (of which only three were molluscs) collected. Constrained Canonical Analysis (CCA) was run on two matrixes: lake-type vs environmental variables and species vs environmental variables. The CCA results allowed differentiation of three groups of lakes: lakes with a higher alkalinity, lakes with a higher portion of 'bare rocks' and lakes with higher ammonia levels and a boggy environment. With respect to the distribution trends, lake and catchment size did not seem to affect faunal parameters such as species density, which on the other hand appeared to be positively correlated with altitude with a maximum reached between 2400 and 2600 m AMSL, strongly decreasing above 2600 m. Invertebrate diversity and taxa number showed a negative trend with elevation, clearly related to the progressive disappearance of specialist species, replaced by generalists.

In 2007 Sturm visited 12 mountain lakes of the Austrian Central Alps compartment, where a total of 8 gastropod and 5 bivalves were found. Twelve environmental factors (altitude, water temperature, shading, water pH, conductivity, oxygen saturation, biological oxygen demand after 5 days - BOD5, nitrate concentration, total hardness, mean grain size of the bottom substratum and percentage of submerged vegetation and algal cover) were recorded and correlated with species diversity and abundance using multivariate statistical analysis. Two matrices (Mollusca taxa abundance by sites and environmental variables by sites) were realised and Canonical Correspondence Analysis (CCA) run. Results indicated that both species number and abundance of freshwater molluscs decline remarkably with increasing altitude, strictly related to higher values for substratum grain size and total hardness. Furthermore, high altitude habitats are dominated by generalist species such as *P. casertanum* among sphaeriids and *G. truncatula, R. labiata, R. balthica* among Lymnaeidae. It remains unclear whether generalist species are capable of colonising these hostile environments because they find an empty ecological niche or because of their wide tolerance to extreme chemico-physical conditions.

Jurkiewicz-Karnowska (2009) performed PCA on the aquatic molluscan communities (36 snails and 18 bivalves species) inhabiting 121 floodplain water bodies located within the River Bug lowland system, in Poland. Nine ecological parameters were recorded for this analysis: location within the river valley, size, depth, hydrological connectivity, bottom sediments, dominating macrophytes, canopy, water permanence, and successional stage. The most relevant parameters affecting species composition were: water permanence, size and depth followed by bottom sediments, successional stage, macrophyte abundance and hydrological connectivity. Water permanence was also used to separate the sites into 3 groups of water bodies: temporary, considerably desiccating and permanent. The PCA revealed a good separation among the 3 site groups, suggesting distinct habitat preferences among different species of molluscs (e.g. *Pisidium henslowanum* inhabiting large permanent water bodies).

In 2010 de Mendoza & Catalan studied the distribution of a variety of invertebrate groups (65 different taxonomic ranks, including 4 gastropod genera and the genus *Pisidium* for bivalves), inhabiting the littoral zone of 82 mountain lakes located in the Pyrenees range. Altitudinal environmental variables such as altitude, longitude and latitude together with 28 ecological variables were considered and PCA was run to explore different trends among variables. Redundancy Analysis (RDA) was also performed on a minimum subset of significant variables strongly correlated with altitude in order to define an 'altitudinal environmental gradient'. PCA showed that the altitudinal environmental gradient represents the most important ecological gradient across the study area. RDA suggested a clear contribution of single environmental factors varying with altitude, affecting the distribution of about 50% of the macroinvertebrate groups, the vast majority (including Lymnaeidae and Sphaeriidae) being negatively correlated to altitude (only four of them were found positively correlated to altitude). Furthermore Lymnaeidae and Sphaeriidae respectively showed a preference for macrophytes and fine substrata.

In 2011 Kubíková *et al.* studied the occurrence of *Pisidium* species in 68 submontane oligotrophic springs located in the Blanice River catchment (Bohemian Forest, Czech Republic). A number of ecological parameters related to the habitat-type were recorded, together with some chemical analyses performed in laboratory such as pH, conductivity and ion concentrations. A PCA of 26 environmental variables was run, whilst their influence on single taxonomical groups was explored through RDA. The results of this study showed that only two species of sphaeriids colonized the spring biotopes: *Pisidium casertanum* and *P. personatum.* Their occurrence was mainly correlated to water pH, calcium concentration and type of substratum related to current velocity, with *P. casertanum* being dominant in 53% of the springs, while *P. personatum* only dominated in 34% cases. The authors concluded that *Pisidium casertanum* is a highly tolerant species, whilst *P. personatum* is more sensitive, occupying a narrower ecological niche even though showing a noticeable tropism to withstand low temperatures.

In 2011 Pérez-Quintero sampled 94 sites in the southern Guadiana River basin (SW Iberian Peninsula), where 19 habitat variables grouped into five categories were analysed: climatic, geomorphological, hydrological, heterogeneity, and physicochemical characteristics. A total of 16 gastropod (12 native and 4 alien) and 8 bivalve (including 1 alien) species were identified. PCA was run using habitat variables; the first two axes explained which key factors best described site characterization. PC1 separated headwater from estuary habitats through a geomorphological gradient, whilst PC2 ordered stations along a water availability gradient defined by water permanency and aridity index.

CCA was run to analyse relationships between key habitat variables and freshwater mollusc species, eventually defining malacological assemblages. The greater species richness of native gastropods mostly occurred in permanent headwater streams, where molluscs tend to distribute according to the river longitudinal gradient, in response to environmental conditions variations. Among sphaeriids, *Pisidium casertanum* and *P. personatum* preferred permanent headwater environments, avoiding middle reaches of hydrologically stressed streams and estuarine habitats where they tend to be replaced by taxa more specialized.

The same author carried out a field study in the biosphere reserve 'Dehesas de Sierra Morena' (southwest of the Iberian Peninsula), in order to establish which environmental factors mainly influence biodiversity and distribution of freshwater mollusc communities (Pérez-Quintero, 2012). One hundred and nine sites were selected and 18 environmental variables (physico-chemical and ecological) defined and measured. Nineteen species of molluscs were identified (11 native and 4 invasive gastropods and 4 native bivalves), among which the natives *Ancylus* cf. *fluviatilis, Planorbarius metidjensis,* and the invasive *Physella acuta* were the most widespread gastropod species. Between the bivalves, *Pisidium casertanum* was the commonest taxon occurring in the study area. Environmental diversity was assessed running a PCA on a matrix of environmental variables vs sites. The first PCA axis mainly correlated with topographic (stream order, linear distance to the origin and altitude) and hydrological (channel width, water depth) characteristics, whilst the second axis showed up a good correlation with water availability (permanency), habitat heterogeneity (fluvial habitat index - IHF and macrophytes cover), pH and climatic variables (aridity index, annual precipitation and air temperature). CCA was used to assess relationships between environmental variables and native freshwater mollusc species. Freshwater molluscan distribution was mostly related to annual precipitation, an important factor regulating water availability, which in unstable Mediterranean environments can significantly reduce the hydrological connectivity, creating barriers to those molluscs with poor dispersal abilities.

Eventually in 2013 Pérez-Quintero studied the occurrence of freshwater molluscs (16 gastropods and 3 bivalves) in 35 sites distributed along 18 small coastal basins in the south-western Iberian Peninsula. For this study 6 habitat variables at the basin scale were selected: mean temperature, total rainfall, urban solid waste production, main channel length, basin area and order at mouth. Similarly, 12 habitat variables were singled out at the reach scale: altitude, linear distance to the estuary, order at the sampling point, channel width, water depth, substratum diversity, habitat heterogeneity, instream cover, pH, conductivity, turbidity and water temperature. PCA was run using these habitat variables at both basin and reach scales;

the results clearly suggested a separation between upper and lower reaches. A similar result was obtained through cluster analysis based on Bray-Curtis similarity performed on environmental characteristics and native species richness at the two scales of investigation. Upstream communities were fairly dominated by native stenohaline taxa *(Bithynia tentaculata, Galba truncatula, Radix balthica, Ancylus fluviatilis* and *Planorbarius metidjensis),* whilst downstream communities were mostly represented by native euryhaline species *(Peringia ulvae* and *Myosotella myosotis).* Species richness was found decreasing from the upper stream reaches to the lower stream reaches. Independent variables that best explained this longitudinal gradient were conductivity, habitat heterogeneity, turbidity and linear distance to the estuary. Coefficient of variation of the species richness was lower in the lower reaches than in the upper reaches, suggesting broader temporal fluctuations of upper reaches communities in relation to water availability.

2

MATERIALS AND METHODS

This chapter deals with the methods used in this research project.
The first section describes the techniques used during the field work, including sampling and storage methodology as well as those for recording ecological parameters. With respect to laboratory activities, an overview is provided on the working methodology and on the optical and electronic equipments used.

The second section concerns multivariate analyses used to reconstruct the species distribution patterns in relation to environmental influences.

The third section describes the datasets used to prepare the species distribution maps and the mapping techniques applied in ArcGIS to combine in a single sheet as much information as possible without excessively complicating the view.

2.1. FIELD AND LABORATORY TECHNIQUES

A selection of sampling sites was identified in order to cover all the varieties of biotopes in the study area, for a total of 334 stations of which 130 are ascribed to lentic and 204 to lotic ecosystems.

Sampling strategy consisted in identifying all possible type of habitats occurring in North-East Scotland, through thematic map analysis (topographic, geologic, land use, etc.) and literature references.

The base map used to display single species distributions is the British hydrographic map available at the Edina web site (University of Edinburgh) with Watsonian county limits superimposed. Public SRTM (Shuttle Radar Topography Mission) digital elevations models were also used to identify key aquatic habitats located in the Cairngorms area.

Ninety-four stations were placed along the main rivers and their tributaries (i.e. Isla, Deveron, Ythan, Ugie, Don and Dee hydrographic networks), approximately every 20 km.

Eighty stations were located across the coastal stream sector, which runs from the River North Esk basin to the Buckie area (River Spey excluded).

Seventy-two stations were sampled within the upper river catchments, mainly in mountain areas.

Sixty stations were sampled within the lower valley sectors, covering a large variety of environments including agricultural lochans, boggy areas and limnocrene springs.

Eight stations were located in the major lochs such as Muick and Lee and 7 in the Cairngorms and Lochnagar cirque lochs.

Finally 13 stations were studied in brackish environments such as the estuaries of the rivers Ythan, Dee, and Don.

A general description of the main river catchments investigated during field sampling is given in section 3.3.

Site selection followed sampling strategy, with the aim of investigating virtually every type of superficial water body within the study area with respect to land accessibility. This initial aim was then adapted after the preliminary sampling results, focusing further research on those areas where we would have expected to find particular mollusc associations or the occurrence of rare taxa. Consequently the majority of the sampled stations are located within the lowland sector, where complex interactions between mollusc associations occur.

In the upper catchments of rivers, after a random approach based on the regular placement of the sampling sites along the main channels (in the majority of the cases revealed to be unsuitable for mollusc survival), research focused on the intermountain plateaux or more specifically the areas characterised by occurrence of carbonate rocks. This revised approach demonstrated to be successful and led to the discovery of isolated populations of Sphaeriidae and other generalist species, whose existence requires invoking passive transportation mechanisms.

The final sampling stations map shows the variable distribution of the sites, based on this multi-disciplinary approach, with higher densities reached within the coastal sector and in the lowland areas compared to the sparse distribution within the Highlands.

At each station a typical 1x1 m square area located between 0.5 and 1 m depths was defined for sampling and recording purposes.

The sampling technique consisted of removing systematically the first cm of sediment, which was sifted subsequently using a sieve with a 1 by 1 mm mesh. The residual sample (ca. 1.5kg) was then examined under a stereomicroscope (Wild M5A) and all the malacological thanatocoenosis and biocoenosis separated, counted, classified and stored in the dry collection. Also shell fragments were collected and (where possible) classified.

Any plant, boulder or frame occurring in the sampling area was carefully inspected and all live mollusc specimens picked-up and stored in ethanol 70% to form the wet collection.

The sampling time was standardised to 60 minutes for all sampled sites, in order to homogenise the collecting techniques, allowing a more reliable comparison of quantitative data.

This limited time allowed a quick and reliable evaluation of sampling stations located in remote areas, such as the headwater biotopes in the Cairngorms area, where molluscs are scarce and represented mostly by filter feeders (e.g. *Pisidium* spp.), living in the first centimetre of the bottom sediments.

For the richest lowland habitats such as the kettle-hole lochs, this sampling technique provided a punctual estimate of the mollusc populations living in such vast ecotopes. In some cases where the site lies in an area very important from an environmental point of view or critical for understanding the migration processes such as the Loch Davan-Kinord system, more sampling stations were defined. Certainly the species list and relative abundances compiled during this project for a specific site cannot be compared to other zoological lists available in literature for the same environment, which quite often are the result of more focused studies.

On the other hand the standardised sampling procedure allowed reconstructing, with a certain degree of accuracy, the zoogeographical distribution of the mollusc species and an understanding of the ecological requirements characterising different taxa.
The site was also carefully described in terms of general ecological and hydrological aspects, identifying a number of quantifiable environmental parameters which were used to compute multivariate analyses.
The following are the chosen parameters: altitude, longitude, latitude, substratum size, and current speed.
Substratum size characterization followed the Krumbein (1934) logarithmic scale (Tab. 1), a modification of the Wentworth scale defined by the equation:

$$D = D_0 * 2^{-\varphi}$$

where D is the particle diameter
D_0 is a 1 mm reference diameter
φ is the diameter scale

φ scale	size range mm	Wentworth range inches	Wentworth name	other names
-8 to -∞	256-∞	10.1-∞	boulder	
-6 to -8	64–256	2.5–10.1	cobble	
-5 to -6	32–64	1.26–2.5	very coarse gravel	pebble
-4 to -5	16–32	0.63–1.26	coarse gravel	pebble
-3 to -4	8–16	0.31–0.63	medium gravel	pebble
-2 to -3	4–8	0.157–0.31	fine gravel	pebble
-1 to -2	2–4	0.079–0.157	very fine gravel	granule
0 to -1	1–2	0.039–0.079	very coarse sand	
1 to 0	1/2–1	0.020–0.039	coarse sand	
2 to 1	1/4–1/2	0.010–0.020	medium sand	
3 to 2	1/8–1/4	0.0049–0.010	fine sand	
4 to 3	1/16–1/8	0.0025–0.0049	very fine sand	
8 to 4	1/256–1/16	0.00015–0.0025	silt	mud
∞ to 8	∞–1/256	∞–0.00015	clay	mud
∞ to 10	∞–1/1024	∞–0.000039	colloid	mud

Tab. 1. Granulometric size frequency distribution table (Krumbein, 1934).

Stream speed includes 7 classes: very low (VL), low (L), low-medium (LM), medium (M), medium-high (M-H), high (H) and very high (VH).

Chemico-physical analyses of the water column bottom were also performed using a Universal WTW MultiLine P4 meter equipped with four probes: SenTix 41 (pH combined electrode with integrated temperature probe; pH accuracy 0.01 +/- 1 digit; temperature accuracy +/- 0.1 K), CellOx 325 (dissolved oxygen probe; concentration accuracy +/- 0.5% of measured value +/- 1 digit with ambient temperature 5-30° C measuring within the 0-19.99 mg/l range; saturation accuracy +/-0.5% of measured value +/-1 digit when measuring at calibration temperature +/- 10 K within the 0-199.9% range), TetraCon 325 (standard conductivity cell; conductivity accuracy +/- 1% of measured value +/- 1 digit with ambient temperature 15-35° C; salinity measuring range 0-70 according to IOT table UNESCO (1981), accuracy +/- 0.1 in the range 0-42 with 5-25° C and Pt 4805/S7 (redox electrode; accuracy 1 mV +/- 1 digit). Selection of the field parameters to be measured during the sampling phase was related to the key ecological requirements of molluscs and to their characterization based on the ranges recorded by the data logger.

Ion concentration is measured by conductivity (Cond). Together with the pH which reflects the acidic level of waters, conductivity may help to ascribe a trophic level to a specific environment. The oxygen concentration (O_2Conc) is another key parameter which may be related to the type of flow of the stream current (e.g. turbulent flow, falls presence, etc.) or to the photosynthetic activity of aquatic plants. The stagnant conditions frequently encountered at the base of the water column of eutrophic environments are highlighted by the redox potential (Eh). Water temperature (T) is another key parameter if measured at the same time on multiple ecotopes; otherwise it only provides a general record of the sampling site which completes the habitat description.

For those sampling stations located in marine transitional areas, such as the brackish waters in estuaries, salinity (Sal) together with conductivity are certainly the most important parameters to be measured, which allow to perform an ecological zonation of these complex and variable environments.

The system of classification of water bodies based upon salinity chosen for this study is the ‘Venice System’ (Battaglia, 1959, Tab. 2).

Salinity	Thalassic series
60/80 - > 300	Hyperhaline
40 - 60/80	Metahaline
30 - 40	Mixoeuhaline
18 - 30	Polyhaline
5 - 18	Mesohaline
0.5 - 5	Oligohaline

Tab. 2. 'Venice System' thalassic series (modified from Anonymous, 1959).

The field parameters recorded for this project were: T, pH, Eh, Cond, Sal, O_2Conc, O_2Sat%.
Detailed taxonomic analyses on selected specimens of the dry collection were performed at the Centre for Ultrastructural Imaging at Guy's campus in London using a Hitachi 3500 Scanning Electron Microscope.
The selected material consisted of typical individuals and teratological specimens, covering a full range of morphotypes, with the aim of illustrating intra-specific variability and the peculiarity of the aberrant forms. Meticulous observations were carried-out to investigate minute morphological details such as valve micropores and hinge teeth of the sphaeriids or protoconch microsculptures of the hydrobiids. Also mollusc morphological characters have been put in relation with habitat characteristic, with the objective to verify if different morphotypes belong to specific environments.
As general identification guides, Ellis' standard work (1978) on British freshwater bivalve Mollusca was used together with the atlas of Killeen *et al.* (2004). Prosobranch gastropods were mainly classified using the Fretter & Graham (1994) compendium, pulmonate gastropods with Ellis' guide to British snails (1969).
Zoological nomenclature followed the Fauna Europaea Project (Fauna Europaea version 2.4, http://www.faunaeur.org), the revised checklist of the non-marine Mollusca of Britain and Ireland as part of the CLECOM project (Bank *et al.* 2007), the checklist of the European Marine Mollusca (CLEMAM project, http://www.somali.asso.fr/clemam/index.php), the annotated list of the non-marine Mollusca of Britain and Ireland (Anderson, 2005) and its revised version (Anderson, 2006) and finally the nomenclatural debate on non-marine molluscs occurring in the British Isles published by Kadolsky in 2012.
Pictures of shell characters were taken at different magnifications from selected individuals belonging to each sphaeriid species and certain gastropods.
A selection of images showing shell variability and taxonomic character details were singled out and mounted in the plates 1-34.

2.2. BIVARIATE AND MULTIVARIATE ANALYSIS

Chemical and physical parameters were statistically analysed and combined in order to identify common trends and to permit preliminary investigation of the ecological conditions.
The total number of stations for which chemico-physical analyses were carried-out is 306 (out of 334); results are summarised in a series of cross-plots illustrating some clear trends among the measured parameters (Figs. 10, 12, 14-17).
PC-ORD v6 released by MJM Software Design (McCune & Mefford, 2011) was the software package used to run classification and ordination analyses.
The strategy adopted to analyse the relationships between mollusc quantitative data and associated environmental variables is inspired to the methodology described in 1982 by Field *et al.*

Raw data

This step consists of defining a matrix in which stations are described by mollusc species abundances or by ecological parameters.
The species occurrence reported in the matrix follows the pseudospecies abundance concept originally devised by Hill *et al*. (1975), the basic entity used in the process of making a dichotomy. The original abundance values were assigned to five numerical ranges, individually corresponding to pseudospecies as reported in Table-3:

Pseudospecies	Abundance	Qualitative
Pisidium casertanum-1	No = 1	rr (very rare)
Pisidium casertanum-2	1 < No ≤ 5	r (rare)
Pisidium casertanum-3	5 < No ≤ 10	u (uncommon)
Pisidium casertanum-4	10 < No ≤ 25	c (common)
Pisidium casertanum-5	No > 25	a (abundant)

Tab. 3. Pseudospecies abundance summary.

Codes definition for abundance scores tends to normalize data, therefore subsequent transformation is then unnecessary (Field *et al.*, 1982).

Two independent matrices were defined for all mollusc species and sphaeriid only species:

- Matrix-1 (215 stations versus 32 mollusc species) - Dataset associating the sampling stations (with chemico-physical analyses available holding at least one population of a mollusc species) with the relative abundance of all mollusc species;

- Matrix-2 (176 stations versus 10 sphaeriid species) - Dataset associating the sampling stations (with chemico-physical analyses available holding at least one population of a sphaeriid species) with the relative abundance of all sphaeriid species.

Furthermore other two matrices were created to relate stations to environmental variables:

- Matrix-3 (306 mollusc species abundances, including null values, versus 12 ecological parameters) - Dataset associating sampling stations cumulative mollusc species abundances with the ecological parameters;

- Matrix-4 (306 sphaeriid species abundances, including null values, versus 12 ecological parameters) - Dataset associating sampling stations cumulative sphaeriid species abundances with the ecological parameters.

Similarity matrix

Distance matrices were calculated on Matrix-1 and Matrix-2 using Sorensen (Bray-Curtis) equation and then on their transposed versions (species by stations).

Classification

Hierarchical sorting on distance Matrix-1 and Matrix-2 and on their transposed versions was achieved through cluster analysis (Ward's method). This polythetic divisive classification is qualitative rather than quantitative, allowing the species to cluster in ecological associations, characterised by similar environmental preferences.

Ordination

Ordination analysis (Bray-Curtis) was run on distance Matrix-1 and Matrix-2 and on their transposed versions, with the objective to establish species associations on a 2-dimensions cross-plot and to compare them with species groups defined during classification.

Multiple linear regression

In order to test the significance of the 12 environmental independent variables (T, pH, Eh, Cond, Sal, O_2Conc, O_2Sat%, substrate size, current speed, altitude, latitude, longitude), multiple linear regression with back elimination was applied to Matrix-3 and Matrix-4 using Analysis ToolPack in Microsoft Excel 2007. The objective of this method consisted of reducing the number of variables, keeping only those which better explained the dependent variable (mollusc/sphaeriid species abundances).

As consequence other two matrices (without absence data) were defined:

- Matrix-5 (215 stations versus 6 ecological parameters) - Dataset associating the sampling stations (with chemico-physical analyses available holding at least one population of a mollusc species) with the ecological parameters;

- Matrix-6 (176 stations by 7 ecological parameters) - Dataset associating the sampling stations (with chemico-physical analyses available holding at least one population of a sphaeriid species) with the ecological parameters.

Transformed data

Matrix-5 and Matrix-6 were normalized by rows in order to scale down scores.

This operation alters the variable scores, with the effect of scaling down the values so that extreme values do not heavily interfere with the rest of the data.

Canonical Correspondence Analysis

Finally CCA was run on Matrix-1/Matrix-5 (all mollusc species) and Matrix-2/Matrix-6 (sphaeriid species only). This method combined and extracted major gradients among combinations of explanatory variables. Biplot graphs show either species or stations as points and ecological variables as vectors.

2.3. RECORDS DATASETS

The historical dataset was built using all the literature records (totalling 426 records) subdivided into two groups: pre- and post-1950 (Appendix-I). The majority of these records, particularly those falling into the pre-1950 group, do not precisely refer to a specific locality and cannot be used to generate a map of historical records. Also many of the pre-1950 data are difficult to interpret, considering the major taxonomical re-arrangement which occurred during the last century, especially among the Sphaeriidae.

According to these observations, all the historical records fall within an accuracy of a 10 by 10 km grid at best, even those better described, as they generally refer to large biotopes, make it extremely difficult to identify specific sites (i.e. Loch of Strathbeg, Loch of Skene, etc.).

In order to define the position of a historical site record with the highest precision, the cited area was examined using Ordnance Survey maps and Google Earth imagery. For instance in the case of the Powis Burn (Macgillivray, 1843), which disappeared during the 19th century after land reclamation, a possible location is identified in Old Aberdeen, where according to the historical sources, this channel was certainly present.

The freshwater mollusc collection of the Royal Edinburgh Museum (REM) was visited during May 2005 and all the material from the area of interest was carefully examined. The complete list of these material totalling 1 wet and 24 dry records is reported in Appendix-I.

Also the Aberdeen Zoology Department (AZD) mollusc collection was examined and the relevant records (8 in total) reported in Appendix-I. Both collections (REM and AZD) do not report precise information concerning the recording site, so these datasets were mapped using 10 by 10 km grid accuracy.

The NBN Gateway database (http://data.nbn.org.uk/index_homepage/index.jsp) was also consulted to integrate the missing published information and complete the record dataset. This dataset shows a grid accuracy organised at three different levels (100 by 100 m, 33 records; 1 by 1 km, 8 records; and 10 by 10 km, 65 records), which were kept distinct during the mapping process. Moreover all the data sourced from NBN were cross-checked with the data coming from this study, the literature and the museum collection records, avoiding any redundancy. In the case of the 1 by 1 km and 10 by 10 km, it was first verified that no existing data occurred within the selected grid, and in the case of a new record the most viable biotope for the considered species was used to locate the site. This approach allows a map to be built which considers all the available information for a specific taxon, necessary to generate the most complete distribution chart.

Finally the freshwater pearl mussel dataset, the exclusive property of Scottish Natural Heritage (SNH), was used to complete the distribution map of *Margaritifera margaritifera*. This dataset consists of a merger of several surveys of different resolution carried out in the area of interest during the period 1997-2007 by a number of recorders. Considering the high number of stations sampled for these projects, the distribution of *M. margaritifera* is very accurately reconstructed, in contrast to other species characterised by sparse records.

The full data set is composed as follows: 1 m grid resolution (29 records), 10 m grid resolution (8 records) and 100 m grid resolution (243 records).

All the mollusc records collated during this study were transferred to an ArcGIS project, together with geographic information concerning the area.

These data cover five vice-counties: 90 (Angus), 91 (Kincardineshire), 92 (South Aberdeenshire), 93 (North Aberdeenshire) and 94 (Banffshire).

The base map was realized using the Watsonian Boundaries digitized in 2003 under the NBN trust from the original Vice-county System (Dandy, 1969), superimposed on to a layer of the hydrographic network comprising major water bodies and estuarine sectors from the national river coverage and inland water bodies dataset for Great Britain. This latter dataset was generated from the Ordnance Survey Meridian-2 and OS MasterMap data at 1:50,000 scales downloaded from the EDINA Digimap web site (http://edina.ac.uk/digimap).

All distribution maps (1-42) are reported in Annex-III.

The map shows two types of legend, one relevant to the positioning accuracy and a second showing the source of the data and other information concerning the cartographic layers.

Records are displayed using three different symbols: the circle indicates the highest accuracy achieved with GPS positioning (ca. 10 m, this study or NBN 100 by 100 m), the square refers to 1 by 1 km grid, the triangle to the 10 by 10 km grid. With respect to the 10 by 10 km category, it was first verified that no other more accurate data were available for a square (including data from this study). The most suitable site was then selected for the considered species, introducing a certain margin of interpretation and uncertainty in mapping, but allowing the best possible assessment of a taxon's distribution.

The general legend reported in each distribution map distinguishes between different data sources, associating a colour with each dataset; for example blue indicates pre-1950 literature records whilst green refers to those post-1950.

3

THE STUDY AREA

This chapter presents the morphological characterisation of the Grampian Area, starting with the geological and geomorphological setting and moving to a general review of the main characteristics of the water basins, before concluding with a discussion of ecological standard classifications.

The first section introduces a general description of the surface geology, necessary to understand the facies distribution as well as the petrophysical nature of the lithotypes described. An overview of the complex geological setting of the area, with descriptions of the main tectonic units and relevant lithological characterisation is also given.

The Grampian area is mainly dominated by metamorphic rocks belonging to the Dalradian Supergroup as well as by large acid intrusions concentrated along the Dee valley and the Cairngorms area (Fig. 4). Particular emphasis is given to the description and localization of the sedimentary suites, mainly occurring on the edge of the Moray Firth but also along a squeezed narrow strip stretching from the Glen Clunie to the upper Don valley, through the western side of Mount Morven.

The occurrence of these carbonate-rich sedimentary suites within the Cairngorms represents an anomaly, considering that the most widespread lithotypes in this area consist of mica-schists and quartzite belonging to the Dalradian Supergroup or intrusive sialic bodies. The composition of standing water, in the areas characterised by the presence of sedimentary rocks, tend to be slightly different from that typical of running water which is generally poor in ions. The presence of carbonate dissolved in the water is a fundamental element for the development of the shell in molluscs, so these mountain habitats represent important refuge areas for a variety of species. This phenomenon is also particularly evident in areas where surface water is generally soft, essentially formed by meteoric water. The only source of nutrients (such as nitrates and phosphates) in ombrotrophic basins or glacial-related lochs is in fact related to the faeces of wild animals, regularly left behind during their visits.

The second section deals with a short review of the Quaternary glaciations, which caused total extinction of the pre-glacial fauna. A detailed reconstruction of the last 10,000 years is also given, a period during which faunal immigration from the continental mainland took place as deglaciation proceeded.

In the third section a detailed description of the hydrographic setting is given, with particular emphasis on river zonation and general habitat description. Relations between surface geology and hydrographic morphology are discussed here together with the main variations in fluvial dynamics.

Finally a literature overview on both running and standing waters is discussed in the fourth section, with particular emphasis on standard classifications and the various approaches followed by researchers in their attempts to identify and group chemical and physical similarities.

Also discussed is the interaction between agricultural practices and the consequent nutrient enrichment of water, causing development of aquatic plants and eventually raising the trophic level. The most eutrophic habitats of the Grampian Area are all located in natural depressions surrounded by cultivated fields, where stagnant conditions are frequently met. The margins of the eutrophic basins are constantly invaded by a broad strip of aquatic plants, supporting a wide range of invertebrate communities, the most important trophic level in a food chain.

3.1. SURFACE GEOLOGY

The Grampian Highlands are well-defined between two major regional SW-NE structural alignments: the Great Glen of Scotland and the Highland Boundary Fault Zone (HBFZ) (Fig. 4). The former is a well-known deep trench, which traverses the whole Highlands from the Firth of Lorn (in the south-west) to the Moray Firth (in the north-east). The latter is a complex fault zone ranging from Arran and the lower estuary of the Clyde (in the south-west), to the Stonehaven area (in the north-east). The Grampian Highlands are mostly formed by metamorphic and igneous rocks of Late Precambrian to Early Palaeozoic age, representing part of the eroded root of the Caledonian fold belt.

The whole group of metamorphic rocks lying to the east of the Great Glen was called 'Dalradian' by Geikie (1891). This term was then replaced in modern times by the Dalradian Supergroup concept, comprising a set of meta-sedimentary facies outcropping from Western Ireland to the Banffshire coast (Anderton, 1988). The Grampian group (Fig. 4) is the oldest cropping-out in a broad NE trending zone extending from Glen Orchy to near Elgin. It mainly consists of large outcrops of flaggy quartzo-feldspathic psammite as documented in a wide area ranging from Linn of Dee to Meall an t-Slugain. Quartzite is also locally represented, particularly along the upper sector of the Allt an t-Slugain and along the Dee valley, moving upstream from the Linn of Dee. Dark mica-schist does sparsely outcrop around the Cairn Liath. Small outcrops of limestone and calcareous silicate are also sparsely present to the north of Braemar, often associated with felsite (e.g. Clais Fhearnaig, right tributary of the Glen Quoich).

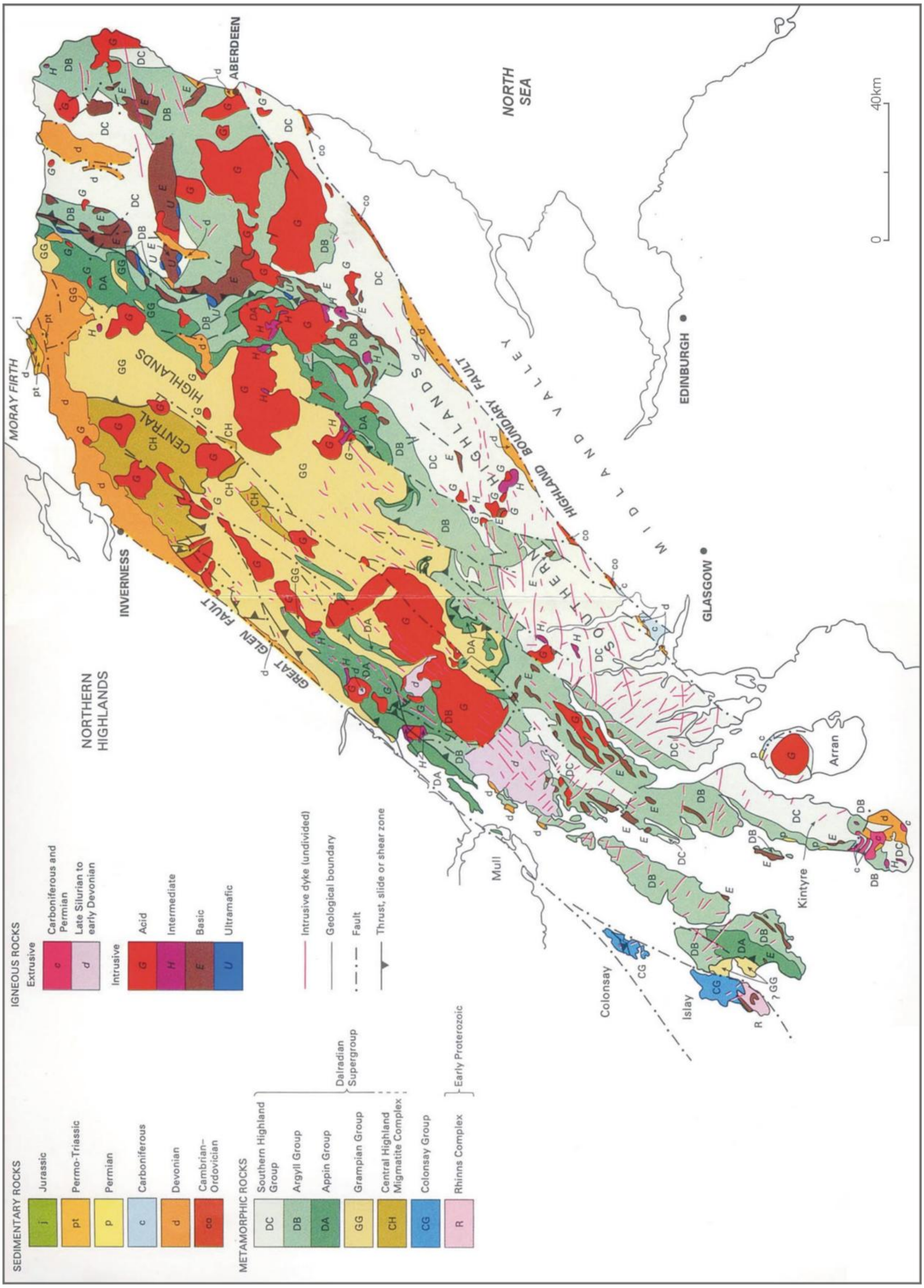

Fig. 4. Solid geology of the Grampian Highlands (from Stephenson & Gould, 1995).

The Appin Group, mostly outcropping in the Central Highlands, is subdivided into three subgroups from the oldest: Lochaber, Ballachulish and Blair Atholl. The Lochaber Subgroup mainly consists of striped pelite, semipelite and psammite, extensively outcropping in the Baddoch Burn upper sector. Dark mica-schist does occur too, along the northern slope of Morrone and on the NW ridge of Carn Liath. The Ballachulish Subgroup is the largest sedimentary unit represented in the area with a largely differentiated suite of lithotypes. These facies mostly consist of graphitic mica-schists, sandy dolomite and pelite with psammite with subordinated quartzite. Good exposures of this meta-sedimentary subgroup can be seen in the upper sector of Glen Clunie and all around Loch Vrotachan. This large unit continues north-eastward, crossing Glen Callater and River Dee valleys and forming a large outcrop area around Meall Gorm. The Blair Atholl Subgroup outcrops over a definitely smaller area and is characterised by finely interbanded sequences of psammite, graphic schist, marble, semipelite and quartzite. This unit can be followed along a narrow band extending from Loch Callater down to Glas Maol and further south.

The Argyll Group, largely exposed to the north-east of the Grampian Area, is formed by three subgroups: Islay (the oldest), Easdale and Crinan. The Islay Subgroup is well-exposed in a SW-NE stripe bounding Glas Maol, mainly consisting of cross-bedded pebbly quartzite and variably interbedded psammite and graphitic schists. The Easdale Subgroup it is represented by graphitic mica-schists with interbedded quartzite outcropping in an area comprised between the Glas Maol and the Loch Kander. The Crinan Subgroup mostly outcrops in the upper sector of Glen Callater. It is dominated by mica-schist and garnet-mica-schist with quartzite and psammite beds.

The Southern Highland Group is exposed along the Aberdeen-Stonehaven sea cliffs, a wide belt of rocks lying parallel to the HBFZ.

This group is dominantly composed of psammitic turbidites, richer in feldspar and granitic rock fragments compared to the other Dalradian metasedimentary units.

A very few small intrusions belonging to the pre-tectonic basic magmatism outcrop in the studied area, particularly to the north of the Cairngorms (Black Water), on the upper River Don (Delnadamph) and on the southern Deeside (Belnacraig). These outcrops mainly consist of basaltic pillow lavas together with fragmental ultramafic rocks associated with pelitic to psammitic rocks (Black Water and Delnadamph) or fine grained hornblende-schists intercalated with layers of psammite and calc-silicate rocks (Belnacraig).

Large syn-tectonic granitic intrusions are confined to the east of Inverness but very small bodies can be found sparsely distributed across the whole area such as at Portsoy, Windyhills

(River Isla northern side) and Keith. These small and elongated granitic masses exhibit a strong tectonic fabric and a composition dominated by alkali-feldspar augen in a matrix of quartz, plagioclase, biotite and muscovite. Basic rocks largely associated with ultramafic rocks and mainly basic lithotypes are found in isolated spots sparsely outcropping in the area, such as at Belhelvie, Succoth-Brown Hill (River Deveron eastern side), Lawel Hill near Inverurie (River Don eastern side) and Coyles of Muick (southern Deeside). These masses consist of a layered complex of ultramafic and mafic cumulates mostly represented by dunite, harzburgite, troctolite and olivine-gabbro. Morven-Cabrach is a sheet-like body mainly composed of layered norite and hypersthene-gabbro with minor ferrogabbro and monzogabbro. A similar composition is recorded in the Insch and Boganclogh masses, where clinopyroxene-norites and layered olivine ferrogabbros, olivine-monzonites and syenite are the most common lithotypes. Another significant alignment of basic rocks is found between Portsoy and Huntly (including Knock Hill), documenting granular gabbros with allied types. Other isolated bodies outcrop in the eastern lowland sector such as at Haddo House, Arnage and Maud primarily characterised by quartz-biotite-norites with subordinated olivine-norite. Granitoid intrusions are located mainly in the coastal lowland as well as inland, in the medium River Don catchment. The Kemnay and Aberdeen intrusions together with the Strichen and Forest of Deer bodies are examples of north-eastern biotite-muscovites granites suite, intensively foliated lithotypes grey in colour.

The north-eastern diorites to granites suite is mostly located north-westward from the Hill of Fare and comprises the Kennethmont, Syllavethy, Tillyfourie and Corrennie intrusions. The south Grampian suite is limited to small bodies, largely distributed to the north (Abergeldie) and to the south of the Lochnagar Massif (Glen Shee). These plutonic intrusions consist dominantly of hornblende- and pyroxene-diorite, together with subordinated gabbro, monzonite and granite. The Argyll suite is mainly represented by masses outcropping on the northern Deeside, such as the Torphins, Crathes and Balblair intrusions. Their composition ranges between coarse-grained quartz-diorite and tonalite, locally passing to monzogranite.

The Cairngorm Suite is characterised by a number of very large intrusive complexes, mostly consisting of coarse-grained, variably porphyritic, and leucocratic red-pink biotite-granite. The largest of this body is the Cairngorm Granite, covering an area of approximately 365 km^2. Proceeding eastward three other impressive outcrops are found: Lochnagar, River Gairn and Ballater, all characterised by a similar composition. Another large intrusion is the Mount Battock, comprising several irregular bodies mainly consisting of pink biotite-granite moderately coarse grained. Moving north-eastward more isolated masses do occur such as the: Hill of Fare, Bennachie and Peterhead, composed of coarse-grained granite locally cut by a suite of pink aplite sheets.

The last group is represented by the Lower Old Red Sandstone volcanism, characterised just by small isolated spots, mainly located in the northern lowland (Rhynie, Cabrach and Gollachy Burn). Vesicular andesite lava is the dominant lithotype recurring in all the outcrops.

Associated with the HBFZ is a narrow belt consisting of stripes of unrelated lithotypes, such as: altered serpentinites, gabbros, quartzose sandstones, conglomerates, limestone and amphibolites. A good exposure of this tectonic 'mélange' is visible to the north of Stonehaven (Trewin *et al.,* 1987). A serpentinite fault-bounded sliver characterises the narrow and sharp Garron Point ridge, located to the north of Stonehaven.

Among the non-metamorphosed sedimentary series only Devonian rocks outcrop in the area, mainly occurring along the Moray Firth coast and in isolated spots located in the middle of the Grampian Area. The Old Red Sandstone Group which was deposited during this period is traditionally subdivided into three units: Lower, Middle and Upper. The Lower unit outcrops in isolated spots near the villages of Tomintoul, Cabrach and Rhynie as well as immediately to the east of Banff. The dominant facies chiefly comprises massive conglomeratic fans and breccia screes, laterally passing to fine sandstones and calcareous mudstones. The Middle unit is mainly found in a narrow belt located to the east of Turriff and Banff, represented by the 'Findon Group'. A number of different facies do outcrop in this area, ranging between thick sequences of reddish conglomerates and breccias topped by fish beds composed of red mudstones with calcareous nodules. Other unassigned Devonian Old Red Sandstones bodies outcrop immediately to the north of Aberdeen. These are mainly red cobbly to sandy deposits of a very limited extension.

3.2. QUATERNARY GLACIATIONS

The Quaternary is a period of deep modification for the Grampian topography due to repeated glaciations, which affected the territory over the last 750,000 years. Periods of ice-sheet development (stadials) alternated with interglacials during which temperate climate occurred. Interglacials lasted an average of 100,000 years. In the Grampian area onshore sedimentary evidence of 5 stadials has been recorded in several places, mainly in the lowland (Tab. 4). The first stadial (Anglian) occurred around 480,000 years BP, followed by the Wolstonian Stadial (350,000-132,000 BP), the Early Devensian Glaciation (122,000-26,000 BP), the Dimlington Stadial (26,000-13,000 BP) and the Loch Lomond Readvance (11,000-10,000 BP).

<table>
<tr><th>Isotope stage</th><th>Approx. age years BP</th><th colspan="4">Stage (chrono/climatostratigraphy)</th><th>Glaciations</th></tr>
<tr><td>1</td><td>0-10,000</td><td colspan="3">Flandrian (Interglacial)</td><td>PG</td><td>-</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">10,000-26,000</td><td rowspan="5">Devensian</td><td rowspan="3">Late</td><td>Loch Lomond Stadial (10,000-11,000 BP)</td><td rowspan="2">LG</td><td>Loch Lomond Readvance</td></tr>
<tr><td>Windermere (Late-glacial) Interstadial (11,000-13,000 BP)</td><td></td></tr>
<tr><td colspan="2">Dimlington Stadial (13,000-26,000 BP)</td><td>Main Late Devensian Glaciation</td></tr>
<tr><td rowspan="2">3
4-5d</td><td>26,000-50,000</td><td colspan="3">Middle</td><td rowspan="2">Early Devensian Glaciation?</td></tr>
<tr><td>50,000-122,000</td><td colspan="3">Early</td></tr>
<tr><td>5e</td><td>122,000-132,000</td><td colspan="4">Ipswichian (Interglacial)</td><td>-</td></tr>
<tr><td>6-10</td><td>132,000-350,000</td><td colspan="4">Wolstonian (Stadial)</td><td>Wolstonian (Saalian) Glaciation</td></tr>
<tr><td>11</td><td>430,000</td><td colspan="4">Hoxnian (Interglacial)</td><td>-</td></tr>
<tr><td>12</td><td>480,000</td><td colspan="4">Anglian (Stadial)</td><td>Anglian Glaciation</td></tr>
</table>

Tab. 4. Subdivisions of the Quaternary of Scotland (redrawn from Stephenson & Gould, 1995); PG=Post-Glacial, LG=Late-Glacial.

The higher mountains being almost free of drifts show clear evidence of glacial erosion relevant to different stadials. During the interglacials deep modification of the topography occurred. Fluvioglacial streams straightened and deepened their valleys, causing watershed breaching and forming lakes dammed by ice sheet remnants. Evidence of sedimentary events predating the main Late Devensian Glaciation, mostly occur in North-East Scotland. At Dalcharn near Inverness a fossil soil containing pollen of full interglacial has been described, underlying a sequence of three tills; one of them predates the main Late Devensian Glaciation. This evidence demonstrates that the Northern Grampian Highlands were covered in pine forest during an interglacial phase preceding the Late Devensian (Stephenson & Gould, 1995). During the Dimlington Stadial an ice sheet largely, perhaps entirely, covered the Grampian region. The limit of glacier extension during this stadial is still unclear, which, according to Synge (1956) and Sutherland (1984), would have left part of the Buchan area probably free of ice. On the other hand Hall & Sugden (1987) state that cold-based ice sheets in Scandinavia have little erosive action, leaving finely preserved fluvioglacial features. A similar glacier could have crossed the Buchan area during the Dimlington Stadial, without leaving significant traces of its passage.

The majority of the Scottish lochs were formed during the late stages of the Dimlington Stadial, approximately 14,000 years BP (Battarbee & Allott, 1994).

The Windermere Interstadial (13,000-11,000 BP) was characterised by the almost complete disappearance of the ice sheet. At about 11,000 BP the ice re-advanced again mainly in the Western Highlands because of the Loch Lomond Stadial climatic deterioration. This climatic change caused the re-appearance of small glaciers in the Cairngorms but overall signalled a return to arctic tundra conditions for 1,000 year or so. In the lowlands sector small blocks of ice buried beneath sandy-gravelly sediments seem to have formed a number of small kettle-hole lochs, such as the one located in the Allan Park of Cults (Smith, 1981). Only lochs situated in the north-west of Scotland were re-covered by ice as a result of the Loch Lomond Readvance.

Vasari & Vasari (1968) studying the pollen and macrofossils from the earliest sediment of the Loch of Park in Aberdeenshire, corresponding to the Loch Lomond Stadial, documented a flora characteristic of an arctic alkaline lake. Alhonen (1968) reached similar conclusions after having studied diatom assemblages collected from the same site.

The formation of cirque lochs occurred at a later stage, as they occupy the source areas of glaciers, the last valley portion to be cleared from ice during deglaciation. The oldest Lochnagar sediments appear to have an age of 9,000 years BP (beginning of the Flandrian Interglacial), based on microfossil assemblages and geochemical evidence (Dalton *et al.*, 2001). The Flandrian Interglacial commenced at about 10,000 BP, when the climate finally started improving and crowberry and juniper scrub rapidly made their appearance. This cold association was then progressively replaced by deciduous woodland, which also spread towards the mountainous area of the Cairngorms. This climatic amelioration continued throughout the Early Flandrian, allowing the expansion of a mixed association of birch and hazel followed by oak and elm, until about 6,000 BP, when a cooler and wetter climate became established. During this stage the growth of widely spread peat blankets was favoured, allowing the deposition of several metres of vegetable debris. These deposits are now deeply eroded, especially in the uppermost portions of river drainage basins, a phenomenon directly related to the regional uplift of central Scotland (Hall & Bishop, 2002).

According to this sequence of events the Scottish mollusc fauna appears to be the result of a recent re-immigration, which can date back at least to the beginning of the Windermere Interstadial (13,000 years BP) for those lochs situated within the lowland sector. The Cairngorms were probably partially covered by ice during the Loch Lomond Readvance, and the areas left free were probably unsuitable for mollusc survival.

The peculiar distribution of *Pisidium conventus* and *P. lilljeborgii* respectively a truly Arctic and a Subarctic species mostly restricted to cold environments, may reflect an ancient Windermere Interstadial distribution, which is currently under contraction as a consequence of the global warming trend.

3.3. HYDROGRAPHICAL SETTING

This section describes the general characteristic of the main hydrographic systems, with particular emphasis on the interaction between geology and hydrology. The complex longitudinal alternation of different river reaches is also investigated and put in relation to the topographic gradient.

3.3.1. River Deveron Catchment

The River Deveron shows a general south-north orientation, draining the northern side of the Ladder Hills and flowing for a total length of 98 km to the Moray coast in the vicinity of Banff.

Its upper sector is characterised by two main catchments, one drained by the Black Water and the second by the Allt Deveron. The Black Water flows mainly through metamorphic Dalradian sediments, dominantly characterised by quartzose-mica-schist, grit, graphitic-schist and slate. The Allt Deveron drains the northern portion of the Morven intrusion, mostly formed by gabbro and allied types and the overlaying quartzose-mica-schist of the Dalradian Group, outcropping to the south-west of Cabrach. These two head areas are surrounded by a belt of medium height hills, with the maximum elevation reached by The Buck (721 m AMSL) and Cook's Cairn (755 m AMSL). These streams flow through wide glacial valleys with a low topographic gradient, causing the formation of small meanders starting from the base slope. Then both streams enter incised valleys before merging near Dalriach. From here onwards the river flows through a narrow valley bordered by low altitude hills, mostly characterised by slate, phyllite, mica-schist and graphitic-schist. Before reaching Haugh of Glass the river flows through the ultramafic rocks of the Succoth-Brown Hill complex outcropping to the eastern side of the channel. The river then flows in a west-east direction, forming a peculiar meander around the northern flank of the Dunbennan Hill, before entering Huntly. The Huntly area is dominantly characterised by granular gabbros with allied types and also partially melted hybrids of the Dalradian sediments. Near Huntly the river meets the River Bogie, which comes from the south at right angles, causing an abrupt change of direction of the main channel. The Water of Bogie is on the eastern flank of The Buck, mostly draining pelite and semipelite rocks on the hill slopes and Middle Old Red Sandstone in the bottom of the valley, between Rhynie and Lumsden. The River Deveron then flows into the

River Isla, coming from the west, causing another right angle change in direction. The River Isla rises at Lochpark; a narrow loch situated between low hills in a saddle located less than 10 km from the River Spey bottom valley. In this area outcrops of graphitic schists and shales with subordinate quartzite and grit are mostly found. Once the Isla joins the River Deveron, a set of large meanders forms as far as Turriff. The most impressive of these meanders is centred on Fourman Hill, which is composed of epidiorite, hornblende-schist and allied types, rocks particularly resistant to water erosion. From Turriff to the sea the river maintains a south-north direction, flowing through a medium size valley and forming tight meandering reaches with a small radius of curvature. The area is characterised by Dalradian rocks, mainly consisting of quartz-mica-schist, grit, slate and phyllite. The final tract of the river, just before entering the sea, is represented by a straight reach, with a pebbly-cobbly bottom characterised by a fast water flow. Only a few pockets of muddy sediments are found just below the A98 (T) bridge, where strong tidal flows sweep the channel.

3.3.2. River Ythan Catchment

The River Ythan originates in a lowland area surrounded by small hills, whose average elevation does not exceed 400 m AMSL. Its total length is 60 km and is characterised by a low estuary strongly affected by tidal influence. The Ythan upper catchment is dominantly characterised by outcrops of quartz-mica-schist, grit, slate and phyllite, belonging to the Upper Dalradian Group. The tributaries network is formed by short streams, which generally connect to the main river channel at right angles. Some artificial lochans have been created conveying running waters into natural depressions in order to use them as agricultural reservoirs or fisheries. The Loch of Fyvie is definitely the most important lentic environment occurring in the whole catchment, being characterised by a wide and shallow basin holding a rich and diversified community of aquatic plants. Downstream of Methlick, the river crosses igneous lithotypes, mainly represented by gabbro, granite, syenite and granophyre together with metamorphic rocks such as quartzite, grit and quartzose-mica-schist. Near Haddo House an ingenious system of interconnected small lakes and ponds created along a right tributary of the River Ythan, represents a valuable artificial ecosystem.

The Ythan river channel is dominantly characterised by pebbly-cobbly sediments, though it also includes boulder beds and bedrock reaches, where the stream turbulence is higher. Straight reaches dominate on meandering and braided patterns, although at least four high order meanders ($r > 1$ km) are recognized along the whole course. The longitudinal gradient gently decreases proceeding towards the mouth, where it becomes nearly flat, allowing establishment of a wide tidal flat on both sides of the channel. During low tide the mud flats are extensively exposed, especially at the confluence with the Ythan's tributaries (e.g. Tarty Burn). Tidal influence is apparent inland as far as Ellon, passing through the Kirkton of Logie Buchan Bridge, where marine live littoral fauna is still found, for example (personal data) *Littorina littorea* (Linnaeus, 1758).

3.3.3. River Don Catchment

The River Don is the second longest river in the studied area (131 km) after the River Dee, mostly developed along a west-east orientation.

The upper sector is bounded by a hill range with an average elevation of 700 m AMSL, sharing the watershed with the rivers Avon and Gairn. The head of the valley is clearly oversized compared to the size of the Fèith Bhàit, the uppermost tributary of the River Don. This is the result of river capture caused by Glen Avon, which took over the entire uppermost catchment of the Don basin, currently occupied by Loch Avon. The upper River Don basin is characterised by the occurrence of several varieties of metasedimentary rocks referred to the Dalradian Group and mainly represented by semipelite, pelite, limestone and calcareous clastic levels. Downstream from Strathdon village the outcropping rocks are composed mainly of heterogeneous metasedimentary rocks gradually passing to psammite and pelite. The Correen Hills, which constitute the northern shoulder of the basin, mainly consist of Dalradian sediments such as quartz-mica-schist, grit, slate and phyllite. To the south the valley is separated from the Dee catchment (Loch Davan and Loch Kinord area) by a low hill range. On the lowest saddle of this ridge two shallow lochans (Pronie and Witchock) are found, lying over the Mount Morven ultramafic intrusion, dominated by Norite and Olivine-ferrogabbro. Moving eastwards the upper sectors of the Long and Socach streams are surrounded by a hill range of about 500-600 m AMSL, mainly consisting of quartzose-mica-schists. Eastward from the village of Alford the River Don flows between Bennachie and Cairn William, mainly constituted of granite, syenite and granophyre. After the village of Monymusk the valley becomes wider again and crosses the Dalradian rocks (quartzose-mica-schist). At the foothill a number of old artificial shallow lochans are found, supporting well-established and diversified aquatic vegetation. Near Inverurie the river intercepts the River Urie and then flows with a dominantly meandering pattern towards its mouth. The River Urie shows a quite large catchment, being formed of two main tributaries: the Gadie Burn and the Water of Bogie. These streams drain a large area, whose upper sector is crowned by the Correen Hills (to the south) and Tap o' Noth (to the north).

Another important feature of the Don catchment was the Aberdeenshire Canal, which operated for half a century (1804-1854) before it was dismantled and its track occupied by the railway. It was a 31 km trading exploiting the water of the Don in order to facilitate boat transportation between Inverurie and Aberdeen harbour (Massie, 1981).

Near the village of Kintore the River Don has left an ox-bow lake, occurring on the right bank, indicating rapid changes in the channel migration. In the vicinity of Dyce a number of shallow lochans occupy a large natural depression, which becomes marshy southwards, particularly in between Lily and Corby lochs. The area is affected by a large granitic intrusion, which extends from Dyce to Aberdeen. Moving towards the Don mouth the Dalradian schist occurs widely, particularly exposed on the river channel left bank, upstream of the Bridge of Don. The river mouth shows limited tidal flats, the wider being situated along the right bank. This seems to be related to a relatively fast flow of water, related to a high longitudinal gradient next to the sea.

3.3.4. River Dee Catchment

The River Dee is the fifth longest river in Scotland at 140 km in length, draining a surface of about 2,100 Km^2. The river sources, Wells of Dee, are located in the middle of the Cairngorms, south-west of Braeriach summit. The area is surrounded by the highest hill range of the Cairngorms, in a typical alpine environment at about 1,220 m AMSL. From this high plateau the stream flows quietly, before falling to the incised valley, deeply excavated by the action of glaciers. Cirque lochs are typically found in this area, such as the Loch nan Stuirteag, situated in the upper sector of the Geusachan Burn. Other examples can be found on the northern slope of Cairn Toul (Lochan Uaine) and at the base of the south-east cliff of Ben Macdui (Lochan Uaine, same name as the Cairn Toul corrie). Ombrotrophic bogs are often situated on the saddles of the highest crests, frequently found ice-capped during the winter months. All these areas are dominated by the Cairngorms intrusive complex, composed mainly of granite, syenite, granophyre and allied types. The Lairig Ghru collects all the fast waters coming off these high plateaux and with its moderate gradient allows the development of meandering reaches along the main channel. Residual shallow water bodies are frequently found on the bottom of the valley, being the result of meander migration across a wide alluvial plain (e.g. the shallow lochan situated at the foot of the eastern slope of Carn Crom). Near the White Bridge the Geldie Burn flows into the River Dee, after having drained a vast area surrounded by a hill belt of about 900-1,000 m AMSL. The Geldie Burn used to be much longer, before the River Feshie captured its upper sector, in the saddle between Carn an Fhidhleir and Cnapan Mòr. Downstream from White Bridge braided reaches alternate with meandering reaches until near Braemar. Longitudinal gravelly bars and small islands are quite often distributed along this tract of the river. Ey Burn flows into the River Dee near Inverey, after having drained a large area culminating in hills of about 950-1,000 m AMSL. This zone is prevalently represented by quartzite, grit and mica-schists (particularly in the upper sector) although sandy dolomite and calcareous silicate schists do occur on the northern slope of Beinn lutharn Bheag. Near Braemar the Clunie Water merges together with the River Dee, causing a slowing down of the stream and creating a large marshy area on the Dee's left bank. Clunie Water drains a wide area, comprising two independent mountainous catchments: the Baddoch Burn and Glen Callater. The Baddoch Burn catchment is mainly represented by graphitic schists and slate, with the exception of the apical portion, where the Cairnwell granitic intrusion occurs. On the north-east slope of the Cairnwell at about 750 m AMSL, a quite elliptical cirque loch is found: Loch Vrotachan. At this location dolomitic limestones interbedded with psammite, pelite and quartzite outcrop all around the glacial depression, providing a consistent amount of dissolved carbonates to the water. Glen Callater flows in a NW-SE oriented valley, which separates Carn an Tuirc from Lochnagar. Loch Kander, a typical cirque loch, is located in the upper part of the valley, in an area dominated by graphitic mica-schists. Another cirque loch is identified in a hung valley, north-westward from Meall an t-Slugain (Loch Phàdruig). This area is situated on the margin of the Lochnagar intrusion and is dominated by granite and granodiorite. In the wider portion of the valley, Loch Callater with its narrow and elongated shape, represents a typical fluvio-glacial lake, dammed by a morainal arc laid down during glacial retreat. The eastern side of the loch is predominantly characterised by granites, whilst the western side is entirely represented by graphitic schists interbedded with marble and psammite. At the south-eastern end of the loch a whitish sandy shore does occur, characterised by a well-sorted outwash of glacial drifts. The composition reflects the nature of the rocks outcropping upstream (psammite, graphitic mica-schists and quartzite). The water column is quite shallow all across the loch, as measured after a bathymetrical survey performed at the beginning of the 20th century (Murray & Pullar, 1910). Another peculiar valley is the one incised by Allt an t-Slugain situated to the left side of the Dee. This tributary flows across quartzo-feldspathic psammite; one of these large quartzite outcrops is located on the southern slope of Meall an t-Slugain. In the vicinity of the ruins of a fortified house the stream is blocked by an old rock fall, which forces the water to disappear through a subterranean conduit. As consequence a peculiar shallow pool does occur upstream, whilst the re-emerging water forms an unusual quiet and very shallow pool at the base of this natural barrier. Moving eastwards through the southern catchment of the river, another mountainous area is found: the Lochnagar Massif. Glen Gelder drains the northern slope of the Lochnagar, whose upper tributaries rise from cirque lochs located at the base of the cliffs. The area is entirely dominated by the occurrence of the Lochnagar granite intrusion, characterised by the absence of soil over vast sectors and consequently by a large exposure of bedrock outcrops. Loch nan Eun and Lochnagar are examples of typical cirque lochs, whilst the Sandy Loch seems to be related to a different genetic mechanism (kettle-hole loch). Two other small lochs are found on the north-eastern slope of Carn an t-Sagairt Mòr, filling an incised north-east oriented corrie. On the southern side of the massif Glen Muick drains a very large area, comprising a narrow glacial loch in the upper sector (i.e. Dubh Loch) and the deepest loch of the Grampian Area: Loch Muick. Loch Muick was targeted by the bathymetrical survey performed by Lowe *et al.* (1991), which indicated that the basin was carved by glacial erosion, with a maximum depth greater than 80 m. The Dubh Loch is a glacial basin located in a natural depression deepened by the glacier's progression. Its surface is quite often covered by ice during cold winter. Loch Muick has been excavated by the same glacier, which eroded a deeper and larger valley segment just below the Dubh Loch. The south-western end of the loch shows a shore mainly built by sandy greyish-whitish sediments of glacial origin, washed and sorted by Allt an Dubh Loch. This sand is represented largely by quartz, feldspar and mica, reflecting the composition of the outcropping rocks (granite). The Black Burn flows into the southern shore of Loch Muick, draining a high plateau occupied by a number of ombrotrophic bogs. The River Muick, once it has left the Loch Muick area, forms a set of meanders through a wide and flat valley, before entering into a straighter sector, which extends down to the River Dee confluence. Loch Ullachie is a little loch situated in a natural depression between two hill ridges. The outlet flows directly into the River Dee. The Feardar Burn is a relatively small River Dee left tributary, which drains the southern slope of Culardoch. One of its right tributaries, Allt Cùl, flows through a quite flat depression, where it receives the contribution of subterranean waters, drained by spring creeks. The River Gairn, a left tributary of the Dee, is characterised by a dominantly west-east oriented water basin, whose upper catchment is located on the southern slope of Ben Avon. At the base of Culardoch's northern ridge, a very thin saddle separates the Gairn from the Avon basin. On the northern side of this saddle is Loch Builg (part of the Glen Avon catchment), whilst on the southern side a few lochans are situated in a complex terrain, composed mainly of hummocky moraines. These water bodies are fed by Loch Builg interstitial water, which flows through the rocks before re-appearing on the other side of the slope. One of them is formed by a permanent spring, which discharges directly into the River Gairn. It is possible that in the near future the River Avon, through this saddle, will probably capture the mountain sector of the River Gairn. The River Gairn is characterised by braided reaches. Once past the village of Ballater, the River Dee flows into the Cambus ó May gorge, then the valley opens widely again near the village of Dinnet. During the Dimlington Stadial in this area the Morven glacier merged with the main Dee glacier, causing deep excavations lately occupied by shallow lochs. Loch Kinord and Loch Davan are the two largest water bodies left in this area. They represent typical kettle-hole lochs formed after the ice melted. This area is particularly rich in water bodies, the water table being close to the ground surface. A large marshy area is located at the base of the south-eastern slope of Morven, where there is also a permanent bog. Another smaller marshy area is located uphill, near Bridgend. The Tarland Burn, a Dee left tributary shows a number of large pools in the upper sector, before entering an artificially rectified tract. The stream then feeds the Loch of Aboyne before merging into the River Dee.

The Loch of Aboyne occupies a natural depression filled by water dammed with an artificial barrier. Moving eastward a marshy area is found near Auchlossan. This is a remnant of a larger shallow basin (Loch Achlossan) which disappeared in Victorian times after a land reclamation scheme (Macgillivray, 1855; Bremner, 1935). On the southern side of the valley, the Pannanich Hill separates Glen Muick from Pollagach Burn. A few ombrotrophic bogs are found along the crest of this hill, located in natural depressions. The erosion of the small streams on this ridge is remarkable and in some cases the head of these channels are entirely excavated in peat soils. Another mountainous ridge is found between Pollagach Burn and Glen Tanar, where other ombrotrophic bogs are present. The upper part of the Burn of Glendui is characterised by a marshy area, where the stream starts to meander. The Glen Tanar upper tributaries drain Mount Keen northern slope showing a sub parallel pattern. The Glen Tanar is mainly formed by braided reaches, crossed by a fast stream that removes all the silty-sandy particles, which are deposited in quieter pools downstream. Two artificial small lochs used for fishing purposes are found on the left bank of the stream, created by diverted water from the stream channel. Near the confluence with the River Dee, another small loch partially blocked by a concrete ridge is located on a flat area on Birsemore Hill's northern ridge. Proceeding eastward along the Dee valley another small stream is found, mainly SW-NE oriented: the Burn of Cattie, characterised by a relatively low gradient. The Water of Feugh, a significant right tributary of the River Dee shows an ample upper catchment, before flowing through an incised valley in between Peter Hill and Craig Lash. The final tract of the Water of Feugh shows a rocky substratum with rapid reaches characterised by sediment pockets mainly consisting of pebbly-cobbly elements. On the northern side of the Dee near Banchory an elongated small loch, encased between low relief hills (Bog Loch) is connected to the Dee via the Burn of Canny. To the North of Banchory a vast marshy area, partially drained by artificial channels, occupies the lowermost part of a large depression, originally hosting a larger shallow water basin. To the east a similar feature can be recognized near Drumoak: the Loch of Park, which used to be physically larger during the 19th century (Macgillivray, 1855; Bremner, 1935). At that time the name of the basin was Loch Drum, after the nearby castle. Today the loch is reduced to a large fen, where the soil is completely formed by an accumulation of soft vegetable debris consolidated by macrophyte roots. The outlet of the Loch of Park after one km from its origin is subdivided into two branches, one of them (to the right) artificially rectified at the end of the 19th century. This intervention was necessary to drain a stagnant water body, which used to slow the speed of the current. This little elongated water body, today completely disappeared, bore the name Loch of Park as the existing one. Only in recent times was the Loch Drum name transferred to Loch of Park, generating some confusion in reconstructing the hydrological evolution of the area. Another water body still survives on this branch of the outlet, nearby the confluence with the Dee. This is an artificial elongated pool located within the Crathes estate, formed by a concrete barrier.

The Loch of Skene represents the largest loch occurring in the lowland sector of the Dee valley, separated from the Don basin by an alignment of hills which do not exceed 200 m AMSL. This loch is located in the middle of a large depression and is fed by four different inlets. The only outlet is found on the southern side, regulated by an artificial lock. The loch is quite shallow and the bottom is dominated mainly by well-sorted and packed sandy sediments, which create a firm substratum. Between the Loch of Park and the Loch of Skene flows the Gormack Burn, an artificially straightened stream channel, created to facilitate water drainage over a vast flat area towards the River Dee. On the southern side of the valley another plateau characterised by a very flat summit is identified near the village of Netherley. This relief is entirely constituted of granite and was locally used for industrial extraction, particularly near Stranog Hill. In this site an old quarry left a deep small loch fed by field water, creating an unexpected environment for the area. Moving eastward the River Dee is characterised by an increased number of meandering reaches, as a consequence of its imminent approach to the sea. The Inchgarth Reservoir near Cults, situated on the Dee left bank, is a completely new intervention designed for recreational activities and as a source of potable water. It is roughly elliptical and has a concrete bottom covered by a very thin layer of clayey sediments. On the Dee northern side the Burn of Den flows nearly parallel to the Dee, creating the Maidencraig pool at the end of an incised fluvio-glacial ravine. A few lochans and ponds are found in the Hazlehead Park area and other green areas within the town (e.g. Johnston Park). Westward from the Hill of Rubislaw an impressive abandoned quarry, delimited by very steep slopes, is completely invaded by field water, forming a small deep loch. The Dee finally reaches its mouth, which is today partially obliterated by Aberdeen harbour's infrastructure. The tidal influence is apparent up to the Duthie Park bridge, although mitigated by strong river flow. Tidal influence affect the reach between the Victoria Bridge and the A956 road bridge, as demonstrated by the high salinity of the water measured in this tract during high tide as well as by the occurrence of live marine fauna (Cirripedia).

3.3.5. Cowie Water Catchment

The Cowie Water is a minor W-E oriented stream which flows from Fetteresso Forest down to Stonehaven. Major tributaries include the Burn of Monboys and the Cowton Burn, both located to the left side of the river. The catchment is largely covered by coniferous woods and the stream is characterised by braided reaches in the upper sector and meandering reaches commencing eastward from the Hill of Three Stones. The last 2 km of the stream are only represented by braided reaches.

3.3.6. Carron Water Catchment

The Carron Water is a short stream, which flows between the low hills situated to the west of Stonehaven. The upper sector is formed by two large meanders (r > 500 m) whilst the lower one shows a rapid succession of small meanders (r < 50 m). In the southern part of the catchment a few tiny lochans and a small marshy area occur. Moving eastwards the Loch of Lumgair, a vast fen, covers a depression surrounded by low relief hills. During the 19th century the river channel was probably more elongated and defined than today, as suggested by the geological map annexed to the Macgillivray work on the natural history of Dee Side and Braemar (1855).

3.3.7. Bervie Water Catchment

The Bervie Water upper sector shows a well-developed dendritic pattern, draining the eastern side of Tire Beggar Hill. The stream then turns abruptly at about right angles twice, before flowing through the lowland sector with a distinctly meandering pattern. A few lochans are found near the broad summit of the ‘Cairn’ such as the St Jame’s Lochs. Moving eastward quite a large marshy area is located in a natural depression bounded by low hills. The water is drained southwards via an outlet, which flows directly to the north of St Cyrus.

3.3.8. River North Esk Catchment

The River North Esk has a very long course going deeply into the Grampian Mountains. Glen Lee occurs in an area surrounded by a hill belt exceeding 800 m AMSL before falling to the bottom of the valley, where the Loch of Lee is located. This portion of the valley has a typical U-shaped profile, as result of excavation by a large glacier. A lateral cirque loch (Carlochy) is found along the steep slope of Cairn Lick, 2 km westwards from Loch Lee, which has a similar shape to Loch Muick, although it is smaller and shallower. The south-western end is characterised by very shallow water, with a bottom predominantly constituted of sandy-silty sediments, derived from ice weathering the quartz-mica schist and phyllite rocks outcropping in the area.

In order to conclude this section dealing with the hydrographic networks, a brief overview relevant to the short stream system flowing through the coastal sector is given. These minor water features drain independent water basins and generally discharge directly into the North Sea.

Much of the Buchan lowland is seamed by meandering valleys markedly over scaled in relation to the size of the streams currently flowing. The Den Burn for example, which occurs just 1 km upstream from Maidencraig gorge and flows in a wide thalweg (at the base of the Rubislaw Hill), before passing into the sea under the Union Bridge, may be considered an excellent example of misfit stream (Smith, 1981). This is thought to be related to a melt water origin, having been probably formed at the beginning of the Flandrian Interglacial, when greater surface runoff occurred because of melting ice. A number of perched fluvio-glacial valleys have been formed during a stage when the local gradient was conditioned by the ice surface. The Clais Fhearnaig suspended valley, situated in between Glen Derry and Glen Quoich is another fine example of a meltwater feature (Smith, 1981).

3.4. RUNNING AND STANDING WATERS LITERATURE OVERVIEW

This section describes the different approaches followed by several authors to define an environment classification based on tangible parameters and evidence.

A general overview of the commonest classification schemes currently in use among biologists is provided for both running and standing waters.

For the studied area a local environmental subdivision in groups has been adopted based on morphological and ecological characters. These groups are then compared with the results of the classification analysis which similarly generates a dichotomous subdivision in affinity groups following a hierarchical architecture.

3.4.1. RUNNING WATERS

A number of analytical approaches have been followed by many authors dealing with different disciplines, with the only intent to identify a methodology capable to distinguish different river system sectors. Unfortunately there does not yet exist a unique classification suitable for all the river catchments on a worldwide scale, and only a few schemes have been used widely. This reality forces researchers to use obsolete concepts, rather than innovative methodologies, with the aim of comparing published case histories.

An early classification system of hydrographic networks based on a hierarchical characterisation was introduced by Horton in 1945 and subsequently modified by Strahler in 1952. This approach is organized following two fundamental concepts: the stream order and the drainage density. This method consists of a classification of channel segments in terms of stream order, assuming that no triple junctions occur within the same dendritic network. The following are the rules to be applied for the network analysis:

i) fingertip tributaries originating at source are designated order 1;

ii) the junction of two streams of order u forms a downstream channel segment of order u + 1;

iii) the junction of two streams of unequal order u and v, where v > u, creates a downstream segment having an order equal to that of the higher-order stream v (Fig. 5a).

The main limitation of this classification rests on the weak concept that when a lower-order stream merges into a higher-order stream the resulting order remains unchanged; this is unrealistic, the physical reality being an increase in channel order.

A possible solution of this problem is shown in Fig. 5b, where an alternative method based on link magnitude (the resulting stream order is calculated by adding together the two stream order values of the merging channels) is proposed (Knighton, 1998).

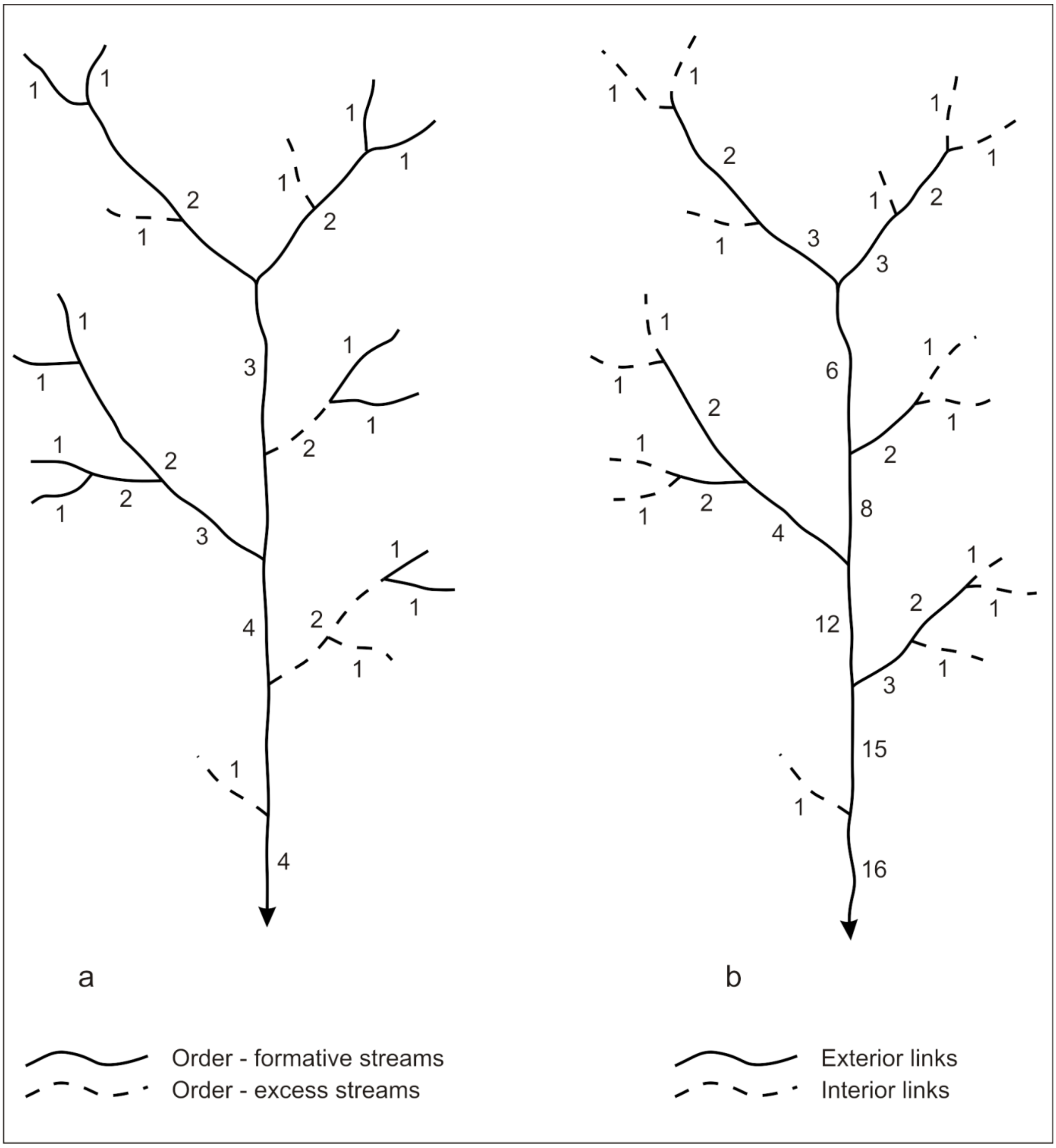

Fig. 5. Drainage networks ordering systems: a) channel segments ordered by the Horton system (1945) as modified by Strahler (1952); b) channel links ordered by magnitude as modified by Knighton (1998).

In terms of channel patterns the conventional classification of Leopold & Wolman (1957) into straight, meandering and braided reaches, appears today unsatisfactory.

Both straight and meandering channels characterised by heterogeneous bed material may develop an alternation of shallows (riffles) and deeps (pools) (Fig. 6a) (Knighton, 1998). This riffle-pool sequence is a common feature found in a large variety of streams, although it is generally associated with gravel-beds. The spacing distance between successive riffles and pools seems to be a multiple (5 to 7 times) of the channel width. Riffles tend to have coarser bed sediments than adjacent pools, as a result of a sorting process generated by the turbulent flow.

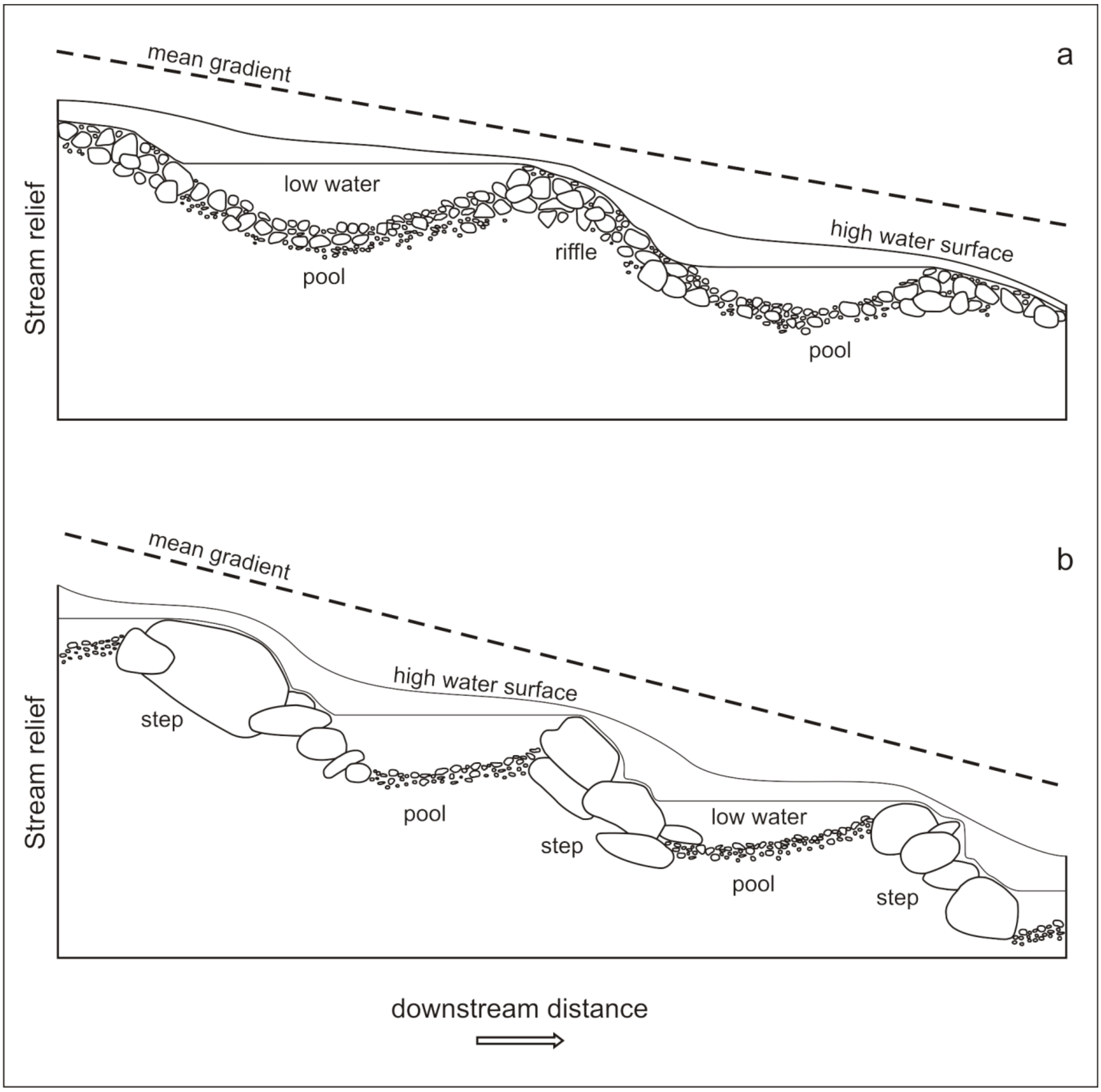

Fig. 6. Fluvial forms: a) longitudinal profile of a riffle-pool system (modified from Knighton, 1998); b) longitudinal profile of a step-pool system (redrawn from Chin, 1989 after Knighton, 1998).

Riffles and pools tend to be absent or poorly developed in boulder streams (Leopold *et al.*, 1995), where they may be replaced by a step-pool sequence (Fig. 6b) (Chin, 1989).

The two sequences also depend on the longitudinal gradient, the step-pool being more characteristic of the hydrographical upper sector and the riffle-pool the middle sector. Thus bed topography and granulometric size of the bed sediments are deeply interrelated features.

In 1980 Vannote *et al.* introduced the 'River Continuum Concept', based on the assumption that a river system presents a continuous gradient of physical conditions from headwaters to mouth. In this framework, the biological communities appear to be located in specific river sectors, where they live in equilibrium with the ecosystem according to their ecological requirements. This model considers the morphology of the river (stream size and relative channel width) as well as the presence of riparian vegetation along the banks, contributing large amounts of allochthonous detritus to the water. This scheme allows prediction of the distribution of macro biological categories based on their feeding habits (shredders, grazers, collectors, microbes and predators) as they are dependant to the size of the vegetable debris: Coarse Particulate Organic Matter (CPOM, >1 mm), Fine Particulate Organic Matter (FPOM, 50 µm-1 mm) and Ultra-fine Particulate Organic Matter (UPOM, 0.5-50 µm) (Fig. 7).Several biozonations have been attempted so far with the objective to identify general rules behind longitudinal distribution of living organisms in a fluvial environment. These ecological classifications consider the river characterization in zones, represented by animal associations adapted to specific environmental factors, generally met in similar fluvial segments belonging to different river catchments.

The most popular approach was proposed in 1963 by Illies & Botosaneanu, who presented a river zonation based on a longitudinal subdivision into three main zones: crenon, rhithron and potamon (Tab. 5).

Longitudinal Zones	
Crenon	Eucrenon
	Hypocrenon
Rhithron	Epirhithron
	Metarhithron
	Hyporhithron
Potamon	Epipotamon
	Metapotamon
	Hypopotamon

Tab. 5. River longitudinal zonation (Illies & Botosaneanu, 1963).

The crenon is the zone of the river sources, located in the uppermost sector of the basin. It is further subdivided into the eucrenon (spring or boil subzone) and the hypocrenon (brook or headstream subzone). This zone is characterised by low temperatures, low pH, high dissolved oxygen content and torrential regime, characterised by a step-pool configuration.

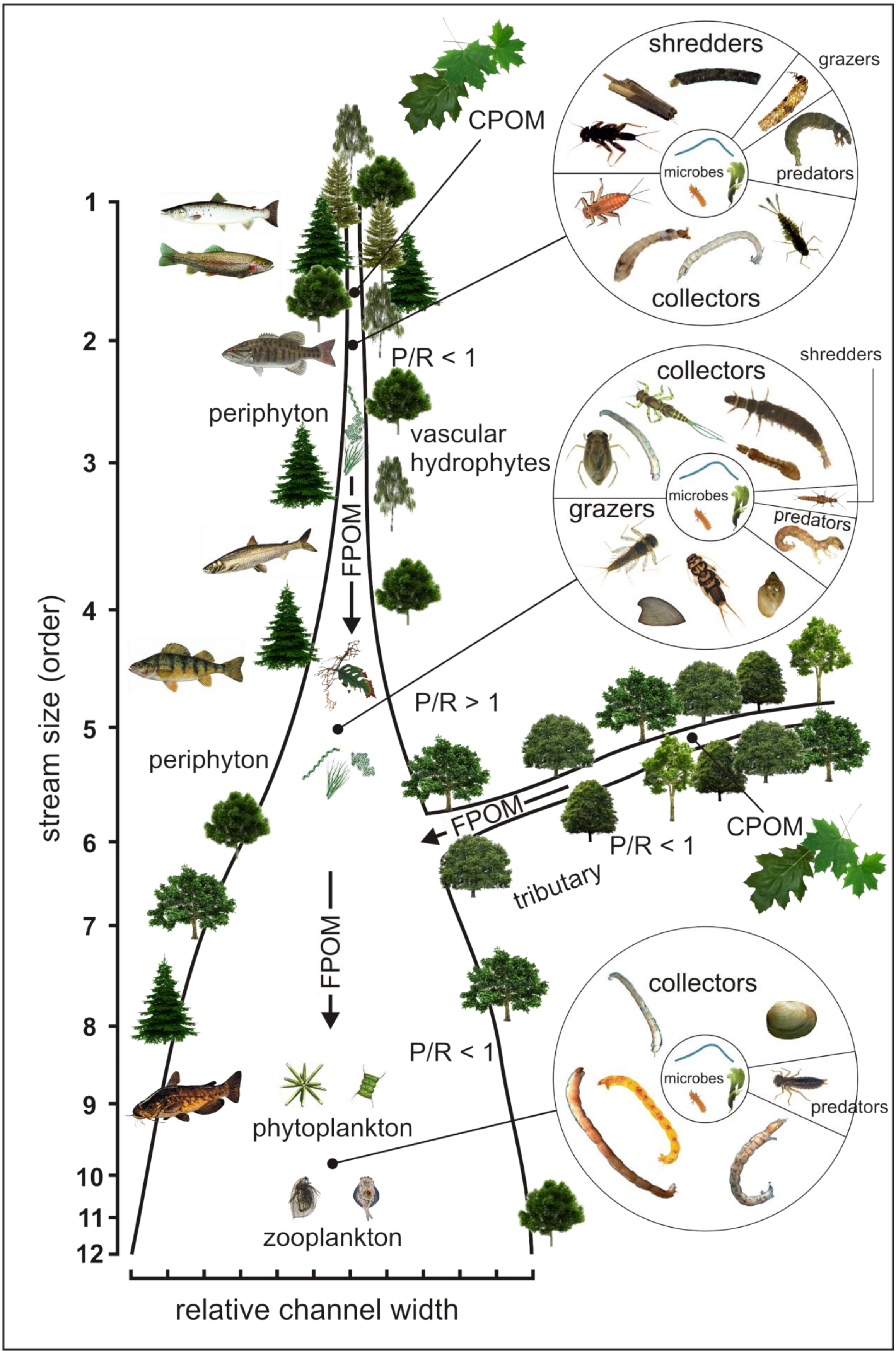

Fig. 7. The River Continuum Concept (modified from Vannote *et al.*, 1980); CPOM = Coarse Particulate Organic Matter, FPOM = Fine Particulate Organic Matter; P/R = gross primary Productivity to community Respiration ratio.

The benthic communities living in this portion of the river are mainly represented by predators, collectors, shredders and grazers feeding on debris transported by the current but also on the periphyton which begins to appear. The rhithron is the upstream portion of the river that follows the crenon. It is characterised by relatively cool temperatures, high oxygen levels, and fast, turbulent flow alternated to laminar flow in the quieter tracts. The most frequent configuration occurring in this sector is represented by the riffle-pool sequence. This river zone is inhabited by a highly diversified macroinvertebrate fauna, mainly composed of predators, collectors and grazers feeding on the periphyton but also on the organic component of the solid load transported by a generally considerable flow. The shredders become less represented as the size of the organic particulate decreases.

The potamon is the remaining downstream river stretch. It is characterised by warmer temperatures, lower dissolved oxygen levels, slow flow and silty-sandy substrata, with soft, organic-rich clayey sediments deposited in the quieter pools.

Among the benthic invertebrates, the presence of species sensitive to pollution gradually decreases, whilst collectors such as sediment-feeders and suspension-feeders dominate the environment. These organisms mainly feed on fine particle-size organic matter, phyto- and zooplankton. The predators are well represented too.

This partition is mainly characterised by the distribution of distinct animal and plant communities in relation to the variations of abiotic patterns such as current and temperature. The major advantage of this classification is represented by its popularity among hydrobiologists, who have applied it to a variety of river systems. The result is the creation of a worldwide data base based on the same analytical approach, which can be used to compare environments located in different ecological settings. On the other hand this method has strong limitations related to the parameters considered in the survey and to the geographical location of the study area.

3.4.2. STANDING WATERS

Standing water definition includes both the natural water bodies such as lochs and lochans as well as artificial systems such as reservoirs, fisheries and ponds. The actual number of lochs and lochans in Scotland is not known yet. This because of their high number and the huge variety of the waterbodies, encompassing small coalescent peat lochans (mainly in North and West Scotland) and massive lochs occupying the major tectonic valleys (mainly in Central Scotland).

Smith & Lyle (1979) attempted to count the total number of the Scottish Lochs with a size greater than 0.04 Km^2, estimated to be 3,788.

Standing waters cover about 2% of the whole inland area of Scotland, with a higher concentration in the north-west of the country, including the islands.

There are a number of valuable general classifications of wetlands and deep water bodies, but most of the time they tend to be valid only for specific areas, being essentially based on chemico-physical variations among ecosystems which are geographically dependent.

The classification proposed by Zoltai & Witt (1995) considers water chemistry, biotic and hydrological gradients, with the major disadvantage of being very general with a subdivision in major ecological categories (Fig. 8). This classification does not include running waters and it is designed only to cover shallow wetlands.

Productivity or the nutrient richness of lakes is the basis of the trophic concept, the most popular classification among limnologists. According to this approach four main trophic classes are identified with all the intermediate gradations:

- oligotrophic (nutrient poor);
- dystrophic (peaty, highly acidic, with low levels of oxygen);
- mesotrophic (nutrient intermediate);
- eutrophic (nutrient rich).

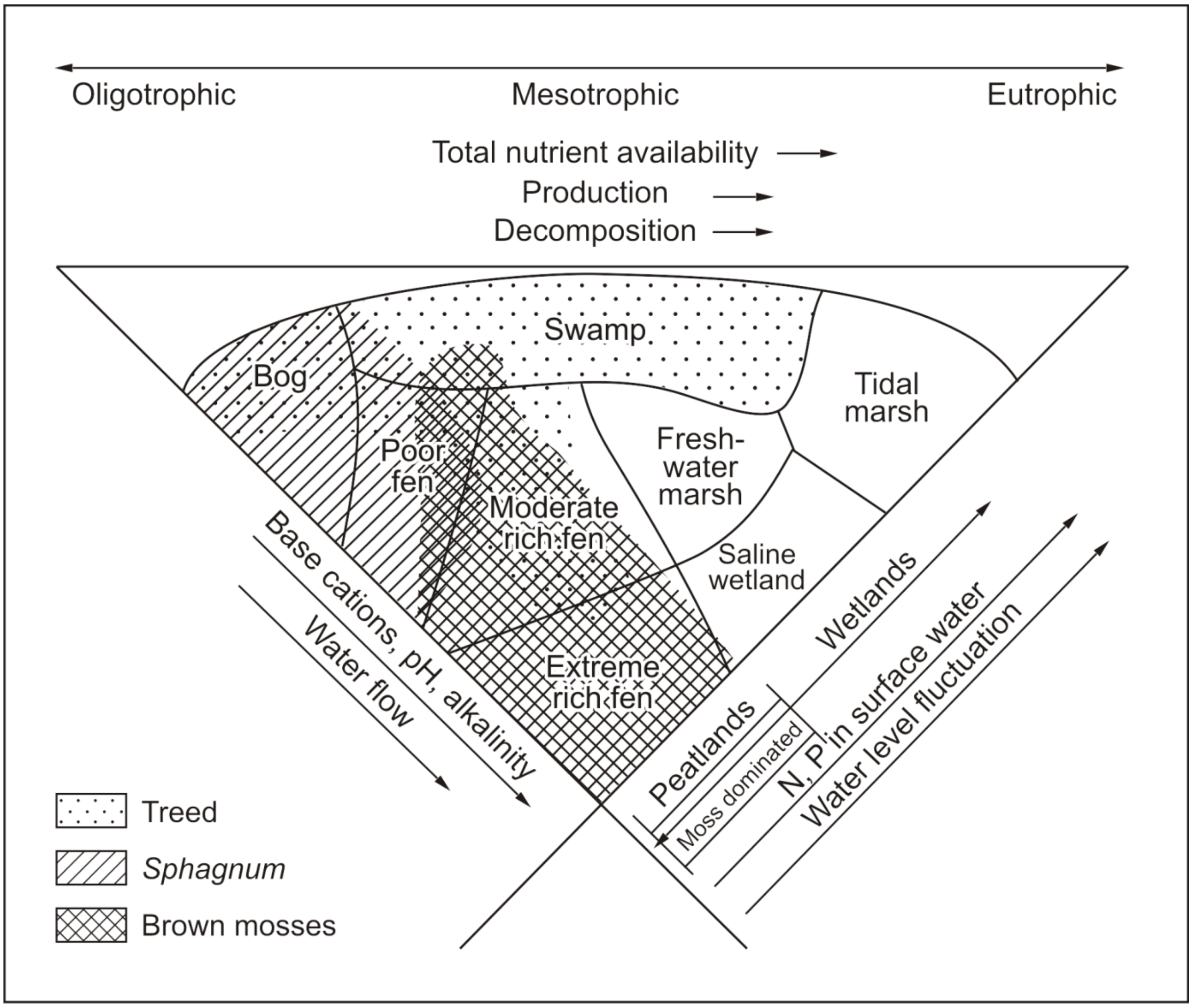

Fig. 8. The relationship between Canadian wetland types and major water chemistry, biotic and hydrological gradients (from Zoltai & Witt, 1995).

This classification covers entirely the gamut from nutrient-poor mountain lochans to those that are nutrient-rich, usually found in lowlands. Even if composed of four major classes, this range has to be considered as a 'continuum', which runs from the oligotrophic lakes at one end to the eutrophic lakes at the other end. All the intermediates are in fact known and this schematic partition is only an additional tool to characterise a habitat and to help in understanding its ecology.

The majority of the water bodies located in the Cairngorms region are generally oligotrophic, including large lochs such as Loch Muick and Loch Lee as well as a high number of lochans and pools found at high altitude. This area is characterised by a high run-off which does not allow the storage of nutrients in the standing waters with the only exception for the pools and bogs formed in peaty soils (dystrophic environments). Local exceptions are also found in the major lochs, where dys- to mesotrophic conditions may be reached in proximity to low energy outlets draining vast areas (e.g. mouth of the Water of Lee, station No. 297). Together with a poor organic content the oligotrophic bodies are characterised by soft water with a chemical composition close to the meteoric water. This environment is only colonised by a highly tolerant and poorly diversified fauna and sometime native salmonids might find a suitable refuge. For molluscs oligotrophic waters represent an impassable obstacle and the main cause of rarefaction for the catholic species in the high altitude ranges.

Mesotrophic lochs are those water bodies characterised by an intermediate nutrient level. Nutrients are mainly represented by a narrow range only encompassing organic nitrogen and total phosphorous. A number of lochs occurring in the mid sector of the River Dee are assigned to the mesotrophic class because of their moderate content of nutrients. According to previous surveys performed by Scottish Natural Heritage (SNH, 2001) and Scottish Environment Protection Agency (SEPA, 2006) on invertebrate and macrophyte communities as well as nutrient composition, only a few lochs have been reported to be true mesotrophic.

Loch Kinord, Loch Davan, Loch of Aboyne and Loch Vrotachan, all located within the River Dee drainage basin, are example of mesotrophic lochs.

Eutrophic lochs in the Grampian Area represent the majority of standing waters located in the lowlands. These water bodies typically show a high level of nutrients such as phosphorous and nitrates largely derived from fertilisers, industry and household detergents together with urban discharges. Eutrophic lochs generally support large vegetation and plankton communities but risk being affected by high levels of pollution as the biomass may grow beyond the limit of natural recycling. A high level of eutrophication can be reached during the summer months, when the water warming associated with high biomass productivity causes oxygen deficiency and large accumulations of nutrients at the bottom interface.

Examples of eutrophic lochs within the Grampian Area are Loch of Skene, Loch of Fasque, Pitfour Lake and Loch of Strathbeg.

4

RESULTS

This chapter discusses the composition of the Scottish malacofauna with particular reference to the studied area.

A total of 334 sampling stations have been investigated during this project, 204 in running and 130 in standing waters, ranging from the coastal sector up to the highland sector of the central Grampian Area (Fig. 9).

The relationships among the water chemico-physical parameters recorded during the sampling campaign are presented and discussed in the first section.

The second and third sections comprise an overview of the running and standing waters, describing the criteria used to group water features to homogeneous classes (Figs. 10-17).

The fourth section describes general ecological and chorological information for each single taxon belonging to the local malacological fauna. The taxa are grouped in four macro-categories according to their zoogeographical origin (native, successfully established alien taxa, historical taxa records not confirmed and occasional historical findings).

The fifth section deals with the spatial distribution of the taxa in relation to environmental and chemico-physical parameters. A combined approach based on classification, ordination, multiple linear regression and canonical correspondence analysis allowed a clear reconstruction of the major distribution trends and identification of species associations pertinent to different habitat types.

The sixth section deals with the mollusc vertical distribution, providing an updated list of the recorded maximum altitude for a number of species and discussing the key ecological parameters limiting their population spread.

The seventh section concerns the passive dispersal mechanisms invoked for molluscs, which is the result of several field observations collected and revised since the mid 19th century.
Plates 36-38 show examples of different habitats for both running and standing waters.

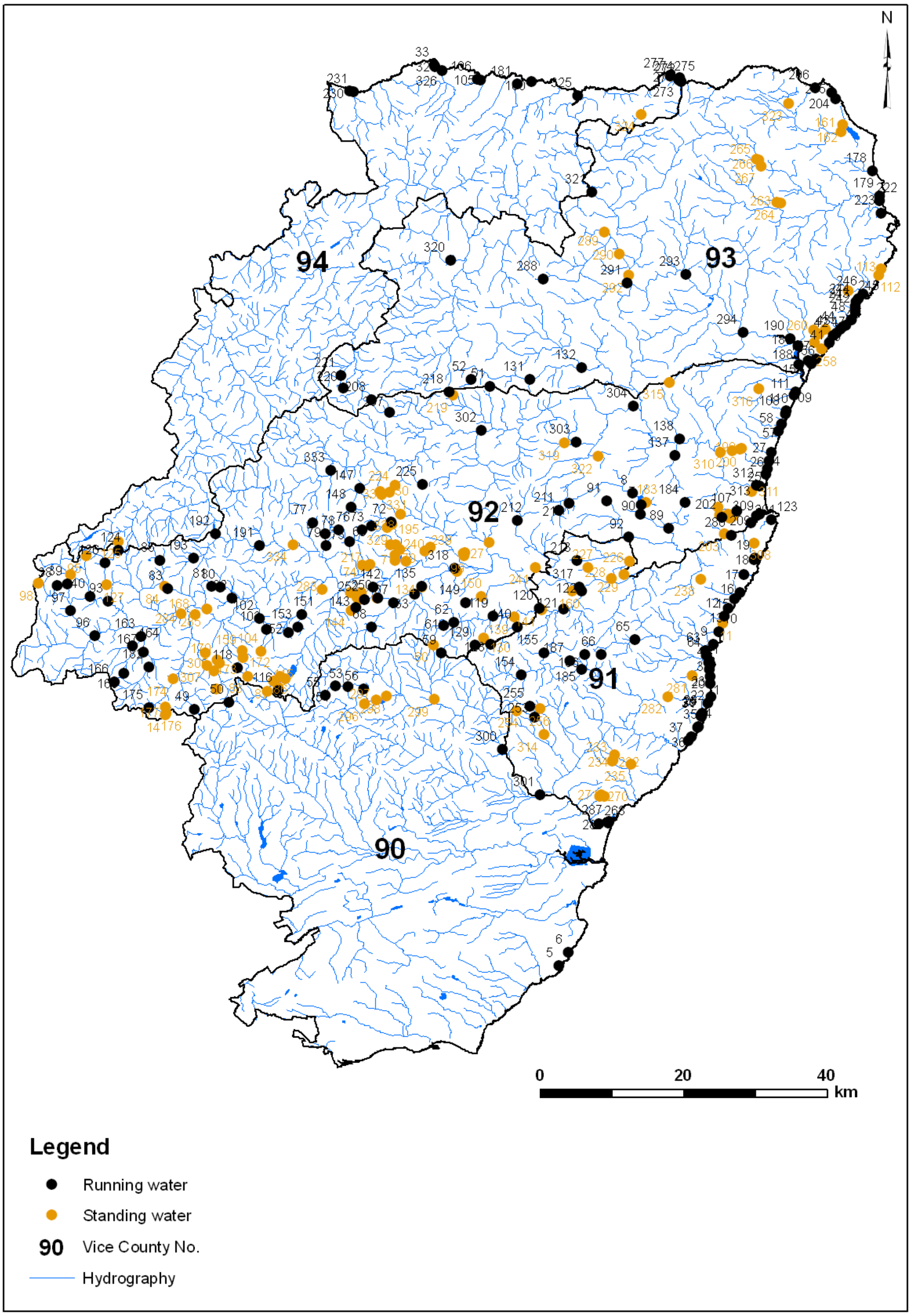

Fig. 9. Sampling stations location map.

4.1. CHEMICO-PHYSICAL WATER PARAMETERS CHARACTERIZATION

Surface waters in the studied area show relatively poor ion content, with a general enrichment trend (negative relation) of the conductivity parameter from the highland to the lowland sectors (Fig. 10). This relation is best explained by a power equation ($R^2 = 0.6294$), because the widest conductivity variation is achieved between 0-200 m AMSL, with no major changes in the interval 200-1300 m AMSL.

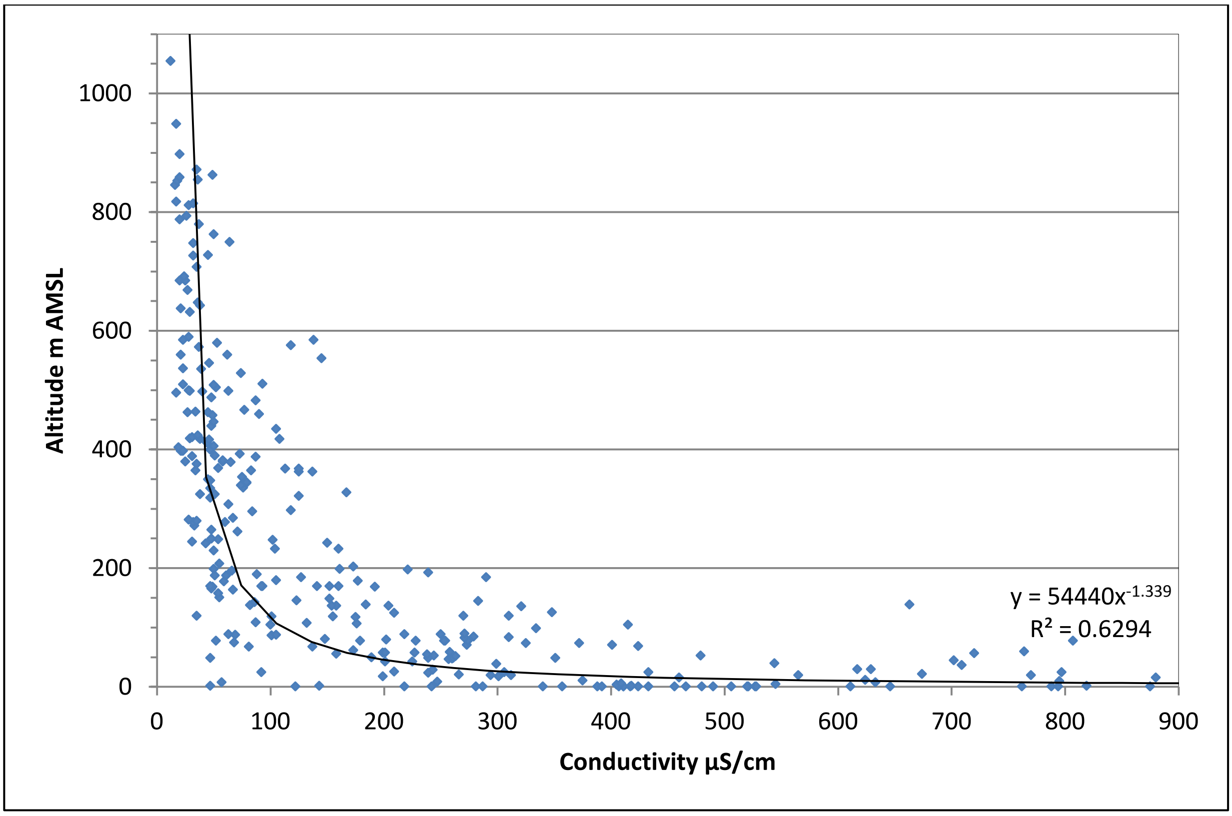

Fig. 10. Conductivity vs altitude cross-plot.

This is particularly evident on a contour map showing the conductivity gradient within the study area resulting from the sampling stations data contouring (Fig. 11). The 100 µS/cm contour line approximately separates the highland from the lowland area, indicating that only waters with poor ion content (less than 100 µS/cm, apart from few exceptions) are found in the mountain sector. Moreover the steep conductivity gradients pointing towards the north-east and the south-east of the area, suggest continuously increasing numbers of dissolved ions in the water moving towards the coast, with major variations related to the topographical gradient. The contour lines morphology superimposed on the DEM, clearly shows this, confirming the negative relationship among these two parameters.

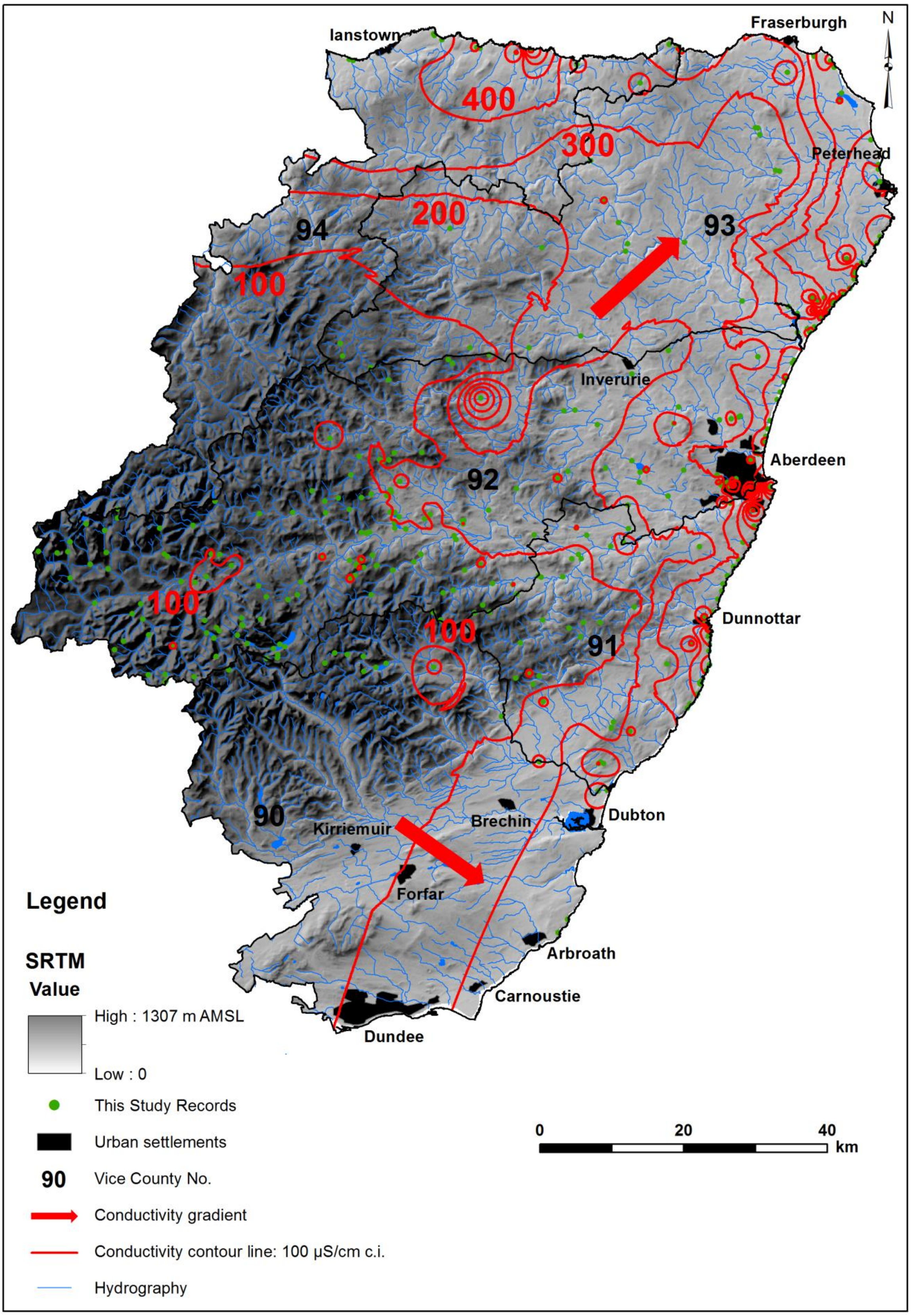

Fig. 11. Water conductivity contour map.

Although not very clearly ($R^2 = 0.1751$), a linear trend can be fit in the pH-altitude cross-plot (Fig. 12).

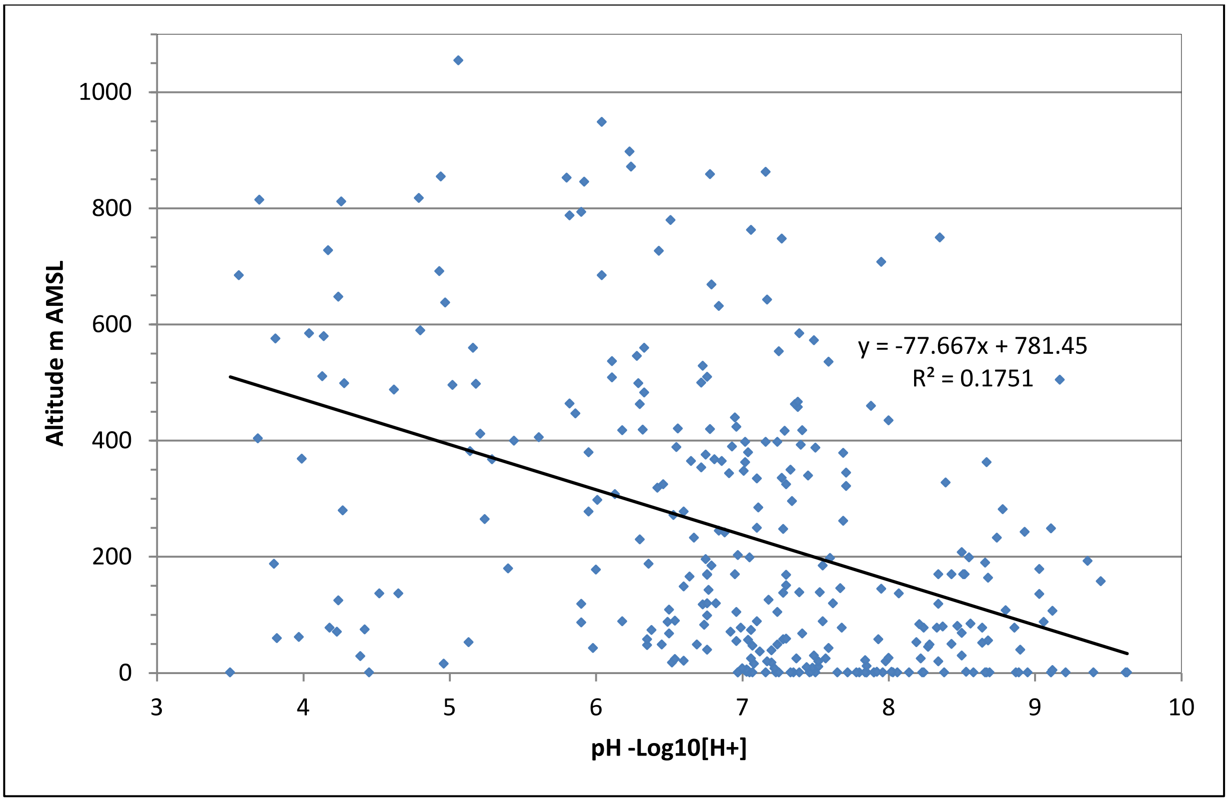

Fig. 12. pH vs altitude cross-plot.

The negative relationship between altitude and pH is related to increasing productivity of surface waters closer to the lowlands and consequently to an increase in alkalinity caused by photosynthesis processes rising in relation to water eutrophization.

This is also evident in the pH contour map (Fig. 13), where similar gradients to those identified for conductivity can be seen. Clearly this map shows a more scattered distribution of pH, with a number of local exceptions, related to environmental productivity. Nevertheless, a general pH increase with decreasing altitude is rather evident, particularly towards the north-east where the pH 7 contour line, analogous to the 100 µS/cm conductivity contour, roughly follows the major break of slope.

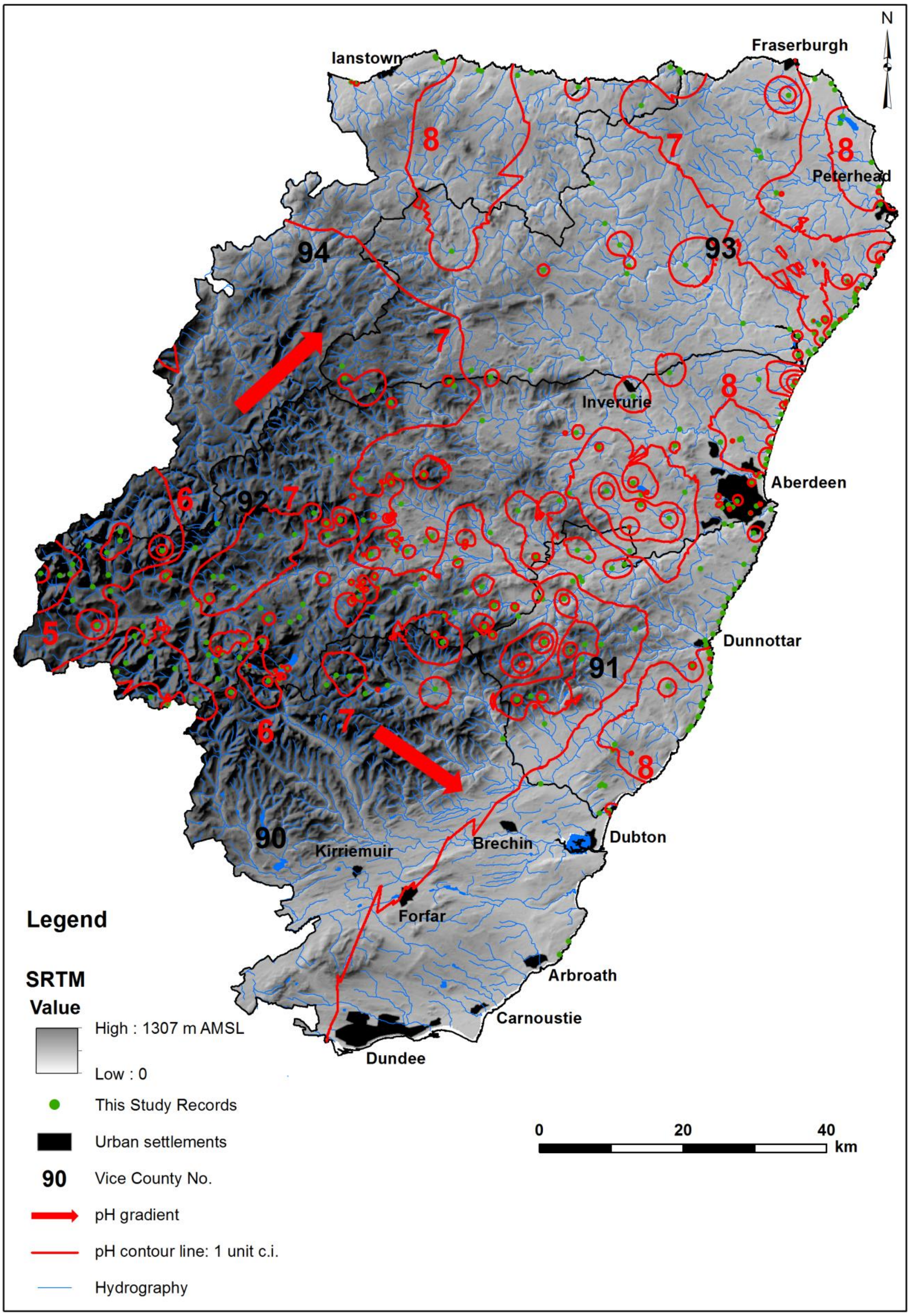

Fig. 13. Water pH contour map.

The relation between altitude, conductivity and pH can also be inferred from the conductivity-pH cross-plot shown in Figure-14.

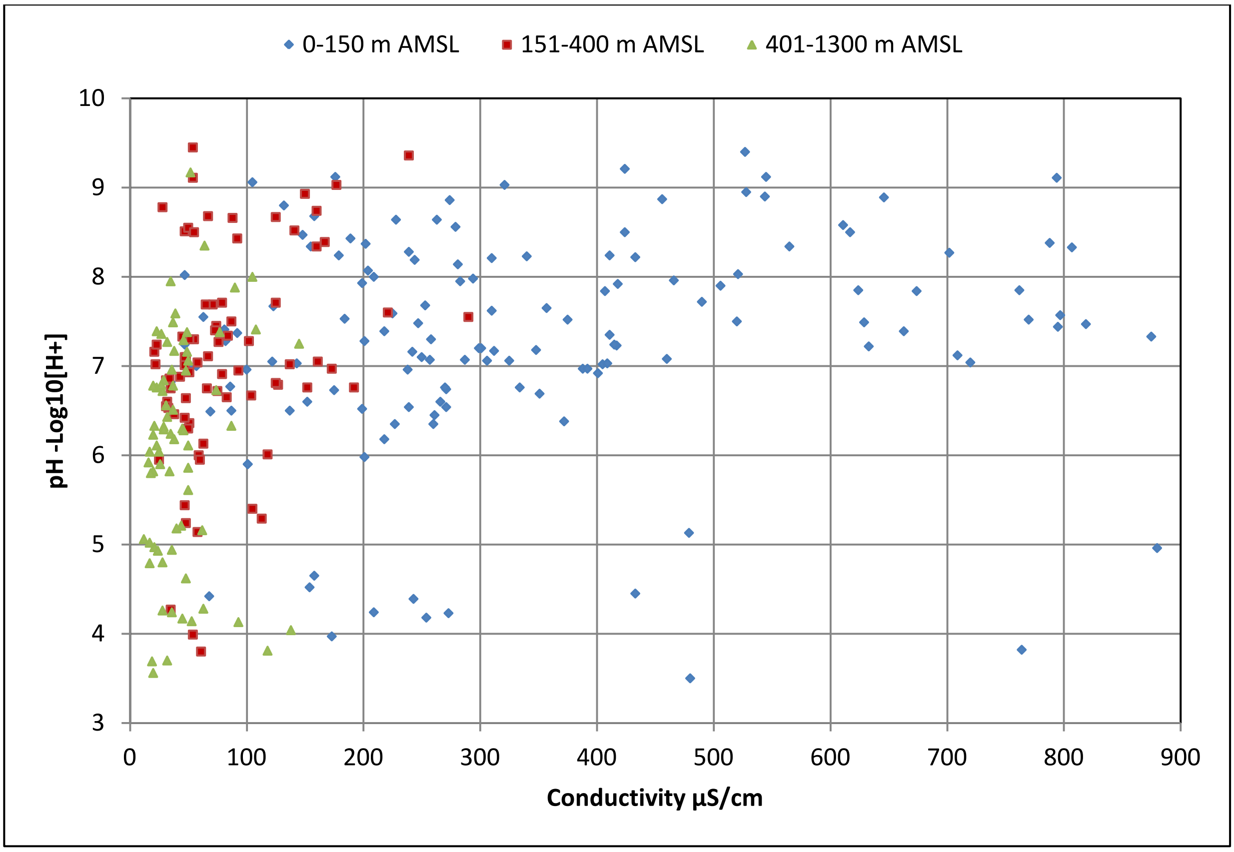

Fig. 14. Conductivity versus pH cross-plot; the coloured clusters refer to three different altitude ranges.

It appears relatively clear that the altitude range class 401-1,300 m AMSL mainly falls in the low conductivity category (0-100 µS/cm), with pH values generally acidic, even though the majority of samples are within the 6-7 pH range, close to neutrality. The environments in the bottom left corner of the graph are located in the Cairngorms Area, where the combination of acid rains and granitic rocks determine the very oligotrophic nature of the waters. The intermediate class (151-400 m AMSL) covers a wider range of conductivity with values generally between 0 and 200 µS/cm and pH values ranging between 6 and 9. The third class (0-150 m AMSL), typical of the lowland sector, shows a scattered distribution in the cross-plot, covering a wide range of conductivity (100-900 µS/cm) with pH values generally above 6, indicating increasing alkalinity with decreasing altitude.

The relation between conductivity and oxygen concentration is shown in Figure-15.

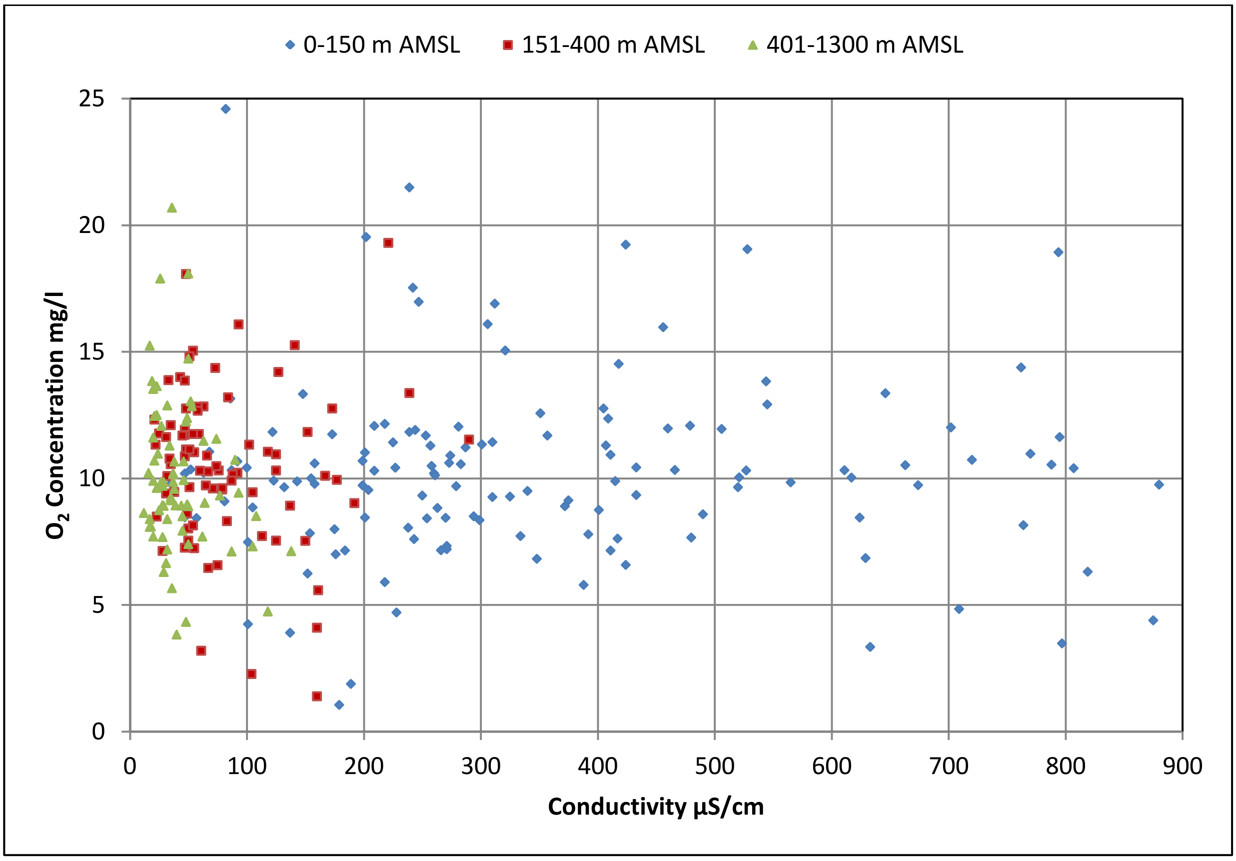

Fig. 15. Conductivity versus O_2 concentration cross-plot; the coloured clusters refer to three different altitude ranges.

Similar to the conductivity-pH cross-plot, the three altitude class partition appears consistent with the data distribution. This is driven mainly by the conductivity gradient which is negatively related to altitude (Fig. 15). The oxygen content generally falls within the 8-12 mg/l range, which is typical of waters with a low level of dissolved ions and poor in nutrients, consistent with the majority of the surface waters investigated, particularly in the highland sector.

The oxygen concentration of surface waters is related to two main factors: water energy and vegetation presence. In the uppermost part of the river catchments the oxygen content tends to remain rather high, especially in those stream sectors characterised by a step-pool or riffle configuration, where the flow is generally turbulent and tends to incorporate significant amounts of air in the form of micro-bubbles. Moreover the water temperatures of these mountain sectors are generally low, facilitating oxygen solubility.

The water composition in the headwater sectors tend to be similar to that of the rain-fall, considering the high precipitation rate and the quick runoff time.

On the other hand the highest values of oxygen content are generally recorded in the standing waters of the lowland sector, where the high nutrient content allows the establishment of diversified vegetation, producing significant amounts of oxygen during photosynthesis. These habitats are frequently oversaturated with oxygen, with a vertical gradient dramatically decreasing towards the bottom of the water column, where the respiration of animals and plants and decomposition of organic matter may establish anoxic conditions (and acidic pH).

Poor oxygen levels at the base of the water column can be found in habitats of virtually every altitude range, depending on stagnation and limited vertical circulation, conditions frequently met in a variety of aquatic environments.

Those stations falling in the bottom left of the Figure-15 graph belong to lowland water bodies located in the middle of the drainage basins, which are characterised by restricted circulation and stagnant conditions at the base of the water column.

The oxygen concentration and pH relation is shown in Figure-16.

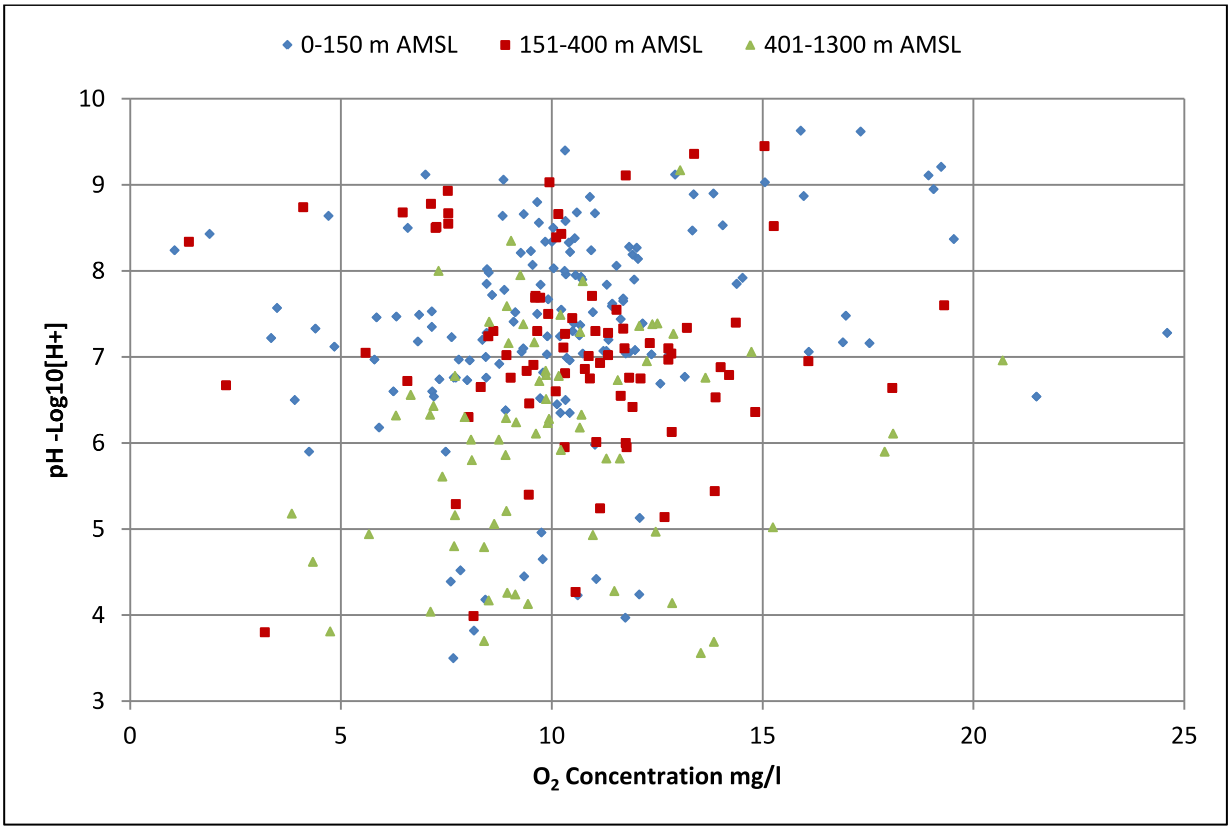

Fig. 16. O_2 Concentration versus pH cross-plot; the coloured clusters refer to three different altitude ranges.

In Figure-16 the altitude classes are not clearly separated as the majority of the data falls into the 6-8 pH and 5-15 mg/l oxygen concentration ranges. Notwithstanding there is a shift of the high altitude class (401-1,300 m AMSL) towards the lower half of the graph, once again an indication of the decreasing pH with increasing altitude. Moreover a pH increase is visible in those stations of the low altitude class (0-150 m AMSL) falling in the upper right side of the graph, which also show an increase in oxygen concentration. This is another indication of alkalinity increasing with decreasing altitude, but also of an oxygen content increment related to the photosynthetic activity of the aquatic vegetation which becomes more and more abundant in lowland habitats.

The oxygen concentration and Eh relation is shown in Figure-17.

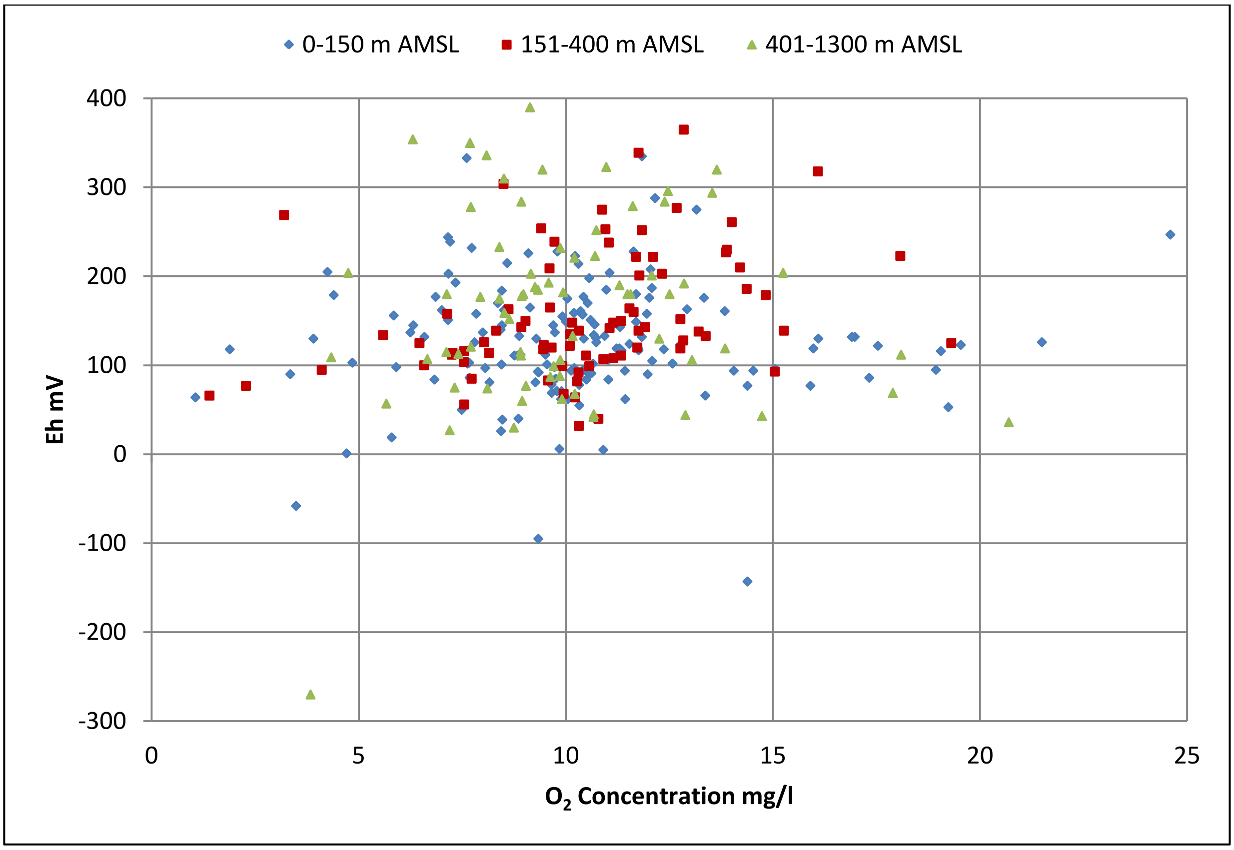

Fig. 17. O_2 concentration versus redox potential (Eh) cross-plot; the coloured clusters refer to three different altitude ranges.

This is a less distinctive cross-plot, as it only displays the majority of samples falling within the 8-12 mg/l oxygen and 80-160 mV ranges, which is typical of oxygenated surface water.

Altitude class 401-1300 mAMSL appears dominating at high positive Eh (oxidizing conditions), indicating good oxygen concentration levels at the base of the water column (e.g. turbulent flow in mountain streams).

On the other side reducing conditions (i.e. negative Eh values) are found in stagnant habitats with heavy production of organic matter. In these environments in fact oxygen concentration is low (and pH as well), because of its consumption during the degradation process of animal and vegetal debris.

Reducing conditions are frequently met in estuarine environments (e.g. St No. 206, -143mV and St. No. 286, -95 mV, bottom side of the graph), particularly in tidal planes, where lateral pools may receive consistent loads of organic particulate, which tends to accumulate at the bottom, where water exchange is limited.

Relationships between chemico-physical parameters and ecosystem characteristics are discussed in more detail in the next two sections, dealing respectively with characterization of the running and standing waters.

4.2. RUNNING WATERS CHARACTERIZATION

For this study a wide subdivision of classes has been used, based on chemico-physical parameters recorded on the field and on morphological evidence from comparison to published classifications.

During two years of field work a total of 204 lotic stations (Fig. 18) have been sampled and subdivided in 5 ecological classes, following a macro-classification based on river zonation and chemico-physical parameters.

The following are the identified classes (in brackets number of stations and average trophic level):

- Linear springs (38 stations, oligo-mesotrophic)
- Streams (101 stations, oligo-eutrophic)
- Rivers (49 stations, oligo-eutrophic)
- Estuarine (13 stations, eutrophic)
- Artificial channels (3 stations, oligo-mesotrophic)

The distinction between streams and rivers is mainly based on the hierarchical characterisation following Strahler's (1952) considerations (Fig. 5) combined with the effective water capacity and the type of flow. Generally speaking channels indexed with an order equal or higher than 3 are referred to rivers, orders 1 and 2 are placed into streams and the uppermost sectors of order-1 may refer to linear springs. A high water capacity associated with a turbulent to laminar flow may be another character confirming the attribution based only on morphological evidences.

According to the methodology adopted for running waters differentiation, 101 stream and 49 river habitats have been sampled for this study.

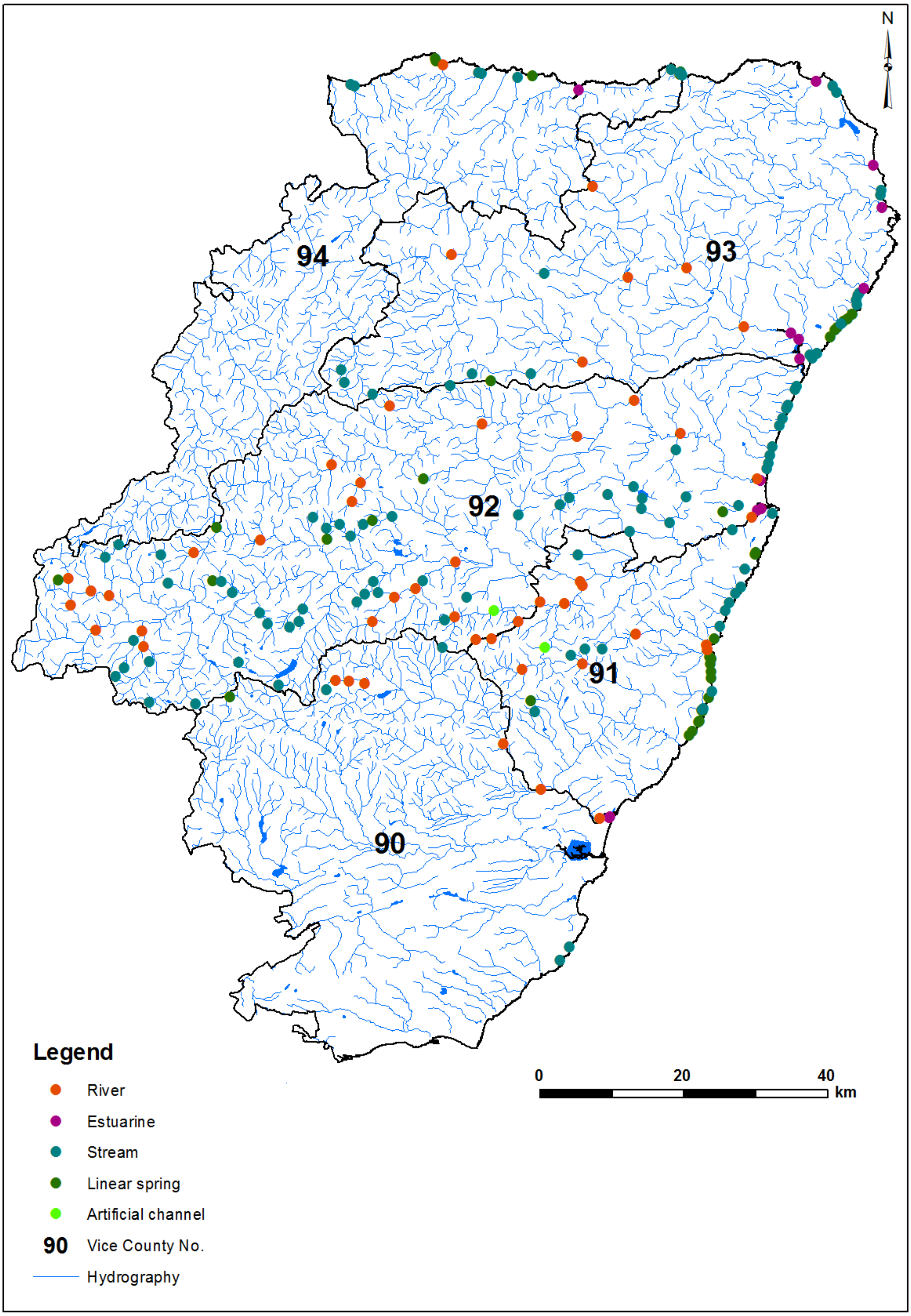

Fig. 18. Running waters characterization map.

Linear springs

Linear springs mainly occur along the coastal sector, where small-medium streams develop quite frequently on the plateaux located on top of the cliffs and reach the sea flowing through steep thalwegs (frequently order-1). The altitude range of this sector is 0-100 m AMSL. Deep gorges are regularly found along the coastal system, where the groundwater spills out from the fractured bedrock forming turbulent streams. The stream-bed is generally represented by a coarse matrix (gravelly-pebbly) covered with boulders. The bedrock is frequently exposed and waterfalls often break the flow, dropping several metres. Being close to the sea, the ion content of the water reflects its interaction, mainly influenced by sea spray. Conductivity range is between 375 and 1,045 µS/cm (average 684 µS/cm); some of these values are among the highest recorded in the entire surveyed area. The pH is generally neutral (7.84, range: 7.04-9.12) even though there is a slight tendency towards alkalinity, due to photosynthesis process performed by aquatic macrophytes growing along stream banks. The dissolved oxygen content is highly variable, mostly related to the current speed (3.35-13.84 mg/l, average 9.33 mg/l). Quiet pools are generally characterised by low oxygen concentration as result of decomposition processes (e.g. 3.35 mg/l in St. No. 273 near Pennan), on the other hand fast reaches with turbulent flow show very high levels of O_2 (e.g. 12.93 mg/l in St. No. 3 near Stonehaven).

The Eh varies between -58 and 228 mV (average 146 mV), reflecting the occurrence of reducing bottom conditions in some stream reaches (e.g. St. No. 42 near Collieston).

Linear springs are also found in other catchments, such as in the uppermost sectors of the drainage basins or at the base of hill slopes located in the lowland. Fed by groundwaters, these springs move continuously along the stream channel depending on vertical fluctuations of the water table level. The groundwater in these medium-high sectors is fed mainly by snow melting and/or by meteoric precipitation. The pH is slightly acidic (5.14-7.41, average 6.56), indicating a clear meteoric provenance and a gentle interaction with granites or metamorphic units. The ground infiltration in fractured rocks is in fact very high and the travelling time for the meteoric water to reach the field water is very short. An alkaline pH value (9.17, St. No. 225) has been recorded in only one case, related to an extremely slow water flow chocked by macrophytes and causing stagnation. This station represents an exception among the linear spring category; it is fed by water spilled from an old well.

The ion content in linear springs is quite poor (48-250 µS/cm, average 93.78 µS/cm), which is in agreement with the average values measured for surface waters in the mountain or hill sectors. The oxygen concentration is high (7.12-13.05 mg/l, average 9.97 mg/l), corresponding with a rapid flow and clear water.

The Eh confirms the good oxygenation of the bottom sediments (83-277 mV, average 135 mV). Linear springs cover the oligo-mesotrophic range widely.

Streams

Streams are a very common feature in Scotland, a consequence of the high rainfall and proximity of the water table to the ground surface. The great abundance of water in the region favours the development of a complex hydrographic network, regardless of the permeability of the drained substratum.

Three major categories of streams are identified in the studied area.

The first corresponds to mountain streams, a very dense network of channels found in the uppermost sectors of hydrographic basins (order-1+2). The elevation range of this system is mainly between 1,300 m AMSL (corresponding to the highest parts of the Cairngorms) and the 401 m AMSL contour line (Pl. 35, Figs. a-b).

In relation to their meteoric origin, these running waters show a very poor ion content (20-77 μS/cm, average 42 μS/cm) with no clastic material in suspension. The waters are very clear and the stream bottoms are mainly composed of a gravelly-cobbly matrix covered with boulders. The environment is well-oxygenated (7.41-18.10 mg/l, average 10.91 mg/l), being characterised by turbulent flow and frequent small falls causing the formation of air bubbles. The pH is mostly acidic (3.56-7.95, average 6.25) because of granites and metamorphic rocks outcropping in the area, and also because of the acid rain contribution, the pH signature of which is typically ≤ 5.6.

The Eh spans a wide range, roughly consistent with a series of well-oxygenated environments (42-350 mV, average 178 mV).

These streams are mostly oligotrophic, due to the scarce supply of nutrients from the drainage areas.

The second category includes the midland streams (order-1+2+3) occurring within the 400-151 m AMSL hypsometric range (Pl. 35, Fig. g; Pl. 36, Fig. b). This category basically includes all the channels converging on the major rivers or discharging into lochs (e.g. St. No. 8, Kinnernie Burn, inlet of the Loch of Skene).

The ion content is still quite low (25-192 μS/cm, average 81 μS/cm) although a slight increase compared to the mountain streams is documented. The pH covers a wide range (3.99-8.66, average 6.83) reflecting a high environmental differentiation. These streams are in fact characterised by lower gradients compared to the mountain range and also start receiving nitrates and phosphates from cultivated areas. The oxygen content follows a similar trend, with an average value consistent with well-oxygenated waters (6.58-18.08 mg/l, average 11.47 mg/l) but with high peaks related to eutrophic environments, sometimes established in the quieter stream pools.

The Eh generally indicates non reducing conditions at the water-bottom interfaces (82-365 mV, average 171 mV).

The trophic level covers the full range of oligo-eutrophic environments.

The third category includes the lowland streams, between the isohypses 150 and 0 m AMSL. These streams are mainly located either along the coastal sector or at the foot of the lowland hills (e.g. St. No. 131, Gadie Burn flowing at the base of the north-western slope of the Bennachie Hill). The streams draining the coastal sector are mainly characterised by linear single channels (order-1) directly connected to the sea (Pl. 36, Fig. c). and rarely organized in systems of higher order (order-2).

The ion content is the highest found in the whole region in relation to the vicinity of the sea (173-2,880 µS/cm, average 525 µS/cm). The interaction with the sea is mostly related to the sea-spray as the steep gradient generally characterising these streams does not allow mixing with the transitional groundwater system. The pH has a wide range (3.50-9.63, average 7.35), with very low values for those streams flowing in areas with outcropping granites (e.g. 4.45 in St. No. 110 and 3.50 in St. No. 111, located between Balmedie and Newburgh) or high values for the slow flowing systems, next to the coast (e.g. 9.62 in St. No. 25 and 9.63 in St. No. 26, both located to the north of Aberdeen). The oxygen concentration spans a considerable range (4.40-19.54 mg/l, average 11.57 mg/l), reflecting the great heterogeneity of the environments considered.

The Eh range tends to shift towards low values (6-244 mV, average 119 mV), indicating the near reducing conditions reached in some streams characterised by slow flow and high rate of organic matter decomposition (St. No. 20 near Catterline).

These streams are generally found in very different trophic levels (oligo-eutrophic), depending on the current speed and on the runoff contribution from surrounding cultivated fields.

Rivers

Some major rivers drain vast sectors of the Grampian Area. The rivers Dee and Don with their west-east directions are among the longest found in Scotland. These two rivers show a series of deeply diversified environments proceeding downstream from the mountainous sector. Rivers are mostly represented by reaches of order-3-4 and higher.

The amount of water averagely carried by these rivers is considerable, in relation to the great number of lochs and lochans connected to the drainage system. The uppermost sectors of the Grampian rivers range between 550 and 400 m AMSL, and are characterised by both meandering and braided river systems (Pl. 35, Figs. c-e, h). The water composition tends to be similar to that found in the mountain streams; the only consistent difference is in the amount of water carried by the large channels. Consequently the channel type changes from a step and pool sequence, typical of the uppermost systems, to a braided/meandering type, with the formation of quiet pools where the stream flow becomes weaker (Pl. 35, Fig. c). The Dee sector between Corrour Bothy and the White Bridge (Cairngorms area) for instance is characterised by a low sinuously meandering system, alternating with braided reaches, with channels separated by gravelly-cobbly bars (e.g. St. No. 39). This type of environment is characterised by a fast and turbulent flow, frequently well-oxygenated. The oxygen concentration tends to be generally high (6.31-20.70 mg/l, average 12.38 mg/l). The ion content is often low because of the proximity to the mountain sector (17-90 µS/cm, average 36 µS/cm), where the majority of the water originates. The pH is generally acidic (3.69-7.88, average 6.21), because of outcrop lithology (granites and schists) and meteoric water composition.

The Eh never falls below low-medium levels, indicating the absence of reducing river bottoms (36-354 mV, average 182 mV).

The upper part of the rivers is generally oligotrophic, because of the physiological lack of nutrients.

The medium sector of the studied rivers, comprised between the isohypses 400 and 151 m AMSL, is generally characterised by wide channels gently migrating in confined valleys, sometimes broken by small waterfalls such as the Falls of Feugh (St. No. 122) or incised tracts such as the Rocks of Solitude along the River North Esk (St. No. 300, Pl. 36, Fig. a). The conductivity tends to increase a little (31-118 µS/cm, average 56 µS/cm) compared with the adjacent upstream sector, even if the low ion content still marks a strong affinity with meteoric waters. The pH becomes more neutral (6.00-9.11, average 6.96), capturing a wide variety of lowland habitats, including reaches locally supplied by agricultural runoff. This represents the major source of nutrients such as phosphates and nitrates. The dissolved oxygen concentration remains at high levels (9.41-14.83 mg/l, average 11.59 mg/l).

The Eh does not show reducing conditions at the bottom-water interface (40-339 mV, average 176 mV).

Even if the nutrients supplied from cultivated areas may be locally significant, the background trophic level characterizing this medium sector is basically dystrophic. This because the pH remains commonly acidic and the high organic humus content (derived from peat erosion) confers the typical brownish colour to the water.

The lowermost sector spans the 150 m AMSL contour line and sea level, covering a wide variety of river environments (excluding estuarine environments dealt in the following paragraph), mostly characterised by a slow stream flow carrying significant volumes of water. Depending on the terrain conformation, this sector may be characterised either by straight reaches with a low sinuosity such as the River Dee next to Banchory (e.g. St. No. 317) or by well-developed meandering reaches such as the River Don near Inverurie (e.g. St. No. 304). The ion content is the highest found among the running waters (35-663 μS/cm, average 177 μS/cm), confirming the general trend of enrichment downstream. The pH tends to gently shift towards alkalinity (4.42-8.68, average 7.37), because of the high nutrient concentration related to the successful establishment of aquatic plants along the slow-flowing reaches. The increased photosynthetic activity also produces a high oxygen content (8.47-21.50 mg/l, average 11.58 mg/l) with some local heavy concentrations such as in St. No. 293 (21.50 mg/l) and No. 294 (16.98 mg/l), located along the lower River Ythan reach.

The Eh tends to shift towards low values (39-335 mV, average 170 mV), although reducing conditions have never been observed.

Eutrophic conditions are frequently found in the rivers lower reaches.

<u>Estuarine</u>

Estuarine environments are transitional systems between fresh- and sea-water (Pl. 36, Fig. d). This habitat is characterised by having constant water mixing, related to the natural river flow, contrasted by opposite tidal currents. The sedimentary material is typically represented by silts and clays, which are deposited in the estuary to form mudflats. A mainly specialised fauna live in this peculiar environment, where they generally form immense colonies such as in the case of *Peringia ulvae*. On the other hand, some marine generalists such as *Littorina littorea,* able to survive under low salinity levels and tolerating short-term exposure to freshwater (Fretter & Graham, 1994), may deeply penetrate estuaries. The conductivity measured in estuarine environments investigated during this study ranges between typical freshwater (281 μS/cm) and low salinity brackish water (15,840 μS/cm), with an average of 3,542 μS/cm. The salinity itself (S) ranges from 0 to 9.20 with an average of 1.79, placing these environments within the oligo-mesohaline thalassic series (Tab. 2). As a general reference the conductivity of the seawater amounts to ca. 54,000 μS/cm, corresponding to a salinity of 35.

The pH is consistent with a sea influence (the average pH of seawater is limited to the range 7.5 to 8.4) as suggested by the slight alkalinity (7.25-8.69, average 8.06). The oxygen concentration tends to be very high (5.85-35.60 mg/l, average 14.90 mg/l) consequence of the photosynthetic processes related to the abundant algal communities. Reducing conditions are frequently reached in some isolated pools as highlighted by the Eh range (-143-208 mV, average 78 mV). This is mainly related to the large amount of organic matter supplied or produced locally by the animal communities, as well as to stagnant conditions. Quiet pools are normally found on the edges of tidal streams, where water exchange is minimal, as such decomposition processes dominate in these environments.

Proceeding seawards the granulometric size of the bottom sediments tends to increase markedly, a result of marine wave action sorting and depositing coarse shell debris. Estuaries are in fact well-known to be populated by a great variety of invertebrates, exploiting the richness of nutrients carried by freshwaters.

Eutrophic conditions are generally found in estuarine environments.

Artificial channels

Artificial channels are quite rare in northern Scotland compared to England; the majority were built-up to supply water to farm mills. During the 19^{th} century one large commercial channel used to connect the old Aberdeen harbour with Port Elphinstone (Inverurie), but was put out of business in 1854 (Massie, 1981), a few years after Macgillivray found *Pisidium amnicum* in it.

Since these channels are an artificial diversion of water from a natural stream, the water composition does not undergo significant modification; the only appreciable change affects the current speed and consequently the size and distribution of bottom sediments. In these low longitudinal gradient channels, macrophytes can quickly develop, stopping transport of clastics and favouring the formation of slow-flowing tracts.

The chemico-physical parameters recorded in the 3 sampled stations does not allow any general assessment of this habitat, which reflects the composition of the surrounding running waters (conductivity range 54-409 µS/cm, pH 7.03-9.45, O_2 concentration 11.04-15.05 mg/l, Eh 93-238 mV).

In terms of trophic level the artificial channels follow the same trend of the medium sector streams, covering an oligo-mesotrophic interval.

4.3. STANDING WATERS CHARACTERIZATION

A total of 130 lentic stations have been sampled for this research (Figs. 19-21), leading to a categorization into 6 macro classes and relevant sub-classes. Each one of these classes is characterised by different water chemistry, trophic levels and temperature regimes.

The result of this hierarchical scheme is the following (in brackets number of stations and average trophic level):

Glacial-related lochs (33 stations, oligo-eutrophic)

- Cirque lochs (7 stations, oligotrophic)
- Glacial lochs (8 stations, oligotrophic)
- Kettle-hole lochs (18 stations, meso- to eutrophic)

Coastal Lochs (3 stations, eutrophic)

Artificial Lochs (44 stations, oligo-meso-eutrophic)

- Artificial lochs & lochans (40 stations, meso- to eutrophic)
- Quarry lochans (4 stations, oligotrophic)

Peatlands (38 stations, oligotrophic)

- Ice-melting pools (1 station, oligotrophic)
- Temporary pools (2 stations, oligotrophic)
- Blanket bogs (19 stations, oligotrophic)
- Raised bogs (2 stations, oligotrophic)
- Lowland bogs (10 stations, oligotrophic)
- Fens (4 stations, oligotrophic)

Artificial ecotopes (3 stations, oligo-eutrophic)

- Reservoirs (1 station, oligotrophic)
- Ponds and fountains (2 stations, eutrophic)

Stream Pools (9 stations, meso-eutrophic)

- Natural pools (5 stations, meso- to eutrophic)
- Artificial pools (4 stations, meso- to eutrophic)

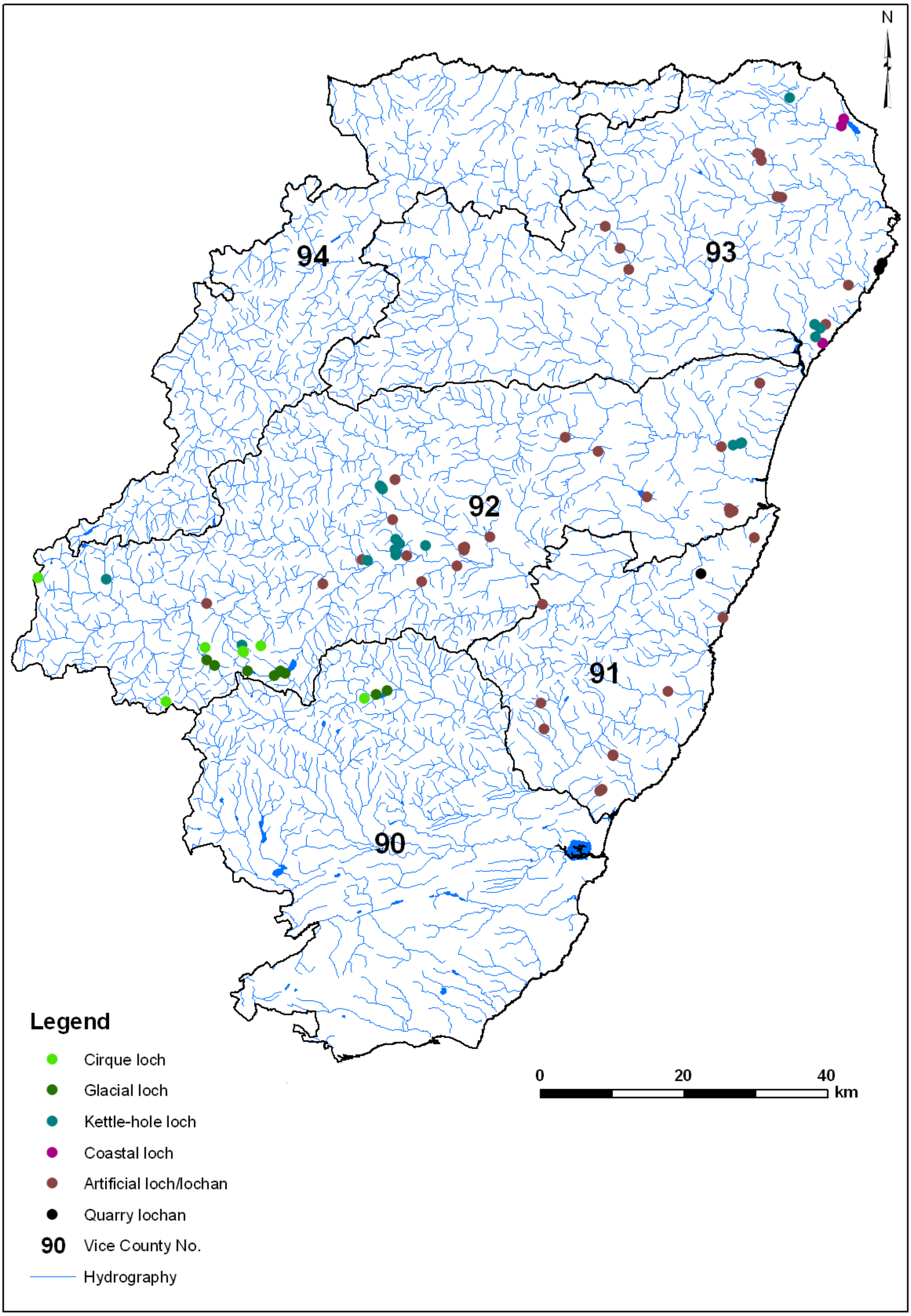

Fig. 19. Standing waters (lochs and lochans) characterization map.

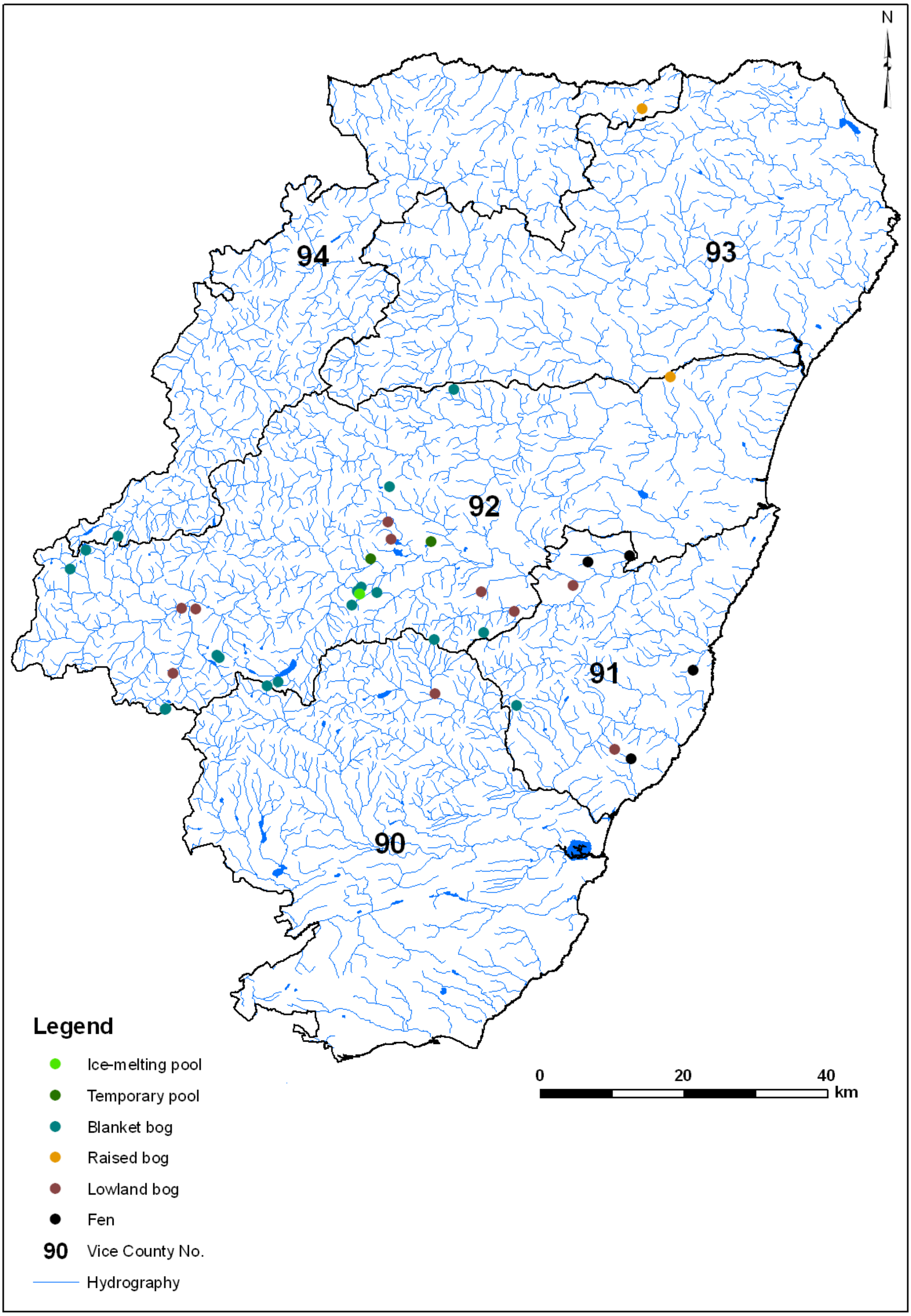

Fig. 20. Standing waters (peatlands) characterization map.

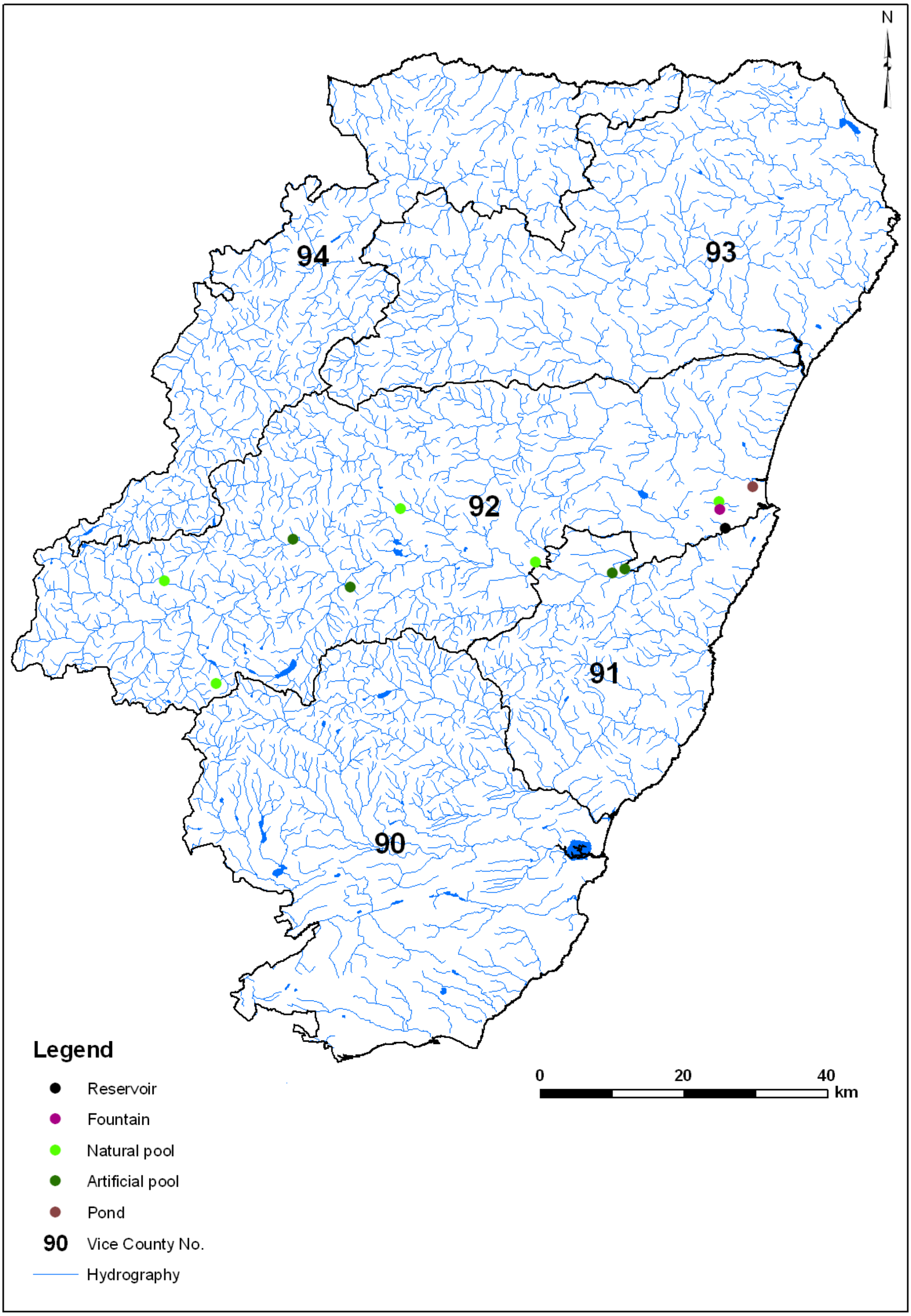

Fig. 21. Standing waters (artificial ecotopes and stream pools) characterization map.

Glacial-related lochs

Cirque lochs

Cirque lochs generally occur in natural depressions formed by glacial excavation in the uppermost valley sectors, within the 1,300-401 m AMSL altitude range. Such depressions are quite rounded, bounded by a semicircular rock cliff (or a very steep slope), whilst the outer side is dammed by a bedrock barrier generally cut by an active outlet (Pl. 36, Figs. f-h; Pl. 37, Fig. a). This configuration is the result of selective erosion caused by the glacier in its apical feeding area. The lochs eventually occupying these areas are often quite deep, surrounded by steep shores or vertical cliffs. These basins are typically oligotrophic as no significant input of nutrients exists at this altitude. Furthermore the rapid runoff does not allow any consistent storage of organic matter or finer sediment fractions in the littoral zone. The conductivity is generally very low (16-64 μS/cm, average 31 μS/cm), whilst the O_2 content remains quite high (8.40-11.62 mg/l, average 9.73 mg/l), indicating a strong affinity with the meteoric water. The pH tends to be relatively acidic (3.70-6.78, average 5.75) as cirque lochs are mainly located in areas dominated by rocks rich in silicate minerals such as granites (Lochnagar Massif) and Dalradian Schists (central Cairngorms). The only remarkable case which differs from this loch-type is represented by Loch Vrotachan, which occupies a vast depression excavated in a sedimentary suite mainly composed of limestones, psammites and shales. The water pH (8.35) is the highest recorded among the water bodies within the Cairngorms mountain range. The Eh range is typical of non reducing conditions at the water-sediment interface (30-279 mV, average 118 mV), although restricted circulation can be found in some lochs with a low water exchange such as Loch Phàdruig near Braemar (Eh 30 mV, St. No. 169).

Glacial lochs

Glacial lochs occupy the bottom of large U-shaped valleys excavated by glaciers during pleisto-holocenic glacial events. These basins are typically elongated along the valley axes and are dammed by natural barriers of morainal deposits or rocky ridges (Pl. 37, Figs. b-c, e). They mostly occur within the 400-151 m AMSL altitude range. Glacial lochs are formed after glaciers retreat and are fed by the hydrographic network which quickly develops soon after the end of the glacial stage. Glacial lochs in Scotland are frequently very deep with steep slopes as in Loch Ness, which is also a tectonic lake, with a maximum depth of 230 m in the central part of the basin (Murray & Pullar, 1910). The glacial lochs of the Cairngorms region are the deepest water bodies found in the Grampian Area, even if depths never exceed the 85 m isobath as for the Loch Muick case (83.2 m, Lowe *et al.*, 1991).

These waters are normally very clear, poor in ion (21-60 µS/cm, average 30 µS/cm), and with scarce nutrients, although, being these lochs of a quite large size, some shallow sectors are mesotrophic. The pH is generally neutral even if it tends to be slightly acidic (4.97-7.24, average 6.49), especially for those basins located at higher altitudes and in granitic terrain (e.g. Dubh-Loch, pH 4.97). The oxygen content is generally high (8.50-12.47 mg/l, average 10.46 mg/l), reflecting large volumes of running water constantly feeding the basins. Bottom sediments are generally coarse (gravelly-cobbly) with frequent boulders, which are found all across the basin. The Eh (92-304 mV, average 172 mV) is consistent with well-oxygenated conditions at the loch bottoms.

<u>Kettle-hole lochs</u>

Kettle-hole lochs are glacial landforms filled by ground or stream water, generally located along the route of major glaciers at wide range of altitude (Pl. 37, Fig. d). These erosional scours are typically rounded and not very deep (rarely exceeding 10 m), being formed by ice masses left isolated during the glacial retreat. Several examples of this loch-type can be found along Deeside (e.g. Loch Davan, Loch Kinord, etc.), mainly located at the intersection with lateral valleys, when glaciers coming from different sectors merged together (Pl. 37, Fig. f). Their origin can at least be placed after the last glacial stage (Dimlington Stadial, approximately 13,000 years BP).

Kettle-hole lochs show a very wide range of ion content (26-709 µS/cm, average 179 µS/cm) and pH (4.39-9.06, average 7.24), because they are located in different geographical compartments. The oxygen concentration is usually low (1.40-17.90 mg/l, average 8.88 mg/l), consequence of the frequent stagnant conditions established at the base of the water column. This trend is confirmed by the Eh (-270-333 mV, average 99 mV), quite often indicating reducing or near reducing conditions at the water-sediment interface (e.g. St. No. 127 located near Braemar). Conversely near the surface very high content of dissolved oxygen is frequently observed, primarily related to macrophytes and algal photosynthesis. In terms of trophic content these lochs span meso- to eutrophic conditions as they are generally situated in lowland areas. A typical example of a naturally eutrophic water body is Loch Davan, which holds a rich and diversified vascular and algal flora supporting a considerable invertebrate fauna.

Coastal lochs

Coastal lochs are typically located beside the coastal dune belt system and are dominated by the influence of the sea. Loch Strathbeg is the largest coastal lake in Britain; it is separated from the sea by a wide dune system which is only crossed by a natural outlet strongly affected by the tidal stream (Pl. 37, Fig. h). The ion content of the Loch of Strathbeg is relatively high (521-611 µS/cm) in the vicinity of the sea and in water mixing near the outlet during high tide. The oxygen content is relatively high (10.05-10.33 mg/l), consequence of photosynthesis of the vast macrophyte communities. The Eh range (62-78 mV) is consistent with relatively good oxidation conditions at the loch bottom. The bottom sediment in the northern portion of the loch is composed of well-sorted sands, reworked by the surrounding fossil dunes. Another example of coastal loch, located in a natural depression at the back of a dune belt, is the Sand Loch near Collieston. Sand Loch water shows lower ion content (199 µS/cm) than Loch of Strathbeg and the pH is more acidic than alkaline (6.52 versus 8.03-8.58 of the Loch of Strathbeg). Oxygen concentration (9.73 mg/l) and Eh (98 mV) are consistent with an environment not affected by stagnant conditions. All these ecotopes show close interaction with sea water, either because they are directly fed by sea water from transitional groundwater systems or by sea spray.

The coastal lochs visited during this survey are naturally eutrophic, being supplied with consistent amount of nutrients primarily produced by the vast bird populations residing in these habitats and the rich plant and algal communities located along the shores.

Artificial Lochs

<u>Artificial lochs & lochans</u>

Artificial lochs & lochans represent the vast majority of the standing waters occurring in the Grampian Area (Pl. 37, Fig. g). Most of the small to medium size water bodies occurring in the lowland sector (0-150 m AMSL altitudinal range) are man-made, such as the reservoirs used for irrigation purposes (e.g. St. No. 263) and fisheries (e.g. St. No. 290). The pH covers an extremely wide range (4.27-9.36, average 6.87) indicating a great habitat diversification within this group. The conductivity follows a similar pattern (35-880 µS/cm, average 246 µS/cm), even if the average value indicates a general shift towards lowland rich waters. The oxygen concentration covers a broad range (2.28-30.40 mg/l, average 10.29 mg/l), encompassing different types of ecotopes. Eh measurements do not indicate stagnant or near reducing conditions at the water-sediment interfaces (62-261 mV, average 125 mV). The trophic level is always high as a consequence of nutrient concentration resulting from agricultural practices and from domestic and industrial discharges. In a few cases the water is naturally eutrophic due to the shallow depth and establishment of dense colonies of vascular plants such as *Carex* spp. along the shores (e.g. Loch of Fasque near Fettercairn or Clyan's Dam near Monymusk), providing consistent amount of vegetal debris. These naturally eutrophic lochs generally support a consistent floating (e.g. *Nymphaea* spp.) and submerged flora (e.g. *Potamogeton* spp., *Chara* spp., etc.), placing them among the most valuable habitats to host sensitive vertebrate and invertebrate species. In other cases, such as lochans located in the medium Dee valley (e.g. St. No. 74 and Loch Ullachie, St. No. 283, both located near Ballater), the water characteristics (neutral pH, low conductivity, high dissolved oxygen content) are similar to those measured in the nearby kettle-hole lochs such as Loch Davan and Loch Kinord.

Quarry lochans

These artificial basins are formed after the abandonment of quarries. These lochans are typically fed by groundwater and are bounded by very steep slopes, sometimes vertical as a result of quarrying activities. The ion content is between 123 and 348 µS/cm, consistent with the average composition of standing water bodies located in the lowland sector. Some lochans located on top of the coastal cliffs show a high ion content (e.g. St. No. 110, 3,310 µS/cm, salinity 1.60, oligohaline), suggesting interaction with the marine environment. The pH is relatively acidic (3.82-7.67, average 6.36), being affected by the nature of the parent rocks, whilst the oxygen content is averagely high (6.83-9.92 mg/l, average 8.15 mg/l). The Eh is coherent with non-anoxic conditions at the bottoms (81-155 mV, average 102 mV). Quarry lochans are generally oligotrophic as they lack inlets which may supply nutrients and are generally located in areas with poor-base rocks such as granites. Therefore quarry lochans represent peculiar environments compared with other closeby standing waters, which are quite often strongly eutrophic. These sites may represent refuge areas in lowlands for a number of cold stenothermophilous species such as the palmate newt *Lissotriton helveticus* Razoumowsky, 1789.

Peatlands

Ice-melting pools

Ice-melt pools are mainly located in the upper river basins (1,300-401 m AMSL), where a great number of small to very small pools occur in natural depressions, particularly after the ice melts at the onset of spring (e.g. St. No. 145). These environments are difficult to colonise as the water is extremely soft and quite frequently they tend to freeze entirely during early spring preventing any colonisation. In addition these pools quite often dry-up during summer, killing possible immigrant faunas. This extreme environment is virtually free of nutrients, so it represents the end member of the oligotrophic class. The oxygen concentration is always high (e.g. 28.10 mg/l in St. No. 145) due to the continuous water supply from melting ice and snow. Only *Rana temporaria* succeeds in breeding in such a demanding environment, where large eggs masses are frequently released in late spring-early summer, allowing this species to colonise high altitude ranges. The water flowing out from these pools originates small creeks, which rapidly merge together forming the first-order streams of the major river systems.

Temporary pools

Temporary pools are harsh environments as they dry up completely during summer causing the death of all the invertebrate communities sensitive to the lack of water. If the soil remains wet young sphaeriids and gastropod eggs may survive until the arrival of rain, assuring colonisation continuity. In cases where winter and summer killings cause mortality of all resident populations, the re-colonisation process is only via passive dispersal. Along the banks the pH is generally relatively high (8.50-8.78) as consequence of the photosynthesis process related to the local development of macrophytes. The ion content remains low (28-55 μS/cm) as these ephemeral habitats rely mainly on meteoric contribution rather than spring or stream feeding. The oxygen content is generally quite limited (7.14-7.25 mg/l), whilst the Eh is consistent with an ombrotrophic environment (112-158 mV).

Temporary pools are generally found in oligotrophic conditions, due to the limited nutrients availability.

Examples of this environment are stations No. 216 and 240, both located in the medium sector of the Dee valley.

Blanket bogs

The blanket bog is by far the most common type of peatland in Scotland developing mainly in uplands characterised by high rainfall and poor soil drainage. The sampled stations are found in an altitudinal range between 412 and 1,055 m AMSL. It is a type of ombrotrophic (rain-fed) mire which receives most of its water and nutrients in the form of atmospheric precipitation. Blanket bogs extend not only to wet hollows but over a vast sector of gently undulating ground (Pl. 36, Fig. e). Unlike raised bogs, blanket bogs may cover the landscape and even the slopes, causing the development of peat outside the topographical depressions. However, the majority of these bogs are located in natural depressions situated along the mountain crests system, mostly on granite-type rocks. The surface of the bog is mainly covered by *Sphagnum* mosses even if a mosaic of other plants can be found. These include the carnivorous sundews and the cotton grasses; heathers are also commonly found on the watersides. Such environments tend to be quite acidic (pH 3.81-7.59, average 5.20) as they accumulate peat usually formed by the natural decay of the *Sphagnum* spp. mosses and lichens. Water logging provides anaerobic conditions which slow down the decomposition of plant material which in turn leads to an accumulation of peat. The bottom sediments tend to be composed almost exclusively of detrital peat and windborne clay-size particles. Low-oxygen content frequently characterises the water-sediment interface even though in some biotopes the development of aquatic plants such as *Potamogeton* spp. may increase oxygen production during the day. Therefore the range of the dissolved oxygen content measured among all the stations is very wide (4.34-11.30 mg/l, average 8.16 mg/l). The Eh range captures a wide variety of environments (27-390 mV, average 196 mV) from near reducing (e.g. St. No. 171, Eh 27 mV) bottom layers to well-oxidized sediment interfaces (e.g. St. No. 115, Eh 390 mV). The water conductivity indicates a generally low ion content (12-138 µS/cm, average 45 µS/cm), which is concordant with its meteoric origin.

Local nutrient enrichments can be related to animal presence that regularly frequents these sites in search of water (e.g. St. No. 234); however blanket bogs tend to be quite oligotrophic.

Blanket bogs are listed in the SNH (Scottish Natural Heritage) SBBI (Scottish Blanket Bog Inventory, http://www.snh.org.uk/sbbi/index.htm).

Raised bogs

The raised bog is a type of peatland which results from the progressive reduction of a shallow lake or a flat marsh, located primarily but not exclusively in a lowland area (0-150 m AMSL altitudinal range). The high groundwater level associated with low permeability substrata and

flat topography impedes the natural drainage, causing water logging. The constant presence of water slows down plant decomposition, providing anaerobic conditions and favouring the development of peat. The raised bog typically consists of a shallow dome of bog peat which starts developing in the centre of the wet area. Therefore this area becomes wholly rain-fed and is often surrounded by strips of fen (the lagg fen) or areas colonised by other types of wetland vegetation, particularly along the streamsides. Raised bogs are quite rare forms of peatland within North-East Scotland and those visited during this study appear to be deeply altered by human intervention. The pH is slightly acidic (6.54-6.60) and the dissolved oxygen always moderate (6.25-7.21 mg/l). The ion content (152-271 µS/cm) is slightly higher compared to that measured in blanket bogs as the water is not totally of meteoric origin.
The Eh indicates a good level of oxidation at the bottom interface (137-239 mV).
Raised bogs are typically oligotrophic, as a consequence of their ombrotrophic nature.
Burreldale Moss (St. No. 315) and the Moss of Minnonie (St. No. 324) are examples of this peatland type listed in the SNH (Scottish Natural Heritage) LRBI (Lowland Raised Bog Inventory, http://www.snh.org.uk/Peatlands/).

Lowland bogs

This is a category of peatland which includes a large variety of environments primarily fed by groundwater as well as meteoric waters. These bogs are mainly located in natural depressions at the base of hill slopes, where groundwaters tend to spill out naturally. Examples of this type of bog are stations No. 160 and No. 168, both located in the medium sector of Deeside. Another bog type is found on the alluvial plains, where groundwater fills local depressions. This environment is highly dependent on river regimes, being mostly fed by meteoric water. Stations No. 174 and No. 299 are examples of this latter type. Finally St. No. 215 is only a part of a very extensive boggy area, which surrounds the lochs Davan and Kinord. Large wetlands are generally articulated in a mosaic of microhabitats, with deeply diversified ecological characteristics.
In terms of chemico-physical parameters, the measured ranges reflect the wide heterogeneity of habitats grouped within the lowland bogs. The pH covers a very broad scale (3.80-8.93, average 6.79), ranging between acidic (e.g. stations No. 150 and No. 329) and alkaline values (e.g. stations No. 215 and No. 234). A similar trend is followed by conductivity (38-221 µS/cm, average 104 µS/cm) and dissolved oxygen (3.20-19.31 mg/l, average 9.17 mg/l).
The Eh also extends over a broad range, nevertheless not revealing any particular near-bottom reducing environment (32-269 mV, average 107 mV).

Lowland bogs are generally oligotrophic as they are constantly fed by soft groundwater.

Fens

Fens in North-East Scotland are frequently considered remnant water bodies of former lochs, which extended over a larger area. In contrast to bogs, fens tend to be quite alkaline (pH range: 6.50-9.03, average 7.63) as they are fed by surface and/or ground waters (i.e. minerotrophic habitat) rather than by rainfall (i.e. ombrotrophic habitat). Macrophytes are generally abundant and produce a consistent mass of organic matter and vegetal debris, forming a thick layer of peat material. This peatland type is subdivided on the basis of the substratum nature and relevant water composition into two subcategories: poor-fens and rich-fens (Fig. 8). Poor-fens occur in areas with base-poor rocks such as sandstones and granites (mainly situated in the uplands), generally associated with *Sphagnum* spp. and heather moors, whilst rich-fens are located in areas with base-rich rocks such as limestones or marls, fed by mineral enriched waters (mainly in the lowlands). Rich-fens are often dominated by sedges, rushes, reeds or meadowsweet; shrub trees cover (mostly willow and alder) may sometimes occur (e.g. Loch of Lumgair near Stonehaven). The four fens sampled during this study all belong to the rich-fens class, having a relatively high conductivity range (137-321 μS/cm, average 203 μS/cm) and a frequently alkaline pH. The oxygen concentration covers an extremely varied range (1.06-15.06 mg/l, average 7.00 mg/l), encompassing environments poorly (e.g. Loch of Leys near Banchory, 1.06 mg/l) and richly oxygenated (e.g. St. No. 235 Whitewater Moss near Laurencekirk, 15.06 mg/l).

The Eh survey (64-137 mV, average 107 mV) does not highlight critical reducing conditions at the fen bottoms.

The fens investigated during this survey tend to be oligotrophic as consequence of quick recharge of the aquifer and permanent waterlogging.

Artificial ecotopes

Reservoirs

Reservoirs are a common feature in densely populated areas as they represent water storage for human consumption. Typically these artificial basins have bottom and sides covered by concrete and only a very thin layer of sediments is present. Access by people and animals is restricted by metallic fences running along the perimeters. In the studied area only one reservoir has been sampled (Inchgarth Reservoir near Cults), which shows neutral pH (7.00) and a very low conductivity (57 µS/cm) consistent with the River Dee composition, from which water is extracted. The oxygen content (8.44 mg/l) and the Eh (26 mV) do not suggest stagnation.

Ponds and fountains

These artificial habitats are typical features of inhabited centres and sometimes hold a surprisingly diverse fauna as they are regularly fed with materials and plants coming from a variety of sources. For instance one of the two stations of *Planorbis planorbis* identified in the area, successfully established since 1980 in the Grampian Area, is found in the pond of the Department of Zoology of Aberdeen (Young, pers. comm.), clearly introduced with ornamental aquatic plants. The water of these man-made habitats tends to have a similar composition to that of nearby aquatic environments, being quite often fed directly by them (e.g. conductivity 132-266 µS/cm, pH 6.60-8.80, Eh 78-203 mV). As these sites are normally overgrown with plants, different conditions are found between the bottom (sometime anaerobic) and the surface, where the dissolved oxygen may reach high concentrations during the day (e.g. 9.66 mg/l in the Hazlehead Fountain in Aberdeen).

Stream pools

Stream pools are riverine reaches characterised by slow flow. These small basins are formed after a natural or artificial blockage of the stream channel, which alters the natural downstream flow. These types of environments are geologically ephemeral, naturally disappearing with the time filled in by sediments, or because the initial conditions have been restored after a flooding event. Despite the precarious character of stream pools, they may act as important refuge habitats for faunas actively dispersing upstream (or passively transported) from the potamon zone.

Natural pools

Natural pools are generally of small-medium size caused by the obstruction of the river channel either after a rock fall (e.g. St. No. 84 in the Cairngorms Area) or by its sinuosity related to selective erosion of hard rock substrata (e.g. St. No. 306, Loch Kander outlet). The pools found in a normal step and pool alternation along the mountain river reaches are not included here as their average size is very small. Natural pools typically show similarities with the water composition of the river that forms them, even if the establishment of a more lentic aquatic flora may cause some significant ecological changes. The ion content varies in a range covering very poor (e.g. 23 μS/cm, St. No. 94) and medium-rich (e.g. 334 μS/cm, St. No. 237) waters, with an average value of 170 μS/cm. These two stations are in fact located in completely different sectors: the former in the Cairngorms and the latter near Aberdeen. The pH shows a similar trend, being comprised between 6.76 (St. No. 237) and 9.12 (Bog Loch near Banchory) with an average of 7.52. The dissolved oxygen content is always quite high (7.01-12.51 mg/l, average 9.73 mg/l), as normally found in running waters or biotopes supporting a consistent aquatic flora.

The Eh covers a typical range for running waters (106-232 mV, average 169 mV).

Artificial pools

Artificial pools are created by an artificial barrier built along a watercourse (e.g. St. No. 247, Brackley Burn, Pl. 35, Fig. f). These basins are frequently located in castle grounds (e.g. Crathes Castle pool near Banchory) or upstream of disused mills (e.g. St. No. 229 near Drumoak). These works are often quite old and the resulting basins appear as mature lacustrine environments, supporting a consistent flora and fauna sometimes of exotic provenance (i.e. *Physa acuta* in the Banner Mills ponds near Aberdeen, Jenkins, 1890). The water composition still maintains the background fingerprint of the running water (51-263 μS/cm, average 146 μS/cm), although the oxygen content may be notably higher as a consequence of vegetation development (St. No. 247, 9.66 mg/l). The pH ranges between slightly alkaline values (7.30-8.64, average 8.02). The Eh range (111-165 mV, average 129 mV) is consistent with generally oxiding environments.

4.4. Freshwater mollusc list

A comprehensive description of all the malacological taxa identified in the studied area is given in this section.

During this study a total number of 20 species of gastropods (Fig. 22) and 12 of bivalves (Fig. 23) have been identified, pretty close to the 17 gastropods and 14 bivalves reported by Kerney (1999b) for the area.

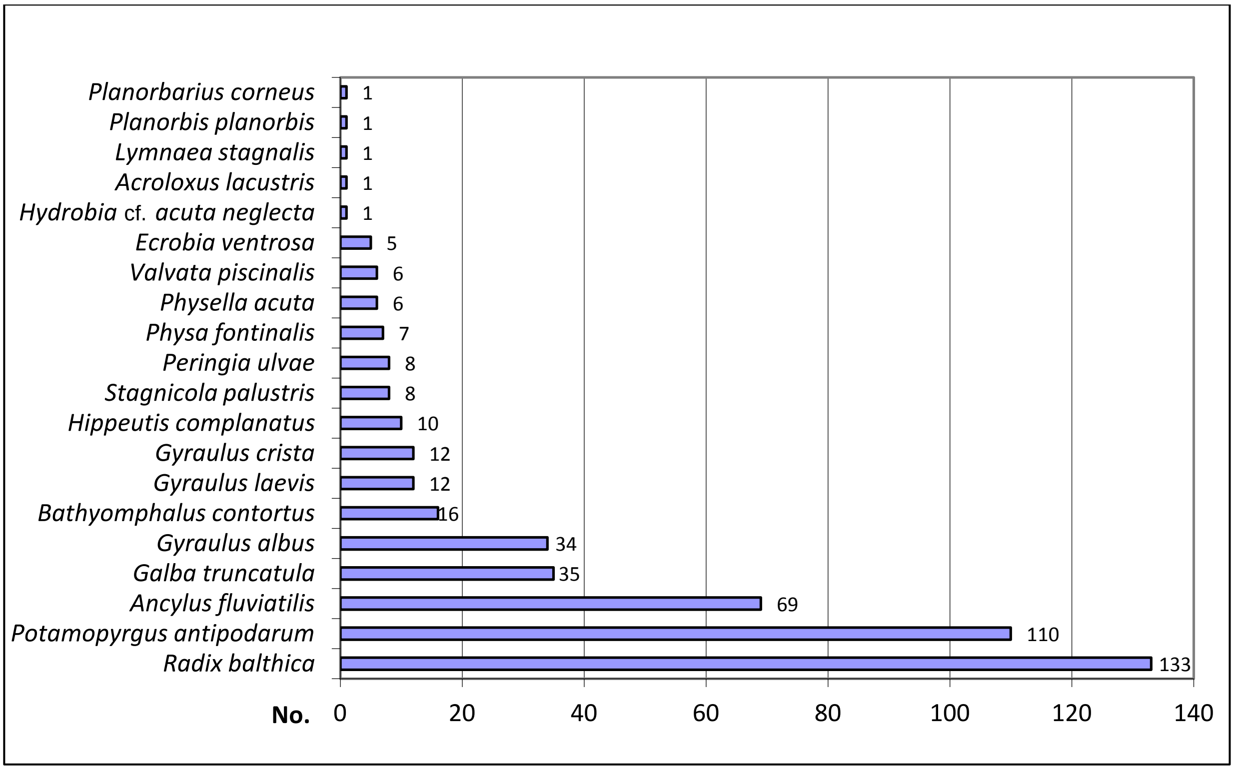

Fig. 22. Gastropoda species occurrences (20 species).

Major differences reside in the higher number of hydrobiids species identified during this field research such as *Ecrobia ventrosa* and *Hydrobia* cf. *acuta neglecta,* not previously reported in the area.

Some recent accidental introduction such as *Lymnaea stagnalis* and *Planorbis planorbis* also raised the total number of species. These species are generally introduced into new environments through water-plant transplantation or with other garden-pond related materials (Beran, 2006).

On the other hand, some rare Scottish taxa reported for the area, such as *Anisus leucostoma, Pisidium amnicum* and *P. pulchellum,* have not been collected during the present field survey, possibly because of their sporadic occurrence.

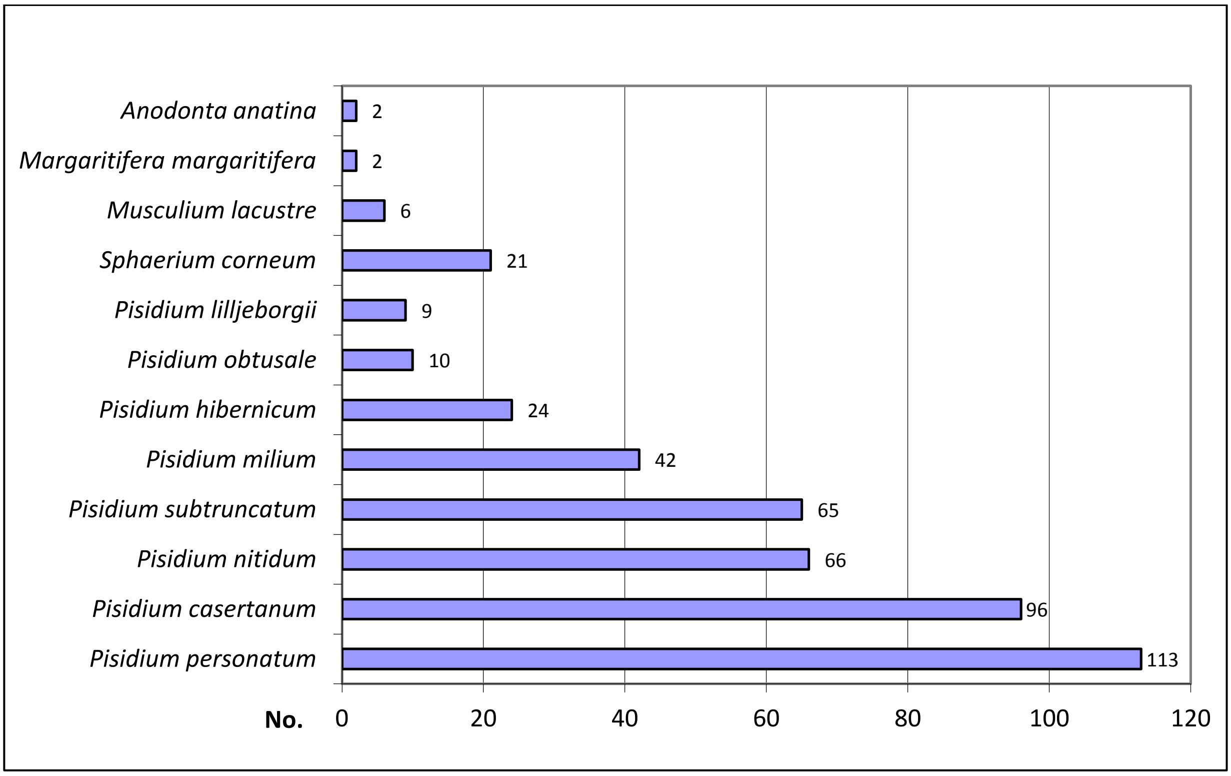

Fig. 23. Bivalvia species occurrences (12 species).

Furthermore some 19th century occasional findings, such as *Viviparus viviparus,* (empty shells), *Theodoxus fluviatilis* (empty shells), *Valvata cristata* (empty shells), and *Bithynia tentaculata* (isolated colonies), have not been re-confirmed, suggesting that they never inhabited the area or disappeared soon after their colonisation (as possibly happened to *B. tentaculata* in the Moray Firth Area). The empty shells historically found in proximity to the mouth of the Dee are believed to be brought in with ship ballasts coming from the estuaries of southern England. All these records refer to the same period: mid 19th century.

Therefore the total number of molluscs inhabiting the investigated area (according to literature references and this study results) amounts to 21 gastropods (Fig. 22; Maps 1-15, 30-35) and 14 bivalves (Fig. 23; Maps 16-27, 37-38).

4.4.1. NATIVE TAXA

In this sub-section are described the molluscan species considered to belong to the autochthonous fauna, that is those taxa who invaded the area after the Dimlington Stadial (i.e. 13,000 years BP at the earliest).

4.4.1.1. GASTROPODA

Class Gastropoda Cuvier, 1795

Order Ectobranchia Fischer, 1884

Family Valvatidae Gray, 1840

Genus *Valvata* O. F. Müller, 1773

Subgenus *Cincinna* Hübner, 1810

Valvata piscinalis (O. F. Müller, 1774)

This species inhabits permanent large bodies of lentic waters or slowly flowing lowland drainage systems. It is tolerant of soft water and prefers silty-muddy substratum even if it is found on stones or on aquatic plants.

Mainly distributed in England and Ireland it is sparsely found in Scotland where a number of isolated populations are known since the mid 19th century.

Five *Valvata piscinalis* records within the studied area have been reported in literature from Aberdeenshire North, Aberdeenshire South and Kinkardineshire (Appendix-I).

During this study 6 populations have been identified, 2 confirming the historical records and 4 new stations. The total number of *V. piscinalis* populations occurring in the area is now raised to 10.

Distribution: Palaearctic; common throughout Europe, becoming sporadic in mountain areas of Britain and Scandinavia.

Reference plate: 34, Fig. j.

The *Valvata piscinalis* shell is formed by a coiled circular spire exhibiting 4-5 whorls separated by pronounced sutures and a flat protoconch. Prosocline growth lines are clearly visible throughout the whole spire, as well as some regularly spaced spiral striae. The shell colour is beige-yellowish with a glossy appearance.

The aperture is circular, with a deep umbilicus but not very broad.

Appendix-III reference map: 1.

Order Neotaenioglossa Haller, 1892

Family Hydrobiidae Stimpson, 1865

The taxonomical status of this family has been only recently clarified, after Wilke *et al.* (2000) demonstrated the existence of three different clades in European *Hydrobia* s.l. represented by the genera: *Hydrobia* s.s. Hartmann, 1821, *Peringia* Paladilhe, 1874 and *Ventrosia* Radoman, 1977. Subsequently Wilke (2003) highlighted the close relationship existing between the European taxon *Ventrosia ventrosa* and the north-east American taxa assigned to the genus *Ecrobia* Stimpson, 1865. After this consideration and on the basis of the date priority, it seems then plausible to replace the genus name *Ventrosia* with *Ecrobia*. This conclusion has been accepted by Anderson (2006), Bank *et al*. (2007) and Kadolsky (2012).

Within the seven taxa of hydrobiids inhabiting the British Isles only four have been historically reported for Scotland: *Ecrobia ventrosa* (Montagu, 1803), *Hydrobia acuta neglecta* Muus, 1963, *Peringia ulvae* (Pennant, 1777) and *Potamopyrgus antipodarum* (Gray, 1843). The introduction of the taxonomic entity *Hydrobia neglecta* by Muus in 1963 as a north-western endemic taxon has been for a long time debated because of its resemblance to the Mediterranean taxon *H. acuta* (Giusti *et al.,* 1995). Hoeksema (1998) after having studied a Biscayan population of *H. neglecta* concluded that it was synonymous with *H. acuta.* Wilke *et al.* (2000) found little genetic differences between the western Mediterranean and north-western Europe populations, concluding that both may be referred to *H. acuta*, although north-western populations ought to be distinguished at a subspecific level (i.e. *H. acuta neglecta)*. In the latest release of the list of the non-marine Mollusca of Britain and Ireland, Anderson (2006) adopts this new terminology, listing the former *H. neglecta* as *H. acuta neglecta*, introducing for the first time this taxon into the British fauna. A similar conclusion is achieved by Kadolsky (2012) who considers the taxon *neglecta* as a subspecies of *acuta*. Under this new lights it appears clear that historical records of *Hydrobia neglecta* and *Ventrosia ventrosa* for the British Isles, mainly based on conchological characters, need to be reviewed and new distribution maps are strongly needed.

Genus *Ecrobia* Stimpson, 1865

Ecrobia ventrosa (Montagu, 1803)

Previously *Ecrobia ventrosa* seemed to be absent from Scotland mainland, the only records coming only from Shetland and Outer Hebrides. This species inhabits water of low to moderate salinities (5-25 parts per thousand NaCl) such as muddy tidal flats, tidal channels and shallow pools in river estuaries. *E. ventrosa* generally prefers more sheltered environments than *P. ulvae,* strongly influenced by freshwater and lacking direct connections with the sea (Muus, 1963; Bishop, 1976; Cherrill & James, 1985). Johansen (1918) in its work on the Mollusca of Randers Fjord established that *Peringia ulvae* lives in water of salinity from 1‰ to 24‰, *E. ventrosa* in water only above 5‰ and *Potamopyrgus jenkinsi [= P. antipodarum]* in water ranging from 1‰ to 20‰.

Fretter & Graham (1978) report a wide range of salinity for this species (2‰-34‰), although they confirm that a narrower range is probably preferred (6‰-20‰) as originally indicated by Muus (1963).

Compared to other hydrobiids *E. ventrosa* appears to be more selective with respect to the environment, remaining restricted to isolated salt marshes.

No historical records within the studied area have been reported so far.

A few empty shells referred to this taxon have been collected in 5 estuarine stations within the studied area, 3 in the River Ythan, 1 in the River Dee and 1 in the River North Esk. Only one live specimen was found in St. No. 188 (River Ythan), which allowed the correct identification of the taxon. *E. ventrosa* has been always found associated with *P. ulvae,* although the typical environment for the former hydrobiid has not been identified yet due to the lack of direct observations on live specimens. The occurrence of this species in mainly freshwater shell lags could indicate a possible provenance from small low salinities pools situated upstream from the high tide mark. However this taxon seems to be extremely rare in Scotland, being clearly replaced by *P. ulvae,* a less specialized and more flexible inhabitant of estuaries.

Distribution: west European and Mediterranean coasts, north to Iceland and to 63° N parallel in the Baltic Sea.

Reference plate: 34, Fig. a.

Ecrobia ventrosa shows a slender rather transparent and glossy shell, formed by 6-7 whorls markedly tumid, separated by deep sutures.

The whorls are crossed by a set of thin prosocline growth lines intersected by another set of weaker spiral lines.

The aperture is rounded-elliptical (egg-shaped), forming an angle of 15° degrees ca. with the shell axis and it is bounded by a basally out-turned peristome.
The adapical side of the peristome shows a quite rounded sinus.
The umbilicus is relatively deep, covered by the inner lip extroflection.
Appendix-III reference map: 2.

Genus *Hydrobia* Hartmann, 1821
Hydrobia cf. *acuta neglecta* Muus, 1963

Hydrobia cf. *acuta neglecta* according to Anderson (2006) is here considered as a north-western European endemism of the Mediterranean taxon *H. acuta* s.s. The current records are mainly located in England, western coast of Scotland (including Hebridean Isles) and North Ireland.
Mostly found in rather strong brackish water with salinities intermediate between those preferred by *Ecrobia ventrosa* and *Peringia ulvae* (10‰-31‰ according to Fretter & Graham, 1978). It generally occurs in sheltered environments constantly submerged such as lagoons and slow flowing tidal ditches.
No historical records for *H. a. neglecta* are reported in the area of interest. The closest known location is found in the west Muirtown Basin near Inverness (NBN Gateway).
During this field study only one specimen tentatively attributed to *H. a. neglecta* has been found in the River Ugie estuary (St. No. 223). In the same place another specimen belonging to *Peringia ulvae* was also collected. This taxonomic attribution is primarily based on shell morphology as no live specimens were collected.
Distribution: north-west Europe, British Isles.
Reference plate: 34, Figs. b-c.
The presumed *Hydrobia* cf. *acuta neglecta* specimen shown in Plate-34 appears quite slim, with 6 well-defined swollen whorls (flatter than *Ecrobia ventrosa)* separated by deep sutures.
The protoconch is clearly well-distinct from the first whorl (Pl. 33, Fig. c).
The shell is characterised by a regularly spaced and defined set of slightly prosocline growth lines, with no clear evidence of spiral striae as observed in *E. ventrosa* and *P. ulvae.*
The aperture, similarly to that of *P. ulvae,* is oval and it forms a 15° degrees ca. angle with the shell axis. It is markedly different from the mouth of *E. ventrosa* which is clearly more rounded. The aperture adapical side shows an angular sinus, tighter than in *P. ulvae*. The

peristome extroflection is less developed than in *E. ventrosa* and the umbilicus is quite narrow and covered by the inner lip, similar to that of *P. ulvae.*
Appendix-III reference map: 3.

Genus *Peringia* Paladilhe, 1874
Peringia ulvae (Pennant, 1777)

P. ulvae is capable to live within a wide range of salinity and tolerates unfavourable conditions quite often found in salt-marsh and in temporary pools. Ellis (1932) measured a percentage of NaCl ranging between 13.7‰ and 34.7‰ in waters from different locations in the Adur Estuary inhabited by the species. According to Fretter & Graham (1978) this species covers a broad range of salinity spanning between 1.5‰ and 33‰.
This species has been historically recorded only in two stations located in Aberdeenshire North (Appendix-I). Also Marshall (1899) reported the occurrence of *Hydrobia acuta* var. *tumida* from Aberdeen, which could reasonably correspond to *P. ulvae*.
The species does occur in the Montrose area as well (VC 90, Kerney, 1966).
Eight populations have been identified during the field survey, considerably extending its distribution area. The species seems to easily establish wherever a mud flat or a low energy tidal plain occurs (e.g. St. No. 223, River Ugie estuary).
Distribution: west African and European coasts, north to Arctic Russia.
Reference plate: 34, Figs. d-f.
Peringia ulvae has a solid and rather glossy shell, characterised by 6-7 whorls with flattened sides, separated by shallow sutures. The protoconch is most of the time deeply corroded (Pl. 33, Fig. f), whilst the other whorls are ornate by a set of thin prosocline growth lines intersected by another set of faint spiral striae.
The body whorl shows a gentle peripheral keel, which confers a characteristic angularity to the shell.
The aperture is oval forming an angle of 15° degrees ca. with the shell axis and it is surrounded by a peristome, particularly developed in adult specimens. The convergence of the inner with the outer lip forms an adapical sinus characterised by a strong angularity.
The umbilicus is narrower compared to that of *E. ventrosa* and partially covered by the inner lip fold.
Appendix-III reference map: 4.

Order Pulmonata Cuvier in Blainville, 1814

Family Lymnaeidae Rafinesque, 1815

Genus *Stagnicola* Jeffreys, 1830

Stagnicola palustris (O. F. Müller, 1774)

This is a common lowland taxon frequently found in slowly-moving or stagnant waters. It is normally found in both hard and soft water, chocked by aquatic vegetation with the bottom layered by plant debris. It tolerates desiccation periods for its remarkable capacity to find refuge under stones and in damp vegetation.

According to Anderson (2006), two morphologically similar species belonging to the subgenus *Stagnicola* should occur in the British Isles: *Lymnaea S. palustris* and *L. S. fuscus*. The phylogenetic analysis of these two taxa has been performed by Bargues *et al.* (2001) who concluded that the differences between *Lymnaea* s.s. and *Stagnicola* species are too small to justify a separation in distinct genus and can only be placed under different subgenus. On the other hand Bank *et al*. (2007) rank *Stagnicola* as a genus, rejecting the observations initially provided by Bargues *et al.* (2001). According to Bank *et al.* (2007) the genus *Stagnicola* is represented in the British Isles by three different taxa: *S. palustris, S. corvus* and *S. fuscus.*

S. fuscus appears to be a recent segregate of *L. palustris* auctt. verified on dissected materials only from eastern Britain. As consequence the old records of *L. palustris* auctt. represent an aggregate of *S. fuscus* and *S. palustris.* The occurrence of the third species of *Stagnicola* in the British Isles *(S. corvus)* as proposed by Bank *et al.* (2007) requires more data to be ascertained, as it is only based on morphological evidences.

S. palustris is a very common taxon in Ireland and England, becoming progressively less frequent moving northward.

In the Grampian Area *L. palustris* auctt. has been sparsely recorded in the lowland sector of all vice counties except for Angus (Appendix-I).

During this research eight populations of *S. palustris* have been recorded, five in lentic (man-made lochans and fens) and three in lotic waters such as the River Ythan lower reach. The species attribution has been verified after dissection of selected specimens. No individual of *Stagnicola fuscus* have been documented in the studied area so far.

Distribution: Holarctic; common throughout Europe up to 70° N parallel in Norway.

Appendix-III reference map: 5.

Genus *Radix* Montfort, 1810

Radix balthica (Linnaeus, 1758)

This is the commonest taxon found in the British Isles, occurring in aquatic habitats of all kinds. It is found in hard and soft water, from the richest environments to the poorest ones, where quite often is the only inhabiting gastropod. This species is found in oligotrophic environments where the food availability may represent a problem as well as in eutrophic standing waters, in presence of a high load of nutrients. It tolerates seasonal desiccation. *R. balthica* extends from sea level, where it may occur in brackish water, to over 800 m AMSL (Scottish highlands, Tab. 12). This successful species has a strong dispersal power, as suggested by its ubiquitous distribution and also by the rapid colonisation of new man-made habitats.

In the North-East of Scotland *R. balthica* becomes slightly rarer and it is mostly distributed in all type of waters within the lowland and in the vast majority of the kettle-hole lochs spread along the glacial valleys. The first historical records for this species are attributed to Macgillivray (1843, 1855), who found it in a wide range of habitats in the Aberdeenshire. Furthermore it was reported for all vice counties (Appendix-I).

It is unclear if some of the historical generic county records of *Lymnaea auricularia* (Linnaeus, 1758) such as VC94 (Adams, 1896, 1902; Roebuck, 1921; Ellis, 1926; Kerney, 1982) or Fife (Ellis, 1926) might refer to *R. balthica* instead being considered as genuine findings of this species.

During the present field campaign this species has been found in a large number of habitats (133 populations identified), mostly located in the coastal area but also isolated populations in the mountainous sector. The highest populations are found in the metasedimentary stripe of rocks outcropping in the Cairnwell Area: Loch Vrotachan (750 m AMSL) and Loch Kander (677 m AMSL).

Distribution: Palaearctic; common throughout Europe.

Appendix-III reference map: 6.

Genus *Galba* Schrank, 1803

Subgenus *Galba* Schrank, 1803

Galba truncatula (O. F. Müller, 1774)

This is a cold stenothermophilous species, preferably found in clean and cold water in the lowland area. It inhabits a wide range of aquatic habitats with a preference for slow-flowing systems. It is typically associated with the crenon fluvial zone in presence of aquatic vegetation and slow current. It is also found in marshy grassland and limnocrene springs even those subject to desiccation, living mostly out of water.

In the British Isles it is a common species largely found in England and Ireland. Moving northwards it becomes rarer and is dominantly distributed in the lowland.

Within the highlands it remains confined at the lower altitudes, avoiding the mountainous sector. In the north-east of Scotland this mollusc has been recorded in several localities, mainly concentrated within the coastal area of all vice counties (Appendix-I).

During this field campaign a total number of 35 populations have been identified, the majority being located within the coastal sector. The species is very often found in the spring sector of the coastal streams, where the ground water feed the gorges and the incised channels before entering into the sea. Just a few populations have been found inland, mainly in small-sized ponds such as the ones located in Aberdeenshire North near Strichen and Mintlaw (stations No. 263 and No. 266), always associated with spring water. The innermost population has been found in the Invercauld estate pond near Braemar (St. No. 285 at 328 m AMSL), which is fed by a little stream. The species has also been found in marshy areas such as the Loch of Park in the Deeside (St. No. 226) and another unnamed wetland area near Laurencekirk (Whitewater Moss, St. No. 235). Only two populations have been found in a riverine environment, in the crenon zone (Ythanwells, St. No. 288) and in the potamon zone near Newburgh (St. No. 190) of the River Ythan. In the estuarine domain it has been found in a tidal channel of the River North Esk (St. No. 286). In two stations (No. 30 and No. 288) several specimens have been found crawling out of the water. In the first location several specimens were found feeding on the aquatic vegetation over a wet stream bank recently flooded by heavy rainfall, whilst in the second one numerous individuals were seen moving on a wall surface covered by a veil of flowing water.

Distribution: Holarctic; throughout Europe to beyond the Arctic Circle.

Reference plate: 35, Fig. a.

Galba truncatula has an elongated and conical shell formed by 5-6 tumid whorls bounded by deep sutures. The shell is pale and horn-coloured, slightly transparent when fresh. The ornamentation consists of well-defined and regularly spaced prosocline growth lines.

The mouth aperture is less than half of the height of the shell and shows a roughly oval profile, with a sinus located in adapical position.

The umbilicus is small and partially covered by the internal lip.

Appendix-III reference map: 7.

Family Physidae Fitzinger, 1833

Genus *Physa* Draparnaud, 1801

Physa fontinalis (Linnaeus, 1758)

This is a species typically found in clean and cool running waters (hard or soft), mainly in the lowland area. It is also met in lakes but not in small-sized ponds or places subject to desiccation. It does not tolerate polluted water.

It is quite widespread in England and Ireland, becoming less frequent to the north.

In the Grampian Area a number of historical records in Kinkardineshire and Aberdeenshire South exist for this species, confirming its occurrence as a plausible native taxon. Unfortunately the confusion made in the past with the other North American introduced species (i.e. *Physella acuta* and *P. gyrina)* generates some uncertainties with respect to the validity of these latter records (Appendix-I).

During the present field research a total of 7 populations were identified, mostly represented by medium sized lochs (e.g. Loirston Loch, Braeroddach Loch and Loch of Skene). In running water it has been only found in the Leuchar Burn (near Peterculter).

Distribution: European; widespread in lowland areas north to 63° N parallel in Scandinavia.

Reference plate: 35, Fig. c.

The *Physa fontinalis* shell is very thin and transparent, glossy and pale brownish coloured.

It is a sinistral shell formed of 4-5 swollen whorls, of which the last one exceeds the three-quarters of the height.

The general shell outline is oval; also the aperture is rather elliptical, although the inner side appears quite straight and oblique.

The shell ornamentation is given by a distinct set of prosocline growth lines.

The external lip is extremely thin and brittle and the umbilicus is absent, being fully covered by a callus formed by the inner lip.

Appendix-III reference map: 8.

Family Planorbidae Rafinesque, 1815

Genus *Ancylus* O. F. Müller, 1774

Ancylus fluviatilis O. F. Müller, 1774

This is a typical inhabitant of fast-flowing water, characterised by rocky substrata or pebbly-cobbly bottoms with boulders. It is not tolerant of muddy substratum and it is always found adherent to boulders or to any other type of rigid surface. It is commonly found in both hard and soft water, although in the latter environment it frequently shows the effects of apical erosion of the shell. It may occasionally occur in standing water such as lakes but always in places where the suspended matter is minimal and the bottom stones are not coated by mud or thick layers of algae. In the British Isles it is widespread, becoming less frequent northward.

In North-East Scotland *A. fluviatilis* is sparsely reported in all vice counties (Appendix-I).

During the present research 69 stations of *A. fluviatilis* have been identified, largely distributed along the lowland area. These stations span from the sea level up to 677 m AMSL (e.g. St. No. 306, Loch Kander outlet), with the majority falling in lotic environments. In only two cases such as the Loch Kander outlet and Carlochy (St. No. 296, 420 m AMSL), the individuals have been found in slow-flowing water. In the first case the specimens live in a quiet pool of the outlet, whilst in the second case they lie just few metres away from the outlet. In both cases the carbonate-rich nature of the soil together with a cold temperature (with low risk of icing in winters) maintained throughout the year, seem to be important factors that allow the species survival in such unusual habitats for it.

Distribution: west Palaearctic; widespread in Europe with the exception of most of central and northern Scandinavia.

Appendix-III reference map: 9.

Genus *Bathyomphalus* Charpentier, 1837

Bathyomphalus contortus (Linnaeus, 1758)

This species is widely distributed across the British Isles, where it inhabits most kinds of lowland aquatic environments. It is found in hard and soft water, mainly in quiet places with slow flow.

In Scotland it is definitely less frequent than in England, even if it is the most catholic species amongst the Scottish Planorbidae, being found in a large variety of environments of all vice counties (Appendix-I).

During this field research, sixteen stations of *B. contortus* have been identified in both lentic and lotic environments, confirming its wide distribution in the lowland sector. In terms of total number of specimens these populations never reach the magnitude of the other Planorbidae, being always represented to a limited number of individuals. Similarly to *Gyraulus albus* this species tolerates slight pollution and it is sometimes found in medium eutrophic waters. Passive dispersal seems to be very effective considering the high number of freshwater habitats colonised.

Distribution: Palaearctic, throughout Europe to 69° N parallel in Finland.

Reference plate: 35, Fig. i.

Bathyomphalus contortus has a very involute sinistral shell characterised by 7-8 slowly developing whorls with a typical half-moon cross-section related to the partial re-cover of the preceding one. It is rather glossy with a pale horn colour.

The lower side is nearly flat, characterised by a shallow small umbilicus; on the contrary the upper side is concave as the spire is sunken below the body whorl.

The shell ornamentation consists of a delicate set of growth lines regularly spaced.

The aperture is slightly projected upper wards.

Appendix-III reference map: 10.

Genus *Gyraulus* Charpentier, 1837

Subgenus *Gyraulus* Charpentier, 1837

Gyraulus albus (O. F. Müller, 1774)

This is a successful species, found in several types of aquatic environments, preferably quiet or slowly-flowing waters.

It is very common in England and Ireland although its distribution declines towards the north, leaving the north of Scotland practically free of records.

In the Grampian Area several records are historically known, mainly in the coastal lowlands of all vice counties (except for Angus), although some populations have been identified in the Deeside lochs (Appendix-I).

A total of thirty-four stations of *G. albus* have been found during this field campaign, allowing reconstructing more precisely its distribution area. As long as the basic requirements for this taxon are maintained the population can grow considerably, achieving very high densities (e.g. Corby Loch situated near Dyce, St. No. 199). In the Corby Loch population few hundreds of individuals per square metres have been identified with all the individuals found adhering on bottom stones.

G. albus is more adaptable compared to other co-generic species *(G. crista, G. laevis)* and it is capable to live in both hard and soft waters, even in presence of mild pollution and eutrophication.

Distribution: Holarctic; in Europe to 65° N parallel in Finland.

Reference plate: 35, Figs. d-e.

Gyraulus albus shows a sinistral planispiral shell formed by 4-5 rapidly expanding whorls separated by deep sutures, of which the last one covers one-third of the full diameter size.

The lower side is quite flat, characterised by a shallow umbilicus with only the centre truly depressed. The upper side is more depressed than the lower, as it is left bounded by the body whorl which is moderately raised above the planispiral plan.

The shell is thin and very pale horn coloured, with a characteristic ornamentation consisting of a regularly spaced and distinct set of growth lines, crossed by a well-pronounced system of spiral ridges, forming a characteristic graticule.

The aperture is broad and oval.

Appendix-III reference map: 11.

Genus *Gyraulus* Charpentier, 1837

Subgenus *Torquis* Dall, 1905

Gyraulus laevis (Alder, 1838)

Gyraulus laevis is normally found in clean and quiet waters, hard and soft, rambling on the aquatic vegetation or on stones.

This is a very local species, found throughout the British Isles with a northern rarefaction.

In Scotland sparse records are found mainly in the north-east and in Caithness, isles included. Kerney (1999b) reports this species as a partly relict of the last post-glacial, having been found in late glacial and early postglacial lake marls. *G. laevis* has been historically reported for Banffshire, Aberdeenshire North, Aberdeenshire South, and Forfarshire (Appendix-I).

Some old VC90 records of *Planorbis parvus* Say, 1817 (Taylor & Roebuck, 1889, 1901; Adams, 1896, 1902) might refer to the sibling species *G. laevis* as the former is native from North America and its presence in West Europe (Germany) has been only ascertained since 1973 (Glöer & Meier-Brook, 2003). During this research, 12 stations of *G. laevis* have been identified, suggesting that this species occurs in a wide variety of exclusively lentic environments, mainly located in lowlands. Good power of passive dispersal seems to characterise this species considering its wide distribution. Nevertheless all the populations are generally of a small size, probably controlled by other more successful competitors. In a few cases *G. laevis* demonstrates to be the dominant species within the Planorbidae community, particularly versus *G. albus,* indicating good interaction with the environment (e.g. St. No. 236 and St. No. 270).

Distribution: Palaearctic (probably Holarctic); local throughout Europe, extending to beyond the Arctic Circle in Finland.

Reference plate: 35, Figs. f-h.

The *Gyraulus laevis* sinistral and planispiral shell has a coiled spire consisting of 4-5 whorls (with deeper sutures than *G. albus),* of which the last one covers less than one-third of the full diameter size.

The lower side is rather flat, with a shallow and wide umbilicus.

The body whorl is gently raised above the level of the spire, defining a slightly sunken depression on the upper side (Pl. 34, Fig. g).

The shell is yellowish-pale horn coloured and is crossed by a regular set of clearly-defined growth lines, intersected by some irregular and faint spiral ridges (clearly visible under strong shading), not forming a particular pattern as in the case of *G. albus* (Pl. 34, Fig. h).
The aperture is nearly circular and gently projected upper wards.
Appendix-III reference map: 12.

Genus *Gyraulus* Charpentier, 1837
Subgenus *Armiger* Hartmann, 1840
Gyraulus crista (Linnaeus, 1758)

Gyraulus crista is widely distributed within the British Isles although becoming scarcer towards the north. It is found in a wide range of aquatic habitats including large rivers, canals, ditches, major lochs and lochans, always in slowly flowing waters. Though calciphile, *G. crista* is tolerant of soft water. An efficient capability of passive dispersal is thought to be the main reason for this ecological success.
Historical records refer to Banffshire, Aberdeenshire North, Aberdeenshire South and Angus (Appendix-I).
In the studied area this species occurs only in the lowland sector, quite often associated with large populations of Planorbidae such as *Gyraulus albus, Bathyomphalus contortus* and *Hippeutis complanatus.*
The number of populations identified in this field research is twelve, two of which found in slow-flowing streams and 10 in lentic environments. All the investigated populations are numerically limited, quite often because they share the same ecological niche with other dominant communities of Planorbidae. For its scarcity and for the relatively small size of the specimens, this taxon might be under-recorded and new populations could be discovered in the future in ecotopes already accurately sampled.
Distribution: European; nearly throughout Europe but sparse north of about 62° N parallel.
Reference plate: 35, Figs. j-k.
Gyraulus crista shows a sinistral and planispiral coiled shell consisting of 3 whorls, of which the last one lies completely above the spire level, originating a deep depression on the upper side.
The lower side is generally flat, with a small umbilicus frequently raised from the rest of the spire.

The shell is opaque and horn coloured, sometime slightly transparent.

The ornamentation consists of a sharp system of well-spaced growth lines; in some varieties an additional set of transverse ridges, originating spiny protuberances at the periphery, may occur too.

The aperture is oval and markedly angulated.

The specimen shown in Plate-35 is teratological, being represented by a despiralized shell, with the body whorl slightly detached from the preceding coiled section.

Scalarity among Planorbidae is a relatively frequent phenomenon described as early as in the second half of 18th century.

An evidence of scalarity in Planorbidae was already described in 1767 by Geoffroy, who reported the finding of a specimen in the stream Gobelins (located in the Paris area, France) named *'Planorbis* en vis'[1].

The same specimen was also figured in the Desallier d'Argenville famous treatise 'La Conchyliologie, etc…, Planche Huitième de la Zoomorphose (Planche LXXV), Figs. H_1-H_2-H_3' (Desallier d'Argenville, 1780a, 1780b).

Appendix-III reference map: 13.

Genus *Hippeutis* Charpentier, 1837

Hippeutis complanatus (Linnaeus, 1758)

This species is quite adaptable being found in a large variety of environments such as streams, rivers, lochs, lochans, ponds, etc. always in still or slowly-flowing waters. It also needs well-vegetated places, where it is frequently found feeding on the leaves or on the stones. It is calciphile even if in Scotland is quite often found in biotopes with soft waters.

This Planorbidae is very common and widely distributed in England and probably in Ireland where it is under-recorded. Moving northwards it becomes less frequent, with only few populations located just north of the Scottish border.

In the studied area *H. complanatus* has been historically reported for all vice counties (Appendix-I).

[1] Cette rare & singuliere espece est de couleur noire. Ses spirales posées les unes au-dessus des autres la font ressembler à une vis. Ces spirales, au nombre de sept, sont quarrées, & ont à leurs bords tant supérieur qu'inférieur, des angles bien marqués. Le total de la Coquille paroît un peu irrégulier quoique les spirales diminuent également; parceque quelques-unes, surtout les deux petites d'en-haut, ne sont pas posées absolument d'aplomb sur les autres. La Coquille est percée en d'essous d'un petit ombilic, & son ouverture est oblique, bordée d'un peu de blanc.

It is likely that old records of *Planorbis nitidus* O. F. Müller, 1774 such as those from the River Dee mouth (Macgillivray, 1855), Loch of Strathbeg and St. Fergus Canal (Dawson, 1870; Booth, 1913c) may be referred to *Hippeutis complanatus* as ascertained by McMillan (1960) for those specimens identified as *Segmentina complanata* recorded in the Loch of Strathbeg.

During this field campaign *H. complanatus* has been found in 10 stations, 8 of which new for the area, demonstrating that the species is relatively widespread in the lowlands. The species is quite often associated with *Gyraulus albus* and *Bathyomphalus contortus*. In some biotopes *H. complanatus* becomes the predominant Planorbidae, reaching densities of dozens of specimens per square metre (e.g. Corby Loch, St. No. 199). The occurrence of this species in a wide range of environments suggests a good power of passive dispersal.

Distribution: European and west Asiatic; widespread in lowland areas north to 63° N parallel in Finland.

Reference plate: 35, Fig. l.

Hippeutis complanatus has a sinistral and planispiral shell, with a characteristic discoidal appearance. It is very involute with 3-4 strongly keeled whorls in the centre of the periphery overlapping the preceding one.

The lower side is almost flat, whilst the upper one shows a small depression about one-sixth, one-fourth of the shell diameter.

The shell is usually pale silky shiny, translucent and finely striated by growth lines.

The umbilicus is wide and shallow.

The aperture is lanceolate.

Appendix-III reference map: 14.

Family Acroloxidae Thiele, 1931

Genus *Acroloxus* Beck, 1838

Acroloxus lacustris (Linnaeus, 1758)

Acroloxus lacustris is a common taxon in England and Ireland, typical inhabitant of clean and quiet waters. It tends to be calciphile even though it tolerates soft waters.

It becomes scarcer moving northwards, and extremely rare beyond the Scottish border.

In the North-East of Scotland this species has been recorded in Aberdeenshire North, Aberdeenshire South, and Angus (Appendix-I).

During this field research only one freshly-dead specimen was found in the Loch of Bog near Banchory (St. No. 241), a narrow lochan with the shores completely invaded by aquatic plants. The substratum is mostly characterised my mud with a high fraction of vegetal debris.

Distribution: European; widespread in lowland areas north to about 61° parallel in Scandinavia.

Appendix-III reference map: 15.

4.4.1.2. BIVALVIA

Class Bivalvia Linnaeus, 1758

Order Unionoida Stoliczka, 1871 (as Unionacea)

Family Margaritiferidae Henderson, 1929

Genus *Margaritifera* Schumacher, 1815

Subgenus *Margaritifera* Schumacher, 1815

Margaritifera margaritifera (Linnaeus, 1758)

This bivalve typically inhabits quickly-flowing permanent streams and rivers with good quality waters; it is never found in environments with high load of nutrients such as phosphates and nitrates. It likes pebbly-cobbly substrata with sandy pockets free from mud. This mollusc requires clean, cool and soft water with a high content of dissolved oxygen.

It is found in several places in Scotland, Wales and Ireland; although the species is strongly declining worldwide for a number of reasons, primarily pearl fishing, host fish reduction and farmland pollution.

In the North-East of Scotland *M. Margaritifera* has been extensively recorded in the past by several authors along the major rivers of all vice counties: River Ythan, River Dee, River Don, River Ugie, River Doveran [=Deveron], River North Esk, River Cowie, River Isla, Kellie Burn and Burn of Canry [=Burn of Canny] (Appendix-I).

At the moment relict populations of *M. Margaritifera* are found in the River Dee (Maryculter, Young & Williams, 1983b; Inver, Moore, 1987), whilst the historical strongholds for the River Ythan and for the River Don seem to have disappeared since long time (Young, personal communication) apart from a single site in the R. Ythan where three live specimens were recently observed (leg. Cosgrove 1997, SNH unpublished data). The population decline of the River Ythan started during the first half of the 20^{th} century, as direct consequence of the intense pearl fishing (Tocher, 1943) and eutrophication.

The most recent description of the *M. margaritifera* distribution in North-East Scotland was achieved after a series of extensive surveys commissioned by Scottish Natural Heritage (Cosgrove, 1997; SNH unpublished data), particularly along the Deeside.

Reintroduction attempts have been tried since the end of the 19^{th} century. In 1875 McKean placed 150 specimens coming from the River Don in the river Wandle (south-east England), but apparently the large majority died out after a short period (McKean, 1883). Nowadays some secret reintroduction operations in the River Dee hydrographic system have been carried out in

2005 by the Cairngorms National Park Authority (CNPA) and Scottish Natural Heritage, with the aim to expand the distribution area of this endangered species (SNH unpublished data, Anonymous, 2005).

During this field campaign only a few fragments have been recorded in river debris and no live individuals have been identified, although researches were not specifically designed to detect the presence of this mollusc. These new records are from the River North Esk at the Rock of Solitude gorge (St. No. 300) and from the River Dee at Banchory (St. No. 317). *M. margaritifera* has been reported since long time among the endangered categories in several red lists, such as the IUCN red data book (Wells *et al.,* 1983), the Cairngorms Local Biodiversity Action Plan (Cosgrove, 2002) and the Scottish Biodiversity List (Scottish Government, 2005). This mussel is today rather scarce within the British Isles but also in mainland Europe, evidence that forced all the stakeholders involved in environment management and conservation to revise the legal framework concerning the pearl mussel fishing and to adopt patrolling measures to prevent further damages to the threatened populations.

Distribution: Holarctic circumpolar; in Europe it extends from Iceland, Lapland and Norway (up to 71º N parallel) to Portugal and Russia, reaching Japan through Siberia. In the American continent it is confined to the northern region.

Appendix-III reference map: 16.

Family Unionidae Rafinesque, 1820

Genus *Anodonta* Lamarck, 1799

Subgenus *Anodonta* Lamarck, 1799

Anodonta anatina (Linnaeus, 1758)

This large bivalve lives in sizeable bodies of standing water, mainly located in the lowlands. It prefers hard water and it is more frequently associated with sandy bottom and flowing water rather than muddy substratum in stagnant places.

It is well-distributed in England and rarer in Ireland, where it is restricted to the central part. In Scotland it is generally absent, except for some isolated stations in Caithness and in the Buchan Area.

In literature some sparse records are available from Banffshire, Aberdeenshire North, Aberdeenshire South and Kincardineshire (Appendix-I).

The old records of *Anodonta cygnea* in Forfarshire (Taylor & Roebuck, 1889) may be all referred to *A. anatina,* considering the confusion made in the past among the two species. In any case *A. cygnea* occurs in the Firth of Tay area, so the two species coexistence is not completely excluded.

This field campaign only confirmed the occurrence of the populations in Loch of Strathbeg and Fasque Loch, documenting their healthy status. The regional distribution pattern of *A. anatina,* together with the population size and diversification, suggest a natural origin for them rather than a recent introduction.

Distribution: European, widespread in lowlands, northwards to south Scandinavia.

Appendix-III reference map: 17.

Order Veneroida H. Adams & A. Adams, 1856

Family Sphaeriidae Deshayes, 1855

This family is represented by five genera: *Byssanodonta* d'Orbigny, 1846, *Eupera* Bourguignat, 1854, *Sphaerium* Scopoli, 1777, *Musculium* Link, 1807 and *Pisidium* Pfeiffer, 1821 of which only the last three are present in Great Britain.

The taxonomical identification is mainly based on the valves character analysis, particularly the hinge (Fig. 24).

Anatomical analysis is primarily based on the morphology of the nephridia, the gills and the siphons; it may support the species attribution performed following the conchological characters. Sphaeriidae have a heterodont hinge which is composed of two anterior teeth (A_1 and A_3), one cardinal tooth (C_3) and two posterior teeth (P_1 and P_3) on the right valve and one anterior tooth (A_2), two cardinal teeth (C_2 and C_4) and one posterior tooth (P_2) on the left valve (Fig. 24a-b).

Another important specific character is the ligament pit which varies in length, width and depth among different species.

Some species show unique morphological features in the hinge which facilitate their taxonomic attribution. *P. personatum* for instance has a small rounded bulge located at the convergence of the posterior teeth P_1 and P_3 named 'callus' (Fig. 24d). This feature is a constant character found among the *P. personatum* populations, although in some cases it may be so weak that its detection becomes very difficult even at high magnification. An equivalent structure, but certainly less developed, is present on the homologous site (anterior end of P_2) of the left valve (Fig. 24f). This feature can sometime disappear completely; even if most of the times it is present with a variable degree of development.

Furthermore *P. obtusale* shows another characteristic formation, roughly located in the same position of the *P. personatum* callus. This structure practically consists of a thickening of the P_3 tooth, which merges with P_1 (Fig. 24e). This formation has been named 'pseudocallus', to differentiate it from the *P. personatum* 'callus' which has a different genetic origin.

Both 'callus' and 'pseudocallus', and quite often also the lateral teeth (anterior and posterior), show at high magnification a typical superficial texture consisting of some small globular coalescent formations. This 'granular' pattern is also observed in some teratological formations located on the ventral side of the valve, such as in the *Sphaerium corneum* specimen shown in Plate-4. The inner surface of the valves shows other important morphological features, such as the impressions of the anterior and posterior adductors muscles (Fig. 24a-b).

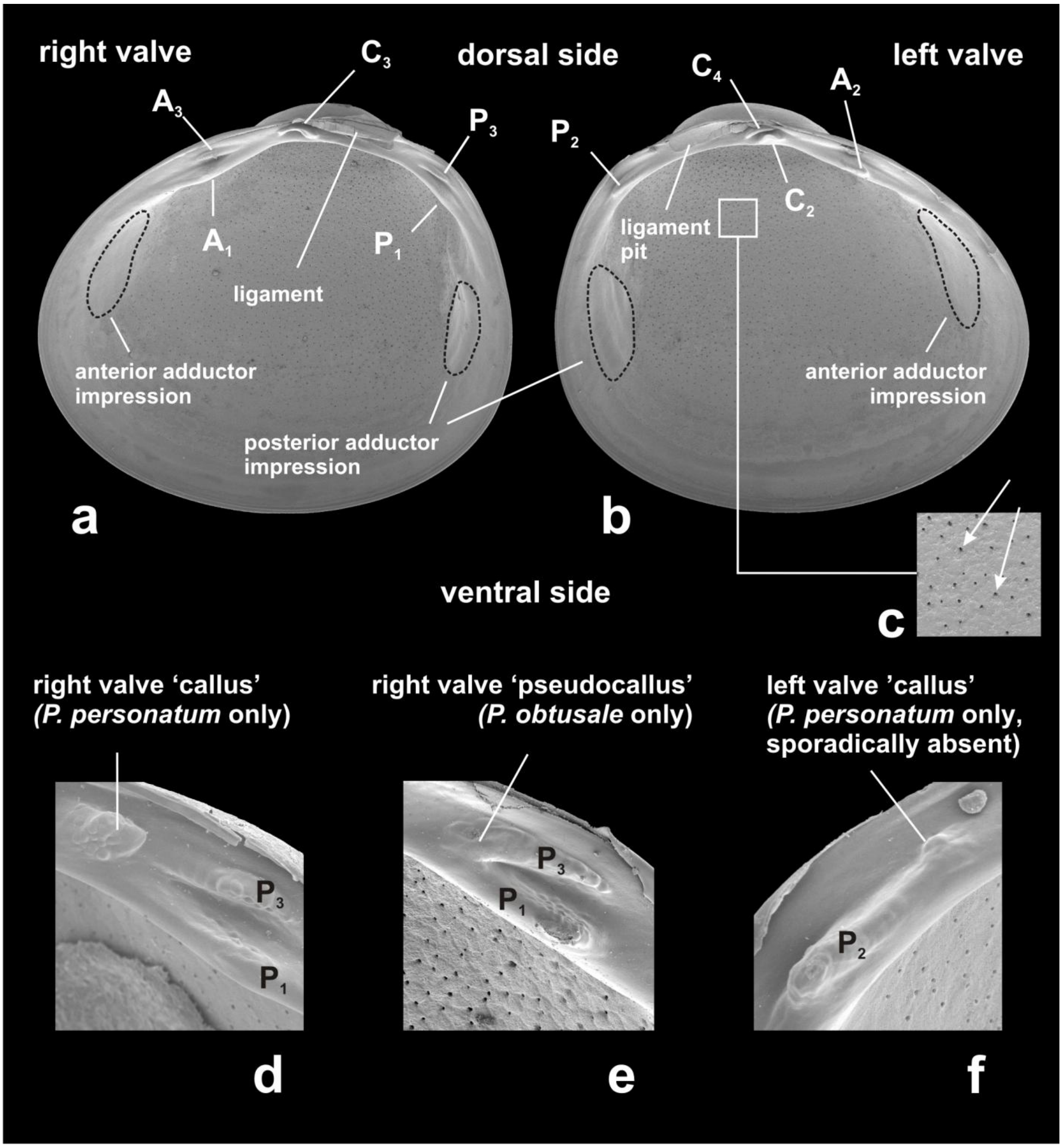

Fig. 24. Sphaeriidae nomenclature table.
a) right valve: C_3 cardinal tooth, P_1 and P_3 posterior teeth, A_1 and A_3 anterior teeth;
b) left valve: C_2 and C_4 cardinal teeth, P_2 posterior tooth, A_2 anterior tooth;
c) details of the inner surface of the left valve showing mantle pores (white arrows);
d) right valve 'callus' only found in *P. personatum;*
e) right valve 'pseudocallus' only found in *P. obtusale;*
f) left valve 'callus' only found in *P. personatum,* sporadically it can be absent.

The central part of the inner valve surface is also characterised by a dense grid of pores or canals (Fig. 24c), extending from the inner surface of the shell to the outer periostracum, without penetrating the outer layer. According to Burky (1983) these structures are believed to be created to facilitate gas exchange and waste removal through the shell.

Morphologically these canals appear to be slightly conical, with the diameter progressively decreasing inwards (Pl. 21, Figs. k, o). In some cases the aperture consists of a rounded print, giving to the structure a characteristic funnel-like appearance (cf. *P. subtruncatum* in Plate-20, Fig. d and *P. hibernicum* in Plate-30, Fig. g). A similar morphology is visible in a *P. tasmanicum* inner valve detail (cf. Fig. 41 in the Korniushin, 2000 revision of the Australian Sphaeriidae).

Shell pores show a different distribution on the valve surface, being denser in the median-dorsal area (subumbonal), gradually rarefying proceeding towards the mantle margin. On the more external fringe of the valve inner surface, shell pores are virtually absent.

Between the investigated populations, some variations from this general trend always occur, as for the case shown in Plate-31 (Figs. c, f), where a *P. hibernicum* specimen shows a sparse occurrence of the shell pores regularly distributed over the 70% ca. of the inner surface. In other cases shell pores appear grouped in clusters located in different zones of the valve, sometime located in an eccentric position *(P. milium* in Pl. 21, Fig. d) and sometime more central *(P. nitidum* in Pl. 23, Fig. f).

Density variations of the shell pores in the family Euglesidae have also been described by Slugina *et al.* (2006), although they concluded that rarefaction patterns are species specific, documenting the inversion of the distribution trends in different species of the genus *Euglesa*.

Shell pores are regarded taxonomically significant by some investigators such as Dyduch-Falniowska (1983), Kuiper & Hinz (1984) and Korniushin (2000). According to the investigations of Araujo & Korniushin (1998) and Grigorovich *et al.* (2000), shell canals densities can be related to exposure at different environmental conditions rather than being a taxonomic character.

According to my observations shell pores patterns do not seem to have a particular taxonomical meaning as different individuals belonging to the same species show both high and low density pores distributions (cf. *P. casertanum* in Pl. 7, Figs. a-f and Pl. 7, Figs. g-l; *P. obtusale* in Pls. 18 and 19). On the contrary it appears plausible that populations living in muddy substrata and stagnant conditions may develop a higher number of canals to favour the external exchanges. This could be the case of the *P. obtusale* population living in the Tarfside bog (St. No. 299, muddy substratum covered by a thick layer of vegetable debris, Pl. 17), which shows a higher density of pores in relation to the specimens living in the Witchock Loch (St. No. 330, sandy-gravelly substratum covered by a thin layer of vegetable debris, Pl. 18). This observation is in agreement with the investigations performed by Grigorovich *et al.* (2000), who reported a similar evidence for *P. moitessierianum* specimens living in different mud and sand substrata in the lower Great Lakes region (North America).

Intraspecific variability within the sphaeriids is very high, with frequent aberrant forms found in the populations. The reason behind this variability is believed to be primarily genetic, with a high tendency to generate teratological forms, which in some case may exceed the 40% of the population (Eggleton & Davis, 1962). This is the case of the so-called 'hinge reversal', where some teeth may be reversed from one valve to the other. This phenomenon has been diligently studied by a number of authors such as Walker (1896), Sterki, (1899, 1906, and 1922), Odhner (1919), Kuiper (1943, 1972), Eggleton & Davis (1962), Herrington (1962), Heard (1969), Anistratenko (1987) and Matsukuma (1996). A more detailed discussion concerning teratology among Sphaeriidae is presented in Appendix-IV.

Among the eight species of *Pisidium* identified in the area, some ecological associations are clearly highlighted and will be further discussed in the chapter relevant to the bivariate and multivariate analyses. Nevertheless it appears quite clearly that although in 80 cases only one species of *Pisidium* at a time has been found in a biotope, in 56 sites it has been recorded the simultaneous coexistence of two species (Fig. 25).

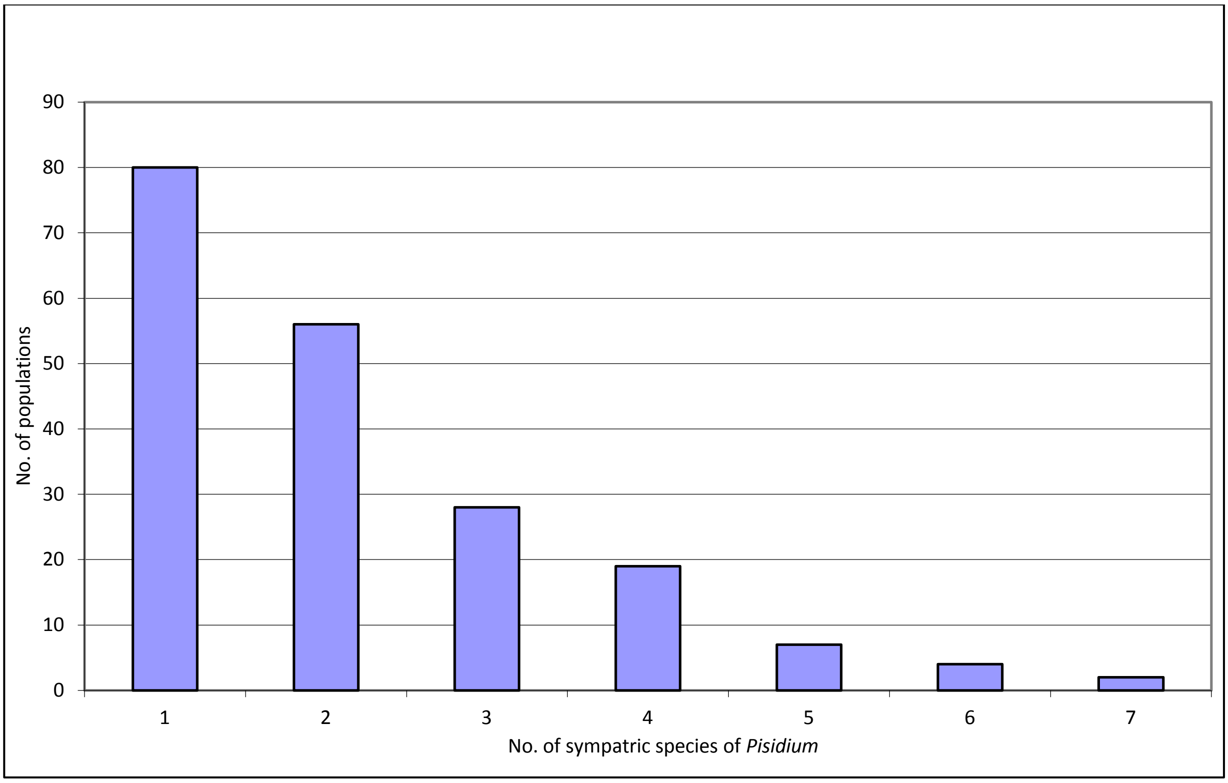

Fig. 25. Sympatric *Pisidium* species distribution.

Moreover in some rare cases up to 7 species of *Pisidium* have been found sharing the same environment (Loch Vrotachan, St. No. 177 and Loch Davan, St. No. 196), suggesting that different taxa may occasionally colonise niches with similar ecological requirements.

Genus *Sphaerium* Scopoli, 1777

Sphaerium corneum (Linnaeus, 1758)

This is a very common species widely distributed in the British Isles, found in a variety of aquatic habitats including ditches, quiet streams, rivers, ponds and lakes. It lives in both hard and soft waters, including brackish habitats, avoiding places subject to desiccation. Because of its capability to crawl on aquatic vegetation, *S. corneum* is also found in places where the substratum is covered by rotten organic debris. It is mostly a lowland species although occasionally it has been found in mountain lakes (Boycott, 1936).

In the North-East Scotland it has been historically found in several localities from all vice counties except for Banffshire (Appendix-I).

After the present field campaign 21 populations of *S. corneum* have been identified, mostly in lentic waters (17) but also occurring in lotic environments (Leuchar Burn stations No. 89 and No. 90; River Ythan, St. No. 294; and the Loch of Skene outlet, St. No. 7). It is frequently found in eutrophic waters within the lowland area (Bishops' Loch, Fasque Loch, Loch of Skene) but it also occurs in the Deeside kettle-hole lochs such as Loch Davan and Loch Kinord. The highest record comes from the Pronie Loch near Dinnet (stations No. 194 and No. 331 at 363 m AMSL), where it shares the same environment with other 4 species of Sphaeriidae *(P. nitidum, P. subtruncatum, P. milium* and *P. hibernicum).*

Distribution: Holarctic extending from Lapland to the Mediterranean, to the east up to northern Asia. It is also found in North America.

Reference plates: 1-4.

The shell morphology displayed in the specimens reported in plates 1-2 shows the typical rounded shape of *S. corneum,* with the umbos projected towards the anterior side. This is the opposite if compared with the umbos of the *Pisidium* species, which are clearly projected towards the posterior side. The cardinal tooth C_3 appears quite elongated with a thick bifurcated posterior extremity (Pl. 3, Fig. b), whilst C_2 shows a sigmoidal shape and is thicker than C_4 (Pl. 2, Fig. e; Pl. 3, Fig. e). Sometime C_2 may be more curved assuming a triangular shape (Pl. 4, Fig. f). The ligament pit shows lozenge geometry, quite narrow and parallel to the ventral edge of the hinge. Both anterior and posterior teeth are quite long and relatively thin.

The Plate-3 illustrates a teratological specimen, with the ventral side affected by a light fold consequent to a gentle crack repair, whilst Plate-4 depicts a more complex restoration job caused by a stronger injury.

No major variations within the shell micropores densities of different individuals can be envisaged (Pl. 1, Figs. c, f; Pl. 2, Figs. c, f; Pl. 3, Figs. c, f; Pl. 4, Figs. d, h).

Appendix-III reference map: 18.

Genus *Musculium* Link, 1807

Musculium lacustre (O. F. Müller, 1774)

This species colonises a wide range of aquatic habitats from slow-flowing waters (i.e. swampy ditches, artificial channels) to standing waters (i.e. ponds, shallow lochans, and weed-choked marshes). It is found in both hard and soft water and it is tolerant of anaerobic substrata, having the capacity to crawl on macrophytes. It may attain altitudes up to 1,400 m AMSL.

M. lacustris is generally distributed in England and more rarely in Ireland. In Scotland this species is quite rare, having just been recorded in a few localities to the north of the Scottish border.

In the studied area this species has been historically recorded only in two sites located in Aberdeenshire North and Aberdeenshire South (Appendix-I).

During this new cycle of field researches 6 additional stations have been found, mainly located within the lowland, in urban areas deeply altered by human interventions. The sampling activities performed in the Loch of Strathbeg did not confirm its occurrence in the loch. A part from the stream flowing northwards from Findlay Fm (St. No. 25), the rest of the stations are represented by artificial or semi-artificial lochans mainly spread in Aberdeenshire South and Kincardineshire. In More detail they are: a fishery near St Cyrus (Mill of Criggie lochan), a pond in the botanic garden of the Department of Zoology of Aberdeen, a lochan located in the Johnston Park (Aberdeen) and a Burn of Den pool situated in the Maidencraig natural reserve next to Aberdeen. It appears quite clearly that some (if not all) of these four populations might be considered as the consequence of an un-deliberate introduction, most probably together with macrophytes. The other two records (Loirston Loch and the stream flowing to the north Bridge of Don beach) may be considered as genuine native populations, which together with the Loch of Strathbeg one and the other old records from Perthshire suggest a very restricted original presence within the territory.

Distribution: Palaearctic (probably Holarctic); throughout Europe, north to South Scandinavia.

Reference plates: 5-6.

Musculium lacustre shares a similar rounded shape with *Sphaerium corneum,* with central umbos, slightly projected towards the anterior side but it is much more convex. The prodissoconch is clearly bounded by a sharp edge, which is a specific character always present in individuals of all the sizes (Pl. 6, Figs. g-i).

The hinge is generally short and narrow, with a ligament pit occupying almost the whole width. Anterior and posterior teeth are quite sharp and thin. The cardinal tooth C_3 shows an anterior half quite thin and parallel to the hinge ventral side and a posterior side with a triangular shape (Pl. 5, Fig. h), whilst C_2 is short with a sigmoidal shape and it is thicker than C_4 (Pl. 5, Fig. k). The micropores density in the central region of the inner valves appears to be relatively constant among different specimens (Pl. 5, Figs. i, l; Pl. 6, Figs. c, f).

Appendix-III reference map: 19.

Pisidium casertanum (Poli, 1791)

This is a very catholic species found in every type of aquatic habitats, including those subject to desiccation. In temporary ponds or extreme habitats it is most of the times the only species present. In Italy *P. casertanum* is invariably found alone or in association with *P. personatum* in a variety of lentic and lotic habitats within the 700-1,200 m AMSL altitudinal range of the Apennine and Alpine chains. Springs or pools which dry up during summer only hold *P. casertanum,* which is capable to survive in absolute absence of water (Pettinelli, unpublished data). It lives in hard or soft water, including those which are acidic, where specimens may survive with valves deeply damaged by the chemical action.

In the British Isles is present everywhere, reaching the maximum altitude at 1,006 m AMSL in the Scottish Highlands (pool on col between Beinn Ghlas and Ben Lawers, Dance, 1971, and 1972).

Old records for the Grampian Area (e.g. Macgillivray, 1843) are difficult to interpret as the species was probably confused with other taxa and it is not mentioned. According to the morphological description provided by Macgillivray (1843) for *P. pulchellum* and considering its vast distribution in the Aberdeenshire, it seems plausible that these records could be tentatively assigned to *P. casertanum*. First records under the *P. casertanum* name were reported by Woodward (1913) for Aberdeen and the River Dee near Banchory and subsequently by Gowan (1926) for Sandend (Banffshire). Then the species has been extensively reported for all vice counties (Appendix-I).

During my field campaign a total of 96 populations (53 lotic and 43 lentic) have been identified, the majority being distributed along the lowlands. The species shows a high morphological variability in response to the ecological adaptation. Thick shells are mostly found along the coastal stream sector, where the waters show a higher conductivity due to the ion content increase. The hinge thickness appears to be more robust, with well-defined cardinal teeth. In soft waters such as those founds in the oligotrophic lochs of the mountainous sector, the individuals are characterised by thin valves nearly transparent. The hinge is also quite narrow and elongated, whilst the cardinal teeth appear to be more slender and sub parallel. The highest populations have been found in the Cairngorms (flooding depression located on the southern slope of the Beinn a' Chaorainn, Braemar, St. No. 124, 872 m AMSL) and in the Lochnagar Massif (cirque loch situated at the base of the north-east cliffs of Carn an t-Sagairt Beag, Braemar, St. No. 173, 846 m AMSL). Both stations are located on granite outcrops and waters are extremely soft (conductivity < 40 mS) and frequently acidic (pH 6.24 in St. No. 124 and pH 5.92 in St. No. 173). This species is occasionally found in the upper sectors of the mountainous streams, where braided reaches occur. These conditions are met on the high plateaux, where slow-flowing meandering channels, quite often incised in peaty soils, sometime host sphaeriid populations. These are mostly characterised by sympatric populations of *P. casertanum* and *P. personatum* (e.g. upper sector of the Glen Lee, Invermark, St. No. 55). *P. personatum* disappears in habitats characterised by less stable ecological conditions, where only *P. casertanum* is capable to survive (e.g. the upper sector of the Black Burn, Ballater, St. No. 116). In the main rivers it is often associated with *P. subtruncatum, P. nitidum* and *P. hibernicum* (e.g. River Don, St. No. 138), whilst it can be found together with *P. milium* and *P. personatum* preferably where the substratum is muddy and invaded by aquatic vegetation (e.g. River Ythan, St. No. 294).

Distribution: Holarctic; probably cosmopolitan.

Reference plates: 7-12.

This is one of the most variable species of *Pisidium* as it is cosmopolitan and capable to colonise a wide range of habitats, sometimes with some characteristic phenotypes. The highland phenotype (Pl. 8), which is frequently found in the high plateaux, shows a rounded shape fairly flattened; also the hinge is relatively narrow compared to the lowland phenotype (Pls. 9, 12).

The cardinal tooth C_3 is gently curved and shows a thickened posterior end with a triangular outline (Pl. 8, Fig. b). C_2 and C_4 are thin and sub-parallel, forming a 30° ca. angle with the hinge ventral side. (Pl. 8, Fig. e). The ligament pit is short and amygdaloid, quite often occupying the whole width of the hinge; anterior and posterior teeth are generally well-distinct and sharp.

Internal micropores appear well-spaced and regularly distributed across the valve surface.

The lowland phenotype shows a thicker shell with umbos well-projected posteriorly, giving a more asymmetric shape. The hinge is remarkably robust with thick anterior and posterior teeth and a short amygdaloid ligament pit.

Some of the individuals of the lowland phenotype can be attributed to *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, a form originally described by Stelfox for specimens coming from the Grand Junction Canal (Hertfordshire and Buckinghamshire, England). This variety, characterised by a thick triangular shell, seems to be found in waters containing a 'sufficient quantity of calcareous matter' (Stelfox, 1918).

A typical individual belonging to this form comes from a small lochan located near Stonehaven (St. No. 11, Pl. 11). This specimen shows a quite short amygdaloid ligament pit, only occupying half width of the hinge (Pl. 11, Figs. a, d).

The cardinal tooth C_3 is strongly curved with a thickened and well-bifurcated posterior edge, showing a clear triangular shape crossed by a noticeable triangular furrow (Pl. 11, Fig. b). C_2 has a triangular shape as well, whilst C_4 is thin and parallel to the dorsal side of the hinge (Pl. 11, Fig. e).

Internal micropores appear irregularly distributed and of different size. (Pl. 7, Figs. c, f)

Appendix-III reference map: 20.

Pisidium personatum Malm, 1855

This is the commonest species of Sphaeriidae occurring in the British Isles, widely distributed in a highly diversified range of aquatic habitats, especially those characterised by the poorest conditions. This species preferentially inhabits stagnant water in grassy pools with muddy substrata covered by rich vegetal debris. It is also found in temporary pools and it may also occur away from the water, lying within ground litter in marshy woodland (Kerney, 1999b). *P.*

personatum also occurs in lotic waters, preferentially lower reaches of streams and rivers. In lochs it is a minor component within the sphaeriids community, confined in poorly-oxygenated habitats. It is found in both hard and soft waters.
In the British Isles it occurs nearly everywhere, reaching the maximum altitude at over 900 m AMSL in Perthshire (Evans, 1918; Dance, 1971).
Within the Grampian Area it has been historically reported for all the vice counties (Appendix-I).
In the studied area a total number of 113 stations inhabited by *P. personatum* have been found (87 lotic, 26 lentic), the majority distributed along the coastal streams system. These streams are characterised by high conductivity, typically comprised between 400 and 500 µS/cm due to the interaction with the sea spray deeply carried inland by the dominant strong north-eastern winds. A consistent number of these coastal streams inhabited by *P. personatum* are fed by ground water, which spills out at the base of the cliffs or inside the gorges, where turbulent flow is generally present. Other coastal streams slowly flow in oversized valleys, remnant of a more powerful hydraulic regime established after the Dimlington Stadial. In these places marshy areas are frequent, quite often associated with dense patches of *Carex* spp. (e.g. Bog of Minnonie, St. No. 324). In all these coastal environments sphaeriids are mainly represented by *P. personatum,* rarely associated with *P. casertanum* (e.g. spring stream of the Blackhills of Cairnrobin, Cove Bay, St. No. 19) or with *P. nitidum,* where the stream size is considerably larger (e.g. stream of the Mill of Findon, Portlethen, St. No. 17). *P. personatum* is also widespread across the lowland, where it is dominantly found in streams and lochans as well as in the river lower reaches (e.g. River Don at the Bridge of Alford, St. No. 302; River North Esk near the Mill of Pert, Edzell, St. No. 301). Small populations also inhabit the main lochs in both the lowlands (e.g. Loch of Skene, St. No. 183; Loch of Park, St. No. 226) and the highlands (e.g. Loch Vrotachan, St. No. 177; Loch Lee, St. No. 297). In the highlands the species is also found in the upper sectors of the mountain streams, where it frequently shares the habitat with *P. casertanum* (e.g. upper sector of the Glen Lee, St. No. 55; Upper sector of Allt Carn Bhathaich, Inverey, St. No. 165).
Distribution: mainly European ranging from Sweden and Faroe Islands to North Africa, to the east it extends up to the Caspian area.
Reference plates: 13-16.
Pisidium personatum shows a round shape quite flattened with small umbos located in median position; the hinge is curved, becoming narrower at the centre with short and sharp anterior and posterior teeth.

This species shows a distinct character consisting of a ‘callus’ formed in the region comprised between the posterior P_1-P_3 teeth and the C_3 tooth (Pl. 12, Fig. c; Pl. 13, Fig. c; Pl. 14, Fig. c; Pl. 15, Fig. c). This morphological detail is a constant feature in *P. personatum*, although it may appear with different degree of development and sometime can be only represented by a very gentle bulge, visible under strong shading. On the homologous side of the left valve is frequently present another weaker ‘callus’, joining together with the main one in the right valve when the valves are shut (Pl. 12, Fig. g; Pl. 13, Fig. h; Pl. 15, Fig. g). This structure is not present in every individual and may disappear completely according to the degree of development of the right valve ‘callus’ (Pl. 14, Figs. c, g).

The cardinal teeth C_2 and C_4 are both quite small, with C_2 a little bit thicker than C_4 (Pl. 12, Fig. f; Pl. 13, Fig. f; Pl. 14, Fig. f; Pl. 15, Fig. f).

C_3 tooth is gently curved, very thin and with its posterior extremity slightly thickened (Pl. 12, Fig. b; Pl. 13, Fig. b; Pl. 14, Fig. b; Pl. 15, Fig. b).

In the Plate-16 (Figs. b, f) is shown a teratological specimen characterised by an extra cardinal ‘pseudo-tooth’ originated from the dorsal hinge margin and present on both valves. It also shows a P_3 reversal (Pl. 15, Figs. c, g) on the left valve (in normal individuals it occurs on the right valve).

The internal micropores are quite small and sparse (Pl. 13, Figs. d, i).

Appendix-III reference map: 21.

Pisidium obtusale (Lamarck, 1818)

Generally distributed within the British Isles, this species is characteristic of small bodies of stagnant water prone to desiccation, particularly those choked with aquatic vegetation. Mitropol'skii (1969) studying a Siberian area near Borka ascertained that this species is capable of hibernation in upland bogs flooded by melting waters. These particular environments receive water only for three months per year (from middle-end of April until the end of July-beginning of August), during the other months the soil remains sufficiently wet for the species survival, covered by falling leaves and dying sedge. Enough humidity is maintained even in winter when the snow drapes everything, isolating the hibernated organisms. *P. obtusale* is also found in ditches, marshes and swamps, where it is often the only species of *Pisidium* present. Moreover it may occur in swampy margins of streams, rivers, canals and lakes, where it is associated with larger populations of other species of *Pisidium* (e.g. *P. nitidum* and *P. subtruncatum).* In habitats poorly-oxygenated (stagnant conditions) it occurs in its own or it can be found together with other very adaptable species (e.g. *P. personatum* and *P. casertanum).* The species is tolerant of hard and soft water.

In Scotland the species shows a scattered distribution, becoming quite rare in the north-east. In Perthshire it attains an altitude of ca. 700 m AMSL (Dance, 1971).

In the Grampian Area *P. obtusale* has been recorded in Aberdeenshire North, Banffshire and Angus (Appendix-I).

The 'Knaeckleith' reference reported by Macgillivray (1855) is not truly a reliable record because of its possible confusion with *P. personatum*.

Ten stations of *P. obtusale* have been discovered during this field research, all lentic environments. The existence of the Tarfside population (Kerney, 2001) has been confirmed. *P. obtusale* inhabits a wide variety of environments mostly natural and artificial lochans, including those disappearing in summer (St. No. 216) or fens completely invaded by aquatic vegetation such as the Loch of Park (St. No. 226). It is also found in Loch Davan (St. No. 196). The highest record in the area is at 546 m AMSL, a blanket bog situated in a very shallow depression fed by ground water (St. No. 248). In this site a perennial active flow is guaranteed by a tiny outlet, which avoids icing in winter, allowing sphaeriids survival. *P. obtusale* is here found together with *P. casertanum* and *P. personatum.*

Distribution: European (probably Holarctic) to beyond the Arctic Circle. Occurring from Iceland, Faroe Islands and Scandinavia to Spain, Portugal, Corsica, Italy, Bulgaria and through Russia into Siberia. According to Kuiper (1987), North American *P. rotundatum* Prime, 1852 is considered to be specifically identical to the Holarctic *P. obtusale* taxon, whilst North American *P. ventricosum* Prime, 1851 is regarded as a distinct Nearctic species.

The subspecies *P. obtusale lapponicum* Clessin, 1873 lives in Lapland, Russia and arctic America. In the British Isles this subspecies has been dredged at –30 m depth in Lough Neagh (Ireland) otherwise it is only found in cold Pleistocene deposits (Ellis, 1978).

Reference plates: 17-19.

P. obtusale has a globular shape slightly convex, owing a short and narrow hinge with an amygdaloid ligament pit. The most characteristic taxonomic feature is the presence of a 'pseudocallus' generated by a thickening of the posterior tooth P_3 before joining P_1 (Pl. 16, Figs. c, k; Pl. 17, Fig. c; Pl. 18, Figs. c, j). This formation differs substantially from the *P. personatum* 'callus' which is an independent bulge located between the cardinal tooth C_3 and the posterior teeth P_1 and P_3. Moreover, there is not an equivalent structure on the left valve, as observed in *P. personatum;* occasionally it could be present a low relief structural feature only visible at high magnification and under intense shading (Pl. 18, Fig. n).

Similarly to *P. personatum* the cardinal teeth C_2 and C_4 are small, thin and sub-parallel, with C_2 thicker than C_4 (Pl. 16, Figs. f, n; Pl. 17, Fig. n; Pl. 18, Figs. f, m).

C_3 is quite straight, very thin and parallel to the ventral side of the hinge (Pl. 16, Figs. b, j; Pl. 17, Fig. k; Pl. 18, Figs. b, i).

In the Plate-17 (Figs. a-i) is shown a teratological specimen characterised by a cardinal teeth reversal, with C_2 and C_4 located to the right valve instead of the left one (Pl. 17, Fig. b) and a very thin and elongated C_3 located to the left valve (Pl. 17, Fig. g). Similarly to what observed in the *P. personatum* specimen figured in the Plate-16, a 'pseudo-tooth' originated from the dorsal side of the hinge does occur nearby C_3 (Pl. 17, Fig. g).

Moreover the same teratological specimen shows an extra tooth adjacent to an unusually short and smooth A_2 on the left valve (Pl. 17, Fig. h); also A_1 and A_3 on the right valve are analogously short and smooth (Pl. 17, Fig. d).

In the Plate-19 are displayed two diphyoidic specimens, showing two marked sinuses located to the posterior side of the ventral margin.

The internal micropores are generally present with high densities all throughout the inner surface of the valves (Pl. 17, Figs. e, i).

Appendix-III reference map: 22.

Pisidium subtruncatum Malm, 1855

This is a common species quite often found in lotic waters such as ditches, streams, rivers, etc., although it also occurs in lochans and lochs. In running waters it is quite often the dominant sphaeriid, generally associated with *P. nitidum. P. subtruncatum* tends not to occur in swampy pools, or lochans with a low drainage and it is never found in places subject to desiccation.

This species is widespread in the British Isles, particularly within the lowland areas.

In the Grampian Area this species has been found in several localities in all vice counties (Appendix-I).

During the present field survey 65 stations of *P. subtruncatum* were found (37 lentic, 28 lotic), demonstrating its strong presence in the area. The species is found in a wide range of environments, mostly lower river reaches, slow-flowing streams and clean ditches. *P.*

subtruncatum has also been found in lochans and lochs quite often in proximity of inlets or outlets, where a slow flow constantly occurs. The species also occurs in mountain lochans, at altitudes remarkably high for the species (e.g. Loch Vrotachan 750 m AMSL and Loch Kander 677 m AMSL). This phenomenon seems to be related to the occurrence of soils rich in limestones and shales, which supply carbonates to the waters. Loch Vrotachan (St. No. 177) lies in fact in a natural depression occurring in a structural anticline formed by an alternation of pelite, psammite, limestone and dolomitic sandstone referred to the Ballachulish Subgroup. In a similar context it is found in a bog located at 435 m AMSL on the right bank of the Baddoch Burn (St. No. 174), characterised by the same stratigraphic series. In this latter ecotope a consistent population of *P. subtruncatum* shares the habitat with other sphaeriids communities represented by *P. casertanum, P. personatum* and *P. milium*. Another example is given by the medium sector of the Glen Ey, which upper sector shows extensive outcrops of pelite and limestones of the Ballachulish Subgroup. In this area a scarce population of *P. subtruncatum* sympatric with an equally rare number of *P. casertanum* has been identified at 467 m AMSL in St. No. 182. A further example of a high altitude carbonate-rich ecotope is Loch Kander (St. No. 306), located in a glacial cirque excavated within graphitic mica-schist interbedded with quartzite belonging to the Easdale Group. In this loch *P. subtruncatum* is found together with *P. casertanum* and *P. milium*.

Distribution: Holarctic, occurring nearly throughout Europe.

Reference plates: 20-21.

Pisidium subtruncatum is sub-triangular in shape with pointed umbos well-projected posteriorly. The hinge is quite long, with well-developed anterior and posterior teeth. The ligament pit is quite long as well and it shows a lozenge shape.

The most important character of this species is the organization of the cardinal teeth. C_2 and C_4 lie parallely each other, with C_2 never trespassing C_4 (Pl. 19, Figs. f, l; Pl. 20, Fig. e). Furthermore C_2 is gently curved and it is thicker compared to C_4 which appears to be slender and quite thin.

C_3 is quite long with the posterior edge slightly thickened and characterised by a gentle incision showing a triangular configuration similarly to that observed in *P. casertanum* (Pl. 19, Figs. b, i; Pl. 20, Fig. b).

The internal micropores appear with a variable density in different individuals; in one case it has been observed a peculiar funnel-like morphology of the micropore mouth (Pl. 19, Fig. d).

Appendix-III reference map: 23.

Pisidium milium Held, 1836

This species lives in a wide variety of aquatic habitats including canals, rivers, ponds, lakes (avoiding those liable to desiccation) and swampy areas. It is a species characteristic of clean, quiet water with rich aquatic vegetation. It is also tolerant of soft water.
P. milium is widely distributed within the British Isles, becoming less frequent northwards.
In North-East Scotland this species has been recorded in Banffshire, Aberdeenshire North, Aberdeenshire South and Angus (Appendix-I).
In the studied area 42 populations of *P. milium* have been identified mainly consisting of lochs and bogs (36 lentic stations) but also of mountain linear springs (St. No. 81), streams (e.g. Feardar Burn tributary, St. No. 82) and of the main rivers (River Don, stations No. 138 and 302; River Ythan, stations No. 291 and 294). There is a considerable incidence of populations at remarkably high altitude for this species such as Loch Vrotachan (St. No. 177, 750 m AMSL), Loch Kander (St. No. 306, 677 m AMSL) and a bog situated on the right bank of the Baddoch Burn (St. No. 174, 435 m AMSL). On the northern slope of Meall Gorm (Inver) a consistent population of *P. milium* was found sympatric with *P. personatum* and *P. nitidum* in a remote spring creek colonised by *Potamogeton* spp. (St. No. 81, 418 m AMSL). The occurrence of this species in the mountainous sector appears to be primarily related to the nature of the substratum. All these places are in fact located on very rich soils, dominantly characterised by interbedded graphitic schists, dark marble, pelite, psammite and limestone. Meall Gorm in particular is characterised by extensive outcrops of sandy dolomites, calcareous silicate-schist, pelite, psammite and limestone. These lithotypes favour water infiltration which re-emerges at the base of the northern slope at the contact with impermeable rocks, originating a conspicuous spring system.
Distribution: Holarctic throughout Europe from Iceland, Faroe Islands, and Sweden to North Africa and Balkans.
Reference plates: 22-23.
P. milium has a characteristic sub-rectangular shape, with large umbos located in the median region. The hinge is quite extended with well-defined anterior and posterior teeth. The ligament pit is quite narrow and long with a lozenge shape.
The cardinal teeth C_2 and C_4 are relatively thin and elongated, with C_2 thicker than C_4 (Pl. 21, Figs. f, m; Pl. 22, Figs. e, k). C_3 is quite long and thin with a gentle curvature and a thickened posterior extremity in the majority of the cases (Pl. 21, Figs. b, i; Pl. 22, Fig. b). In some cases

the thickness of C_3 can remain constant (Pl. 22, Fig. h) and C_2 and C_4 may be parallel to each other (Pl. 22, Fig. k).

The internal micropores appear to be quite irregularly distributed across the valves internal surface (Pl. 21, Figs. d, g); also a consistent variability has been observed among different individuals (Pl. 21, Figs. j, n; Pl. 22, Figs. i, l).

Appendix-III reference map: 24.

Pisidium nitidum Jenyns, 1832

Pisidium nitidum is a common lowland species, mainly occurring in ponds, lochs, marsh drains, streams and rivers. It tolerates soft water, preferentially clean, unpolluted and well-oxygenated habitats, avoiding places subject to desiccation.

In the British Isles it is widely distributed although becoming less frequent northwards. It is sporadically found in lochs situated at altitudes up to 490 m AMSL.

In the North-East of Scotland *P. nitidum* has been found in all vice counties (Appendix-I).

During the present field research 66 new stations of *P. nitidum* have been identified, mostly located in the lowland sector. Among these stations 40 are represented by lentic and 26 by lotic environments, indicating a high capacity borne by *P. nitidum* to colonise highly diversified habitats. This species is mainly found in ponds, streams and rivers as well as in the major lochs. It becomes scarcer in the highlands, although a few populations are present at a remarkably high altitude for this species. Loch Vrotachan (St. No. 177, 750 m AMSL) for instance holds the highest population found in the British Isles, whilst other populations occur at lower altitude in the Braemar area (St. No. 168, 368 m AMSL) and Dinnet (St. No. 194, 363 m AMSL). Notably the first two sites are deeply influenced by the nature of the soil, dominantly characterised by limestones, pelite and psammite, which increase the carbonate content in standing waters. The third site (St. No. 194) occurs in an area dominated by basic intrusive rocks such as olivine-ferrogabbro and norite but meta-sedimentary rocks outcrop nearby too. The primary source for chemical components in the Dinnet area is represented by the Baderonoch Hill, being mainly composed of metamorphic psammite and pelite. In running waters such as ditches, streams and rivers, the species is commonly found associated with *P. subtruncatum* and *P. personatum*.

Distribution: Holarctic, widely spread in Europe from Iceland and Faroe Islands to Spain, Corsica, Italy and Bulgaria.

Reference plates: 24-27.

Pisidium nitidum is sub-quadrangular-elliptical in shape with a very long hinge becoming narrower in the cardinal area. The characteristic three grooves separating the prodissoconch from the rest of the shell are quite often visible even from the inner side (Pl. 23, Figs. a, d; Pl. 26, Figs. a, d).

The ligament pit shows an amygdaloid shape, is short and in some cases may occupy the whole hinge width (Pl. 25, Figs. a, d). The anterior and posterior teeth are well-developed with P_1-P_3 and A_1-A_3 moderately converging.

C_2 and C_4 are quite thin and sub-parallel to each other, with C_2 moderately thicker than C_4 (Pl. 23, Figs. e, k; Pl. 24, Figs. e, k; Pl. 25, Fig. e; Pl. 26, Fig. e). C_3 is rather slender and straight, with the posterior extremity somewhat clavate (Pl. 23, Figs. b, h; Pl. 24, Fig. h; Pl. 25, Fig. b).

The internal micropores distribution appears to vary considerably between different individuals. In Plate-27 (Figs. c, f) is represented a specimen showing very small micropores poorly distributed, whilst in Plate-25 (Figs. c, f, i, l) the pore size looks bigger and the density higher.

In Plate-25 two diphyoidic specimens are displayed showing as many cracking repairs located to the ventral-posterior side of the shell.

Appendix-III reference map: 25.

Pisidium lilljeborgii Clessin, 1866

Pisidium lilljeborgii is a boreal relict, absent from much of England, occurring in Wales, Scotland and western Ireland. In Scotland is virtually restricted to major lakes and corrie lochans within the highland zone. It lives in hard and soft waters, although it usually prefers the latter environment. *P. lilljeborgii* likes clean gritty sand or silt, avoiding muddy bottom (Stelfox, 1929) and it is also tolerant of a wide alkalinity.

This species may reach reasonable altitude in Great Britain (e.g. 750 m AMSL in Loch Vrotachan), whilst in the Alps it is found in mountain tarns up to 2,300 m AMSL.

Within the Cairngorms it has been recorded in Loch Urotachan [=Vrotachan] by Bishop (in Kerney, 1974); the other scattered records located along the Deeside are of unclear meaning and need to be confirmed (NBN Gateway, Appendix-I).

Fossil specimens have also been reported for Dimlington stadial deposits.

During this field survey 9 stations were recorded within the Dee and Don catchments, exclusively distributed in lentic waters. These relict populations survive only in medium sized lochs, mainly situated in the Highlands, where they might successfully compete with the other less specialized co-existing species. *P. lilljeborgii* appears to be currently confined to cold habitats generally mesotrophic (but also eutrophic), supporting a rich aquatic vegetation.
Distribution: Holarctic circumpolar ranging from Iceland, Faroe Islands and Lapland down to both sides of the Alpine chain. It is also found in Lake Baikal and in North America.
Reference plates: 28-29.
Pisidium lilljeborgii has a characteristic shell profile markedly sub-quadrangular, with the dorsal side short and straight, forming a sharp angle with the anterior and posterior sides. As consequence the hinge is quite short, well-curved and becoming quite narrow in the central position; the amygdaloid ligament pit is short and broad.
The external appearance is quite striated, occasionally with some marked growth lines bounding the embryonic shell (Pl. 28, Figs. h-i).
The anterior and posterior teeth are quite short and pointed.
The cardinal tooth C_2 shows a triangular shape, whilst C_4 is thin and straight, overlaying only the posterior half of C_2 (Pl. 27, Figs. e, k; Pl. 28, Fig. e). The cardinal tooth C_3 is generally curved with the posterior edge thickened and bifurcated, delimiting a narrow triangular depression (Pl. 27, Fig. h; Pl. 28, Fig. b). In less frequent cases C_3 may appear straight, with a less pronounced thickened extremity (Pl. 27, Fig. b).
The internal micropores distribution varies considerably among different individuals, with high densities observed in a number of cases (Pl. 27, Figs. c-f) and a scarce appearance in a few other examples (Pl. 27, Figs. i, l).
Appendix-III reference map: 26.

Pisidium hibernicum Westerlund, 1894

A species typically inhabitant of clean and clear water, hard or soft in a wide range of habitats: ponds, lakes, marsh drains, streams, canals and more seldom large rivers.
It is occasionally found in mountain tarns at heights up to 700 m AMSL in Britain and up to 2,400 m AMSL in the Alps.
Within the Grampian Area it has been sparsely recorded from Banffshire, Aberdeenshire South, and Angus (Appendix-I).

During this field campaign 24 populations of *P. hibernicum* were identified mainly in lowland but also in the mountainous sector. Within the Highlands this species has been frequently found associated with *P. lilljeborgii* (Loch Callater, Loch Vrotachan, Loch Davan and Loch of Aboyne), suggesting similar preferences for cold and clean waters. It lives in a wide variety of environments including both lentic (21 stations) and lotic waters (3 stations), with a strong preference for the former habitat. The species altitudinal range covers a wide array comprised between 1 (Stream flowing north of St Combs, Fraserburgh, St. No. 204) and 750 m AMSL (Loch Vrotachan). It is found in hard and soft water, acidic and alkaline, avoiding places chocked with weeds or subject to desiccation. It is also found in large rivers (e.g. River Don, St. No. 138) where it never reaches high density. In the River Don it occurs together with abundant populations of *P. nitidum* and *P. subtruncatum,* and a scarce *P. casertanum* presence.

Distribution: Palaearctic mainly in northern Europe (from Iceland, Faroe, northernmost Scandinavia, Siberia to Spain, Italy, Austria and Hungary). In North America is replaced by *P. ferrugineum* Prime, a closed allied (Kuiper, 1966).

Reference plates: 30-33.

P. hibernicum has a very tumid, equilateral and elliptical shell with prominent umbos located to the median position. The hinge is quite long and curved, becoming extremely thin in the central position; anterior and posterior teeth well-developed, ligament pit quite narrow with an amygdaloid shape.

C_2 and C_4 are quite small and thin, C_4 in the vast majority of the cases does not trespasses the two third of C_2 (Pl. 29, Fig. f; Pl. 30, Fig. k; Pl. 31, Figs. e, k; Pl. 32, Fig. e). C_3 is quite slender and straight, with a posterior end slightly thickened (Pl. 29, Fig. b; Pl. 30, Fig. h; Pl. 31, Figs. b, h; Pl. 32, Fig. b).

Internal micropores show variable densities among different individuals. In Plate-32 (Fig. i) is reported an individual showing a scarce distribution of micropores distributed in clusters, whilst in Plate-30 (Figs. i, k) another specimen shows a higher density organised in a more regular pattern. In Plate-30 (Fig. g) a *P. hibernicum* specimen from Witchock Loch (St. No. 330) shows a funnel-like geometry of the micropore aperture, similarly to what already observed in a *P. subtruncatum* specimen collected in Loch Vrotachan (St. No. 177; Pl. 19, Fig. d).

In Plate-31 (Figs. g-l) is shown a diphyoidic specimen characterised by a ventral fold consequent to a shell repair, whilst in Plate-32 other two diphyoidic specimens show a cracking restoration occurred to the posterior side.

Some anomalous individuals show a different organization of the cardinal teeth, consisting in a progressive separation among C_2 and C_4 accompanied by a stretching of C_3. This is the case of the atypical individual collected in the Pronie Loch (St. No. 194) and photographed in Plate-31 (Figs. a-f). This specimen shows a complete segregation of the cardinal teeth C_2 and C_4 (Pl. 30, Fig. e), combined with an unusual geometry of C_3, consisting in a twisted element, showing a double convexity: the anterior part with a concavity towards the dorsal side and the posterior one towards the ventral side (Pl. 30, Fig. b). Looking at the whole population inhabiting this loch, it appears quite clearly that a complete transitional series between typical and aberrant forms do exist, suggesting that a new variety of *P. hibernicum* is currently under evolution.
Appendix-III reference map: 27.

Old Sphaeriidae taxa

Considering that some of the oldest citations of *Pisidium* were made using taxa no longer used nowadays in malacology such as *P. fontinale* and *P. pusillum,* it becomes very hard to attribute these zoological entities to any of the known species of *Pisidium*.

Pisidium fontinale and *P. pusillum* are now considered synonyms of older taxa such as *P. casertanum,* but old records referring to these species may belong to different species as ascertained by many authors in several cases after the examination of collection materials. The basic classification criteria for the *Pisidium* genus started to be identified and described during the second half of the 19th century and only after the works of Woodward and Stelfox during the first quarter of the 20th century, were satisfyingly defined.

For this project it was decided to create distribution maps based on the old records even for these taxa, which might be incorporated with those of other taxa once ascertained the identity of the old material.

The distribution area of *Pisidium fontinale* is reported in Map-28, whilst *P. pusillum* in Map-29.

4.4.2. SUCCESSFULLY ESTABLISHED ALIEN TAXA

The following taxa represent aliens accidentally introduced by man during the 20th century and now fully integrated with the autochthonous fauna. Some of them have been introduced from other continents such as *Potamopyrgus antipodarum* from New Zealand and *Physella acuta* from North America. It is believed that these are accidental introductions (transported with intercontinental cargos) propagated from port storage areas/basins (e.g. timbers imported from North America). Moreover these two species quickly radiated all across the European continent, locally to become (as in the *P. antipodarum* case) the commonest molluscs inhabiting lowland areas.

ORDER NEOTAENIOGLOSSA Haller, 1892
Family Hydrobiidae Stimpson, 1865
Genus *Potamopyrgus* Stimpson, 1865
Potamopyrgus antipodarum (Gray, 1843)

Potamopyrgus antipodarum prefers flowing water of any kind, hard or soft, found also in brackish environments with salinity up to 17 parts per thousand NaCl. It is frequently found in streams, rivers, canals, less common in still waters. Substratum nature seems not to be an ecological constrain, as it is found crawling on stones, vegetation or barely on mud. *P. antipodarum* is tolerant to pollution and to seasonal temperature variations.

This species has its origin in New Zealand but it is now well-established in Great Britain and Europe, continuously expanding its territory. First arrival in Britain is documented at Grays, Essex before 1852 (Kerney, 1999b). Furthermore it was recorded in several counties, documenting the active proliferation of this mollusc and its ability to quickly colonise new environments. The parthenogenetic reproduction, which characterises the species, is probably the first cause behind this ecological success. A gravid passive-transported specimen is likely to originate a new colony, which at the beginning is typically composed of an enormous number of individuals, rapidly decaying within few seasons.

The first Scottish record dates back to 1906, when Barclay collected a number of specimens on stones in the River Tay near Elcho (Rodger, 1914). Subsequently the species was first recorded in Forfarshire by Crapper (Boycott, 1924) and then in Kincardineshire (Boycott, 1935). From 1960 until nowadays, a number of field surveys and occasional records allowed to reconstruct and extend the *P. antipodarum* distribution to the other vice counties of the Grampian Area (Appendix-I).

During this field work 110 stations of *P. antipodarum* were identified, 68 from lotic and 42 from lentic environments, virtually covering any type of habitat within the lowland area. The species does not reach significant altitude within the British Isles, being the highest record 401 m AMSL in Wales (Dance, 1971). In this study the highest record is 363 m AMSL, corresponding to the Pronie Loch situated at the base of the western slope of the Baderonoch Hill, Dinnet (stations No. 194 and No. 331). All the other records cover an altitude range comprised between 1 and 179 m AMSL, mostly spread in the coastal sector.

Distribution: Europe north to the Shetlands, south Scandinavia and the Baltic. Native from New Zealand.

Reference plate: 34, Figs. g-i.

Potamopyrgus antipodarum is characterised by a slightly transparent yellowish shell, covered by a thin periostracum, frequently covered by organic and inorganic encrustations. The shell is formed by 6 rather tumid whorls separated by deep sutures and a small protoconch most of the times deeply corroded (Pl. 33, Fig. h). Some specimens like the one shown in Plate-34 own a peripheral keel, ornate by periostracum bristles. The body whorl is quite large and despiralized, with a deep gap separating the last portion of the chamber from the rest of the spire.

The ornamentation is represented by faint and irregularly spaced prosocline growth lines.

The aperture is quite elliptical forming an angle of ca. 20° degrees with the shell axis and it is gently projected downwards. It also presents a slightly angulated sinus at its adapical end.

In adult specimens the aperture is characterised by a thin peristome, which tends to out-turn at the base of the columella.

The umbilicus is very shallow as consequence of the last whorl detachment.

Appendix-III reference map: 30.

Family Lymnaeidae Rafinesque, 1815

Genus *Lymnaea* Lamarck, 1799

Subgenus *Lymnaea* Lamarck, 1799

Lymnaea stagnalis (Linnaeus, 1758)

The great pond snail is typically found in the British Isles in large lentic water bodies but also in slow flowing lowland drainage systems such as rivers, canals and ditches. The mollusc prefers clean and hard water, where it is frequently found on the aquatic vegetation. *Lymnaea stagnalis* dislikes small ponds although it can be found in garden ponds accidentally introduced with the aquatic plants.

Widespread in England and Ireland it becomes rarer towards the north, leaving Scotland nearly free of populations. The only known Scottish populations are in west Lothian (Godfrey, 1900) and in the Clyde area (Scott, 1901; Roebuck, 1920), all un-deliberately introduced.

The only population found in the Grampian Area during this field campaign is an artificial lochan created in 1995 on the left bank of the River Ugie near Strichen (St. No. 266, this study). A few mature and juvenile specimens where found feeding on the aquatic vegetation, in a site fed by the interstitial water of the River Ugie, which constantly flows through the permeable bank. The species has been certainly introduced with the aquatic plants brought from a local garden centre. Another small population that used to inhabit a pond located in the Cruickshank botany garden of Aberdeen University, today has apparently disappeared (Young, personal communication).

Distribution: Holarctic; nearly throughout lowland Europe.

Appendix-III reference map: 31.

ORDER PULMONATA Cuvier in Blainville, 1814

Family Physidae Fitzinger, 1833

Genus *Physella* Haldeman, 1842

Physella acuta (Draparnaud, 1805)

The taxonomic status of this taxon is still under discussion, although some authors converge to the same conclusion: the species is native of North America and introduced to the rest of the world starting from the early 19th century. Dillon *et al.* (2002) demonstrated (on the basis of lack of reproductive isolation in captive cultures) the identity among North American *Physa* *heterostropha, P. integra* populations and British populations of *Physella acuta*. As consequence *P. heterostropha* and *P. integra* are considered as junior synonym of *Physella acuta*. The same conclusion based on morphological similitude was achieved by Anderson (2003) and reflected in the annotated list of the non-marine Mollusca of Britain and Ireland (Anderson, 2006).

The species is generally found in quiet and slow-flowing waters such as lowland river reaches, canals, lakes and ponds. Contrary to *Physa fontinalis, Physella acuta* is capable of colonizing degraded environments either industrially polluted or naturally eutrophic. It is tolerant of de-oxygenated conditions, and may survive in confined habitats such as ornamental fountains (e.g. St. No. 295) or urban ponds (e.g. St. No. 278).

In the Grampian Area it was first noticed by Jenkins in 1890 in some ponds in Banner Mills Co. Subsequently Simpson, (1905) and Booth (1913c) reported in their lists the same locality, confirming the species presence in the area. In 1926 Ellis reported the occurrence of *Physa heterostropha* in Aberdeen, then the aggregate *Physa* spp. was mentioned by Ellis (1951) for Forfarshire and Aberdeenshire South.

During the present research 6 populations of *Physella acuta* were identified, three in lentic and three in lotic environments, indicating a sparse but uniform distribution within the lowland sector (altitude range 1-108 m AMSL).

Distribution: cosmopolitan but originally spread by man from North America.

Reference plate: 35, Fig. b.

The *Physella acuta* sinistral shell is larger and thicker than *P. fontinalis,* consisting of 5-6 whorls pale horn coloured, of which the last one is about three-quarters of the height.

The general shell outline is oval with a pointed spire; also the aperture is rather elliptical, wider than *P. fontinalis* with the inner side fairly straight and oblique.

The shell ornamentation is given by a faint set of prosocline growth lines.

The peristome wall is thicker than the rest of the shell and markedly extroflected.

The umbilicus is absent, being fully covered by a thick callus formed by the inner lip.

Appendix-III reference map: 32.

Family Planorbidae Rafinesque, 1815

Genus *Planorbarius* Duméril, 1806

Planorbarius corneus (Linnaeus, 1758)

This large species normally inhabits lentic waters, preferably sizable bodies or slowly moving canals and rivers in England and Ireland. It is a typical component of the benthic fauna of large and well-vegetated lakes. It is frequently found crawling on the plant stems or on submerged logs and stones. It tolerates anaerobic conditions at the bottom interface.

Planorbarius corneus is currently expanding its territory although is not found north of the Scottish border except for the isolated station of the Pitfour Loch, Old Deer (Young in Kerney, 1978). This population still survives today in good health (St. No. 264, this study), with numerous individuals found crawling over the aquatic vegetation.

Distribution: European and west Asiatic; in Europe extending to 64° N parallel in Finland.

Appendix-III reference map: 33.

Genus *Planorbis* O. F. Müller, 1773

Planorbis planorbis (Linnaeus, 1758)

In the British Isles *Planorbis planorbis* is frequently met in all type of slow-flowing and well-vegetated lowland habitats, including river lower reaches, canals, lakes and ponds, with a preference for shallow bodies subject to desiccation. It generally prefers hard water.

This species is widespread in England and Ireland, having its northern limit at the Scottish border.

This Planorbidae is in fact virtually absent from Scotland, being only known in two stations (Appendix-I): a pond located in the Cruickshank botany garden of Aberdeen University (Young, 1980, 2003 unpublished data) and Maryculter (Norris, 2011; grid reference in NBN Gateway). The former population seems to be quite stable and survives today with a consistent number of individuals (St. No. 311, this study) despite the pond is completely emptied every year for regular cleaning and maintenance. This is a typical example of accidental introduction (probably with aquatic plant brought up from England), which may last over a long period, as long as the environmental conditions suitable for the species remain unchanged.

Distribution: European & west Asiatic; in Scandinavia to 63° N parallel.

Appendix-III reference map: 34.

4.4.3. HISTORICAL TAXA RECORDS NOT CONFIRMED

Two gastropod species previously reported for the area were not found during this research: *Anisus leucostoma* (Millet, 1813) and *A. vortex* (Linnaeus, 1758).

<u>*Anisus leucostoma*</u>

A. leucostoma seems to be extremely rare in Scotland having been recently found only in the Loch of Aboyne (Young in Kerney, 1984). Kerney (1999b) in its latest version of the freshwater mollusc distribution atlas, reports some additional sites within the lowland coastal sector such as the Loch of Strathbeg, another spot near Fraserburgh, Aberdeen and two other sites in the Montrose area (Appendix-I).

A specimen of *Planorbis vortex?* found in 1860 by Dawson in Cruden and deposited in the Arbuthnot Museum of Peterhead, was tentatively attributed to *Planorbis [=Anisus] leucostoma* by McMillan (1960).

The historical *Planorbis Vortex Spirorbis* and *Planorbis spirorbis* records for Aberdeen (Macgillivray, 1843, 1855; Taylor, 1853, Roebuck, 1891a), Loch of Strathbeg (Scott, 1891), Banffshire (Dawson, 1870), Forfarshire (Taylor & Roebuck, 1885) and Aberdeenshire South (Taylor & Roebuck, 1889), could refer to *Anisus leucostoma* according to the recorders original descriptions and the partial synonymy among *Anisus leucostoma* and *Planorbis spirorbis*. Furthermore the distinction between *Anisus leucostoma* and *A. spirorbis* is problematical and still under debate as the two taxa are very similar and also some intermediate forms are known identified through dissection (Glöer, 2002).

Distribution spans from North Africa, through Europe, Iceland, in Sweden to 63° N parallel, west Asia (Appendix-III reference map: 35).

<u>*Anisus vortex*</u>

Anisus vortex is only found in Scotland in the southern part (i.e. Firth of Forth area, Kerney 1999b), although some historical records of *Planorbis vortex* for the Aberdeen area (Macgillivray, 1843, 1855; Dawson, 1870; Buchanan white, 1874) and the Forfarshire vice county (Taylor & Roebuck, 1889) may suggest its sporadic presence further north (Appendix-I, Appendix-III reference map: 36).

Among sphaeriids no populations of *Pisidium amnicum* (O. F. Müller, 1774) and *P. pulchellum* Jenyns, 1832 have been identified.

P. amnicum

P. amnicum is not present in northern Scotland. Only one isolated population has been identified so far, living in the Loch of Strathbeg (Forteath, 1977; Young in Kerney, 1977) together with *P. nitidum, P. casertanum, P. subtruncatum* and *P. milium* (Appendix-I). The older records for the Inverury [=Inverurie] Canal, (Macgillivray, 1843, 1855) and the Hilton Quarries (Taylor, 1853), both habitats today disappeared, are quite doubtful and need to be reviewed. During this field research no new populations of *P. amnicum* have been discovered, neither its occurrence in the Loch of Strathbeg has been confirmed. One single specimen preserved in 70° ethanol labelled *Pisidium amnicum* – Loch of Strathbeg (collected by M. P. Kerney during the 70') and stored in the collection of the Department of Zoology of the Aberdeen University, has been examined and the species attribution confirmed.
Distribution is Palaearctic (probably Holarctic), throughout most of Europe, north to south Scandinavia (Appendix-III reference map: 37).

Pisidium pulchellum

Pisidium pulchellum previously reported in the area by few recorders was not found during my field survey. In the Grampian Area it was found: in a moss on Sandend Links, Banffshire (Roebuck, 1917a), in a dam on Luther water, Auchenblae, Kincardineshire (Waterston, 1929), in Loch Davan and Loch of Skene (NBN Gateway). Older records reported by Macgillivray (1843, 1855) for several localities near Aberdeen, Buchan, Kincardineshire and Banffshire may refer to different species (Appendix-I). Distribution is Palaearctic, in Europe mainly in the lowlands between the Alps and the Baltic, rare in Scandinavia (Appendix-III reference map: 38).

4.4.4. Occasional historical findings

Occasional findings have been sparsely recorded in the area over the past centuries, mostly near Aberdeen harbour.

The majority of these findings refer to isolated specimens picked from detrital shelly lags deposited on the shoreline at high mark tide. The shells have been always found empty, suggesting that an unknown vector was responsible for their introduction probably after their death. Macgillivray (1843, 1845) hypothesised for the material collected from the Aberdeen beach a possible allochthonous origin from southern England, transported and released in the Aberdeen harbour together with ship ballasts.

On the other hand a cryptic presence could be invoked for *Valvata cristata* and *Bithynia tentaculata,* who have been time by time occasionally found in the Grampian Area or in adjacent zones.

Theodoxus fluviatilis

Theodoxus fluviatilis (Linnaeus, 1758) presence in Scotland has been only confirmed in the lochs of Harray and Stenness located in the Orkney Islands (Boycott, 1936; Nicol, 1938).

Macgillivray (1843, 1855) reported the occurrence of two specimens on the beach between the mouth of the Dee and the Don (Appendix-I). These records were subsequently reported in the mollusc catalogue compiled by Dawson in 1870 for the Aberdeen, Banff & Moray regions.

The Macgillivray records have unanimously been considered as an accidental introduction of empty shells through ship ballasts (Appendix-III reference map: 39).

Viviparus viviparus

Viviparus viviparus (Linnaeus, 1758) is virtually absent in Scotland, having not been found to the north of Yorkshire.

Macgillivray (1843) reported the occurrence of two dead shells, one from the beach near the mouth of Dee and another from Torrie [=Torry]. Taylor (1853) mentions its occurrence (not living animals) within the Aberdeenshire and Kincardineshire (Appendix-I).

Other dead shells were found by Macgillivray (1855) on the beach near the mouth of the Don. These records were subsequently reported in the mollusc catalogue compiled by Dawson in 1870 for the Aberdeen, Banff & Moray regions.

Even in this case malacologists think that these two records may be referred to casual transport of empty shells through ship ballasts (Appendix-III reference map: 40).

Bithynia tentaculata

Bithynia tentaculata (Linnaeus, 1758) is a common species largely distributed in England and Ireland, although sparse populations are known from the Scottish border. Richter (1954) described an isolated population in a pond at Brodie (Forres) in the Moray area, documenting the northernmost population of Great Britain.

Macgillivray (1843) found two specimens ascribed to this taxon on the beach near the mouth of the Dee. Taylor (1853) mentioned its occurrence (not living animals) within the Aberdeenshire and Kincardineshire vice counties. Dead shells were also found by Macgillivray in 1855 on the beach near the mouth of the Don (Appendix-I). In 1862 Jeffreys reported its occurrence in Frazerburg [=Fraserburgh] in Aberdeenshire, record confirmed and extended by Dawson in 1870 who mentioned in his catalogue its presence in Fraserburgh and Aberdeen. In 1874 Buchanan White mentioned its occurrence in canals and slow streams in Frazerburgh [=Fraserburgh], Aberdeenshire. In the Rimmer's standard work on freshwater molluscs (1880), Aberdeenshire continues to appear as the northernmost British area colonised by *Bithynia tentaculata*. In 1886 Coates reported its occurrence in the Aberdeenshire vice county according to the historical records (fide Jeffreys, 1862 and Buchanan White, 1873 [and 1874]). The last mention of *B. tentaculata* in the area is made by Roebuck (1891a) in his 'Census of Scottish land and fresh-water Mollusca', who reported Fraserburgh, Aberdeenshire as a valid record for this species (Appendix-III reference map: 41). It is not excluded a possible cryptic presence for this species in the area, where few individuals passive transported in suitable habitats may survive for years before disappearing due to adverse environmental conditions.

Valvata cristata

Valvata cristata O. F. Müller, 1774 was found (one single specimen) by Macgillivray (1855) on the beach at the mouth of the Dee. Strangely Dawson (1870) reported the beach between the Dee and Don as recording locality for this species, perhaps confusing it with the site where Macgillivray (1843) collected in different occasions two specimens of *Theodoxus fluviatilis*. *Valvata cristata* occurs to the south-west of the Grampian area (Clyde and Forth area) and also to the north-west (near Inverness). One old record from Forfarshire (VC 90) is also reported by Taylor & Roebuck (1889) and confirmed by Adams (1896) (Appendix-I, Appendix-III reference map: 42).

These old records suggest again an accidental introduction with the ship ballasts, but it's not possible to exclude its neglected presence in the north-east of Scotland, which leaves an open possibility to discover living populations.

4.5. ENVIRONMENTAL FACTORS AND THE DISTRIBUTION OF MOLLUSC SPECIES

Environmental factors are considered key parameters governing the occurrence of molluscan species in freshwater habitats. A variety of ecological parameters that influence mollusc distribution have been the subject of many studies in various parts of the world and several techniques mainly based on statistical analyses have been developed since 1960.

Multivariate analysis includes a number of analytical methods designed to identify relationships among matrices of data mainly dealing with species distribution and abundance versus virtually any type of parameter recorded on site. This discipline can rely today on a huge number of case histories performed in a variety of botanical and zoological fields. This data background represents an attractive feature for researchers, always looking for effective comparisons with other studies supporting their own work. The software package used for this analysis is PC-ORD version 6 by MJM Software Design.

A full description of the data conditioning and the general approach followed to run the multivariate analyses is given in section 2.2.

4.5.1. MULTIVARIATE ANALYSIS

The analytical strategy chosen to explore the relation between mollusc distribution data and associated environmental variables is broadly based on the methodology described by Field *et al.* in 1982. The same work flow was applied to all mollusc species matrix (Matrix-1) and to sphaeriids only species matrix (Matrix-2).

The first step consisted of calculating distance matrices using Sorensen (Bray-Curtis) equation on Matrix-1 and Matrix-2 (described in Chapter-2) followed by cluster analysis (Ward's method), a polythetic divisive methodology based on an iterative computation designed to group matrix variables. The resulting hierarchical classifications were stopped in Matrix-1 at the fifth dichotomous level on the stations axis (level 2 distinguished already at arbitrary similarity levels 17 and 33%), providing eleven groups ranging between a minimum number of 7 and a maximum of 42 sites per group (Fig. 26).

On the Matrix-1 species axis, clustering was stopped at the third dichotomous level (distinguished at an arbitrary similarity level of 26 and 32%), allowing the definition of six groups of data (Fig. 27). The second dichotomous division occurred at 11 and 19% similarity level.

The same cluster analysis was applied to Matrix-2 (stations axis). The dichotomous subdivision was arrested at the third dichotomous, defining six stations groups (Fig. 28). The second division was achieved at 25% and 40% similarity level.

On Matrix-2 species axis the clustering split was stopped at the third subdivision level, which accounts an arbitrary similarity of 41%, allowing subdivision into four clusters (Fig. 29). Nevertheless the second subdivision was reached at 22% arbitrary similarity level.

A similar technique was used by Malmqvist & Maki (1994) who ran TWINSPAN on a dataset combining riffle site streams and macroinvertebrates from a mountain area located in northern Sweden.

The first dichotomous division on Matrix-1 (stations axis) splits the sampling data set into two major groups of 54 and 161 stations. This is the most important partition as it breaks apart two major categories of aquatic environments: 1) the most of the running waters from the headwater catchments (including some lentic environments), together with the stream coastal sector, 2) all the rest of lowland waters, including major glacial lochs.

This is principally related to the general enrichment of dissolved ions together with an increase of nutrients in the water proceeding towards the lowlands, favouring the development of a rich and diversified molluscan fauna.

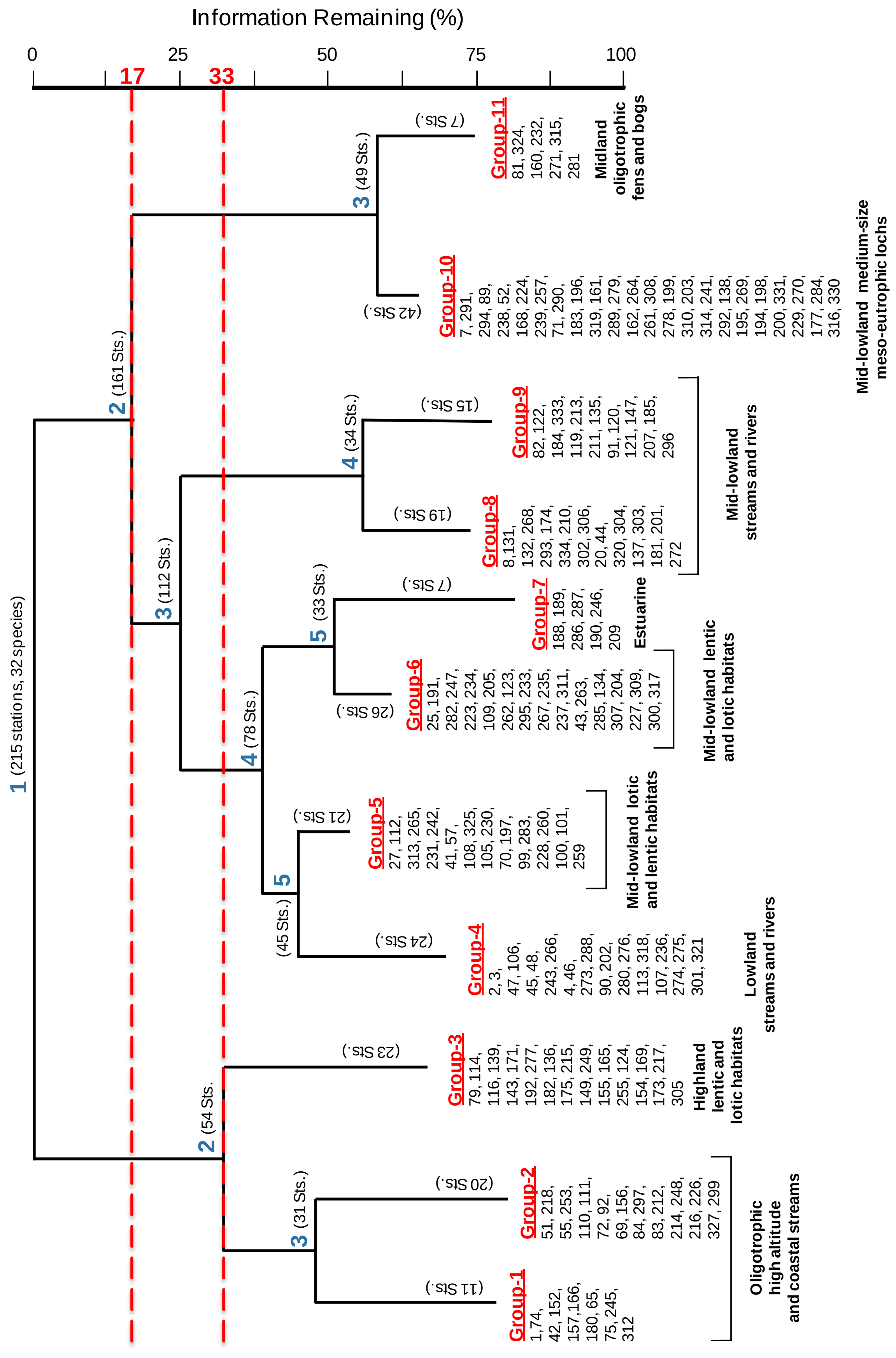

Fig. 26. Cluster analysis (Ward's method) dendrogram 215 stations versus 32 mollusc species (stations axis): fifth level dichotomous division with 11 groups details (groups 1-11). Blue numbers refer to the subdivision level.

The second dichotomous split extends further this subdivision, allowing the definition of four clusters. Group-3 (23 stations) dominantly owing highland lentic and lotic habitats is distinguished from Group-1/Group-2 (31 stations in total), which are essentially represented by oligotrophic streams located in the highland and lowland coastal sectors. On the right side of the dendrogram the previous 161 station group is split into two other groups of 112 (Group-4 to 9) and 49 stations (Group10/Group-11). The first cluster mainly groups together a variety of mid-lowland lentic and lotic habitats, whilst the latter mainly consists of mid-lowland medium-size lochs and oligotrophic fens and bogs.

The third dichotomous division differentiates quite nicely Group-1 from Group-2: the former including poor water quality habitats and the latter formed by ecotopes characterised by more favourable environmental conditions. On the main branch of the dendrogram (112 stations) this third division allows another major clustering between mainly mid-lowland lentic and lotic environments (Group-4 to 7, 78 stations) including estuarine, and rivers and streams (Group-8 and Group-9, 34 stations). The other 49 stations branch splits apart Group-10 and Group-11 respectively including mid-size meso-eutrophic lochs and oligotrophic fens and bogs.

Group-1 (11 stations) is mainly composed of lotic stations from the medium hill sector and streams flowing along the coastal area. These environments are generally quite poor and tend to be rather oligotrophic, sometimes affected by salinity influence due to the proximity of the sea. Habitats included in this group typically host *P. personatum* populations only.

Group-2 (20 stations) is mainly represented by stations distributed along the upper river tributaries of the hill range as well as coastal streams. The typical association is represented by *P. personatum* and *P. casertanum* (in the uplands), sometime combined with *R. balthica, G. truncatula*, *A. fluviatilis* (in the lowlands) and *P. obtusale,* the latter usually found in the poorest environments of the midland and highland sectors, under stagnant conditions and with low-oxygen level content.

Group-3 (23 stations) is mostly constituted by oligotrophic lentic and lotic environments such as bogs, medium-size lochs and streams located in the highland sector. It is constantly characterised by the association *P. personatum-P. casertanum*. This group includes most of the highest stations in the area, in this case only colonised by *P. casertanum*. The upper sectors of the river catchments are generally characterised by fast-flowing waters, typically oligotrophic.

Group-4 (24 stations) is largely composed of lowland river reaches and streams in meso-eutrophic conditions. This group also includes the linear springs located along the coastal stream sector typically inhabited by *G. truncatula,* a stenothermophilous taxon, which prefers clean and cold water. Other molluscs frequently found in linear springs environments are *R.*

balthica, P. antipodarum and depending on the water regime *A. fluviatilis. P. personatum* and *P. casertanum* also represent a typical component of this molluscan community, occasionally found together with riverine sphaeriid species such as *P. subtruncatum,* and *P. nitidum.*

Group-5 (21 stations) comprises lotic habitats mostly located in the coastal area and lentic environments (kettle-hole lochs and artificial lochs and lochans) located in the lowland sector. *R. balthica* and *P. antipodarum* are the most represented species together with *G. albus* (only in lentic environments) and different species of sphaeriids, most commonly *P. hibernicum*.

Group-6 (26 stations) includes a variety of lentic and lotic stations, mainly distributed in the mid-lowland sector. Similarly to Group-5 these habitats host populations of different species of molluscs.

Group-7 (7 stations) is entirely composed of estuarine environments colonised by molluscan assemblages mainly represented by halophile hydrobiids such as *P. ulvae, E. ventrosa*, *H. a. neglecta* and also the pulmonate gastropod *S. palustris.*

Group-8 (19 stations) includes the majority of the river reaches and also streams mainly located in the mid-lowland sector. The most frequent inhabitants of these ecotopes are the gastropods *R. balthica, A. fluviatilis* and *P. antipodarum* along with the sphaeriids *P. subtruncatum, P. nitidum* and *P. milium,* all typically occurring in flowing waters.

Group-9 (15 stations) is dominantly formed by rivers and streams located in the midland sector (151-400 m AMSL), where the scarce molluscan populations are essentially represented by *R. balthica, A. fluviatilis, P. casertanum* and *P. personatum* (more rarely associated with *P. subtruncatum, P. milium* and *P. hibernicum),* species commonly found in lotic environments.

Group-10 (42 stations) is the largest station cluster, chiefly represented by mid-size meso-eutrophic lochs located in the mid-lowland sector such as kettle-hole lochs and artificial lochs and lochans. This group includes the most abundant and diversified molluscan communities of the region. These lentic environments generally hold rich and well-diversified aquatic vegetation, providing shelter and nutrients necessary to establish a complete food chain. Nearly all mollusc species (a part from the halophile hydrobiids) occur in stations of Group-10, with a relative abundance of the limnophile species such as *R. balthica,* and all Planorbidae. Cold relict species like *P. lilljeborgii* find a suitable refuge habitat in some of the ancient sizeable water bodies belonging to this group (e.g. St. No. 196, Loch Davan and St No. 183, Loch of Skene). *P. hibernicum* is also frequently found in a variety of lentic and lotic environments located along the Deeside.

Group-11 (7 stations) includes some of the bogs and fens located in the midland sector. *R. balthica* is the most common gastropod, whilst among sphaeriids *P. milium* is the dominant species followed by *P. nitidum* and *P. personatum.* These environments tend to be relatively acidic; as a consequence the majority of gastropods find unsuitable conditions for their survival.

Similarly to Matrix-1 stations axis, cluster analysis (Ward's method) was run on the transposed distance matrix of species (triangular matrix). Classification was pushed down to the third level (26 and 32% arbitrary similarity level), allowing a repartition into 6 groups, the smallest composed of 3 and the biggest of 9 species (Fig. 27).

The first repartition symmetrically separates a cluster containing Group-A, Group-B and Group-C (16 species) from Group-D, Group-E and Group-F (16 species).

The second dichotomous division (11% arbitrary similarity level) splits apart Group-A/Group-B from Group-C (11% similarity level) and also Group-D from Group-E/Group-F (19% arbitrary similarity level).

The third dichotomous division breaks apart at 26% similarity level Group-E (lacustrine-II association) from Group-F (bin cluster), whilst at 32% it separates Group-A (riverine association) from Group-B (lacustrine-I association).

Group-A is essentially a riverine association characterised by species mostly met in the major river reaches but also in many lentic environments. This group is represented by *P. subtruncatum, P. hibernicum, P. nitidum, P. milium, S. corneum* and *G. albus,* frequently found sharing the same habitat.

Group-B is the lacustrine association-I, essentially represented by *P. obtusale* and *P. lilljeborgii* (sphaeriids exclusively found in lentic waters) together with *P. fontinalis, B. contortus* and *V. piscinalis,* most of the times inhabiting medium-size lochs but also slow-flowing river reaches in the lowland sector.

Group-C is the typical lowland costal association represented by *R. balthica, A. fluviatilis, P. antipodarum, P. personatum* and *P. casertanum,* constantly found within the stream systems opening directly into the North Sea, but also in a wide variety of environments in the lowland.

Group-D is the estuarine association composed of halophile hydrobiids such as *H. a. neglecta, P. ulvae, E. ventrosa* together with the pulmonate gastropod *S. palustris,* the latter also occasionally met in eutrophic water bodies densely vegetated. These species are generally found in the large estuaries of the major rivers such as Dee, and Ythan where they may constitute large populations (e.g. *P. ulvae),* profiting of the high productivity of these transitional environments.

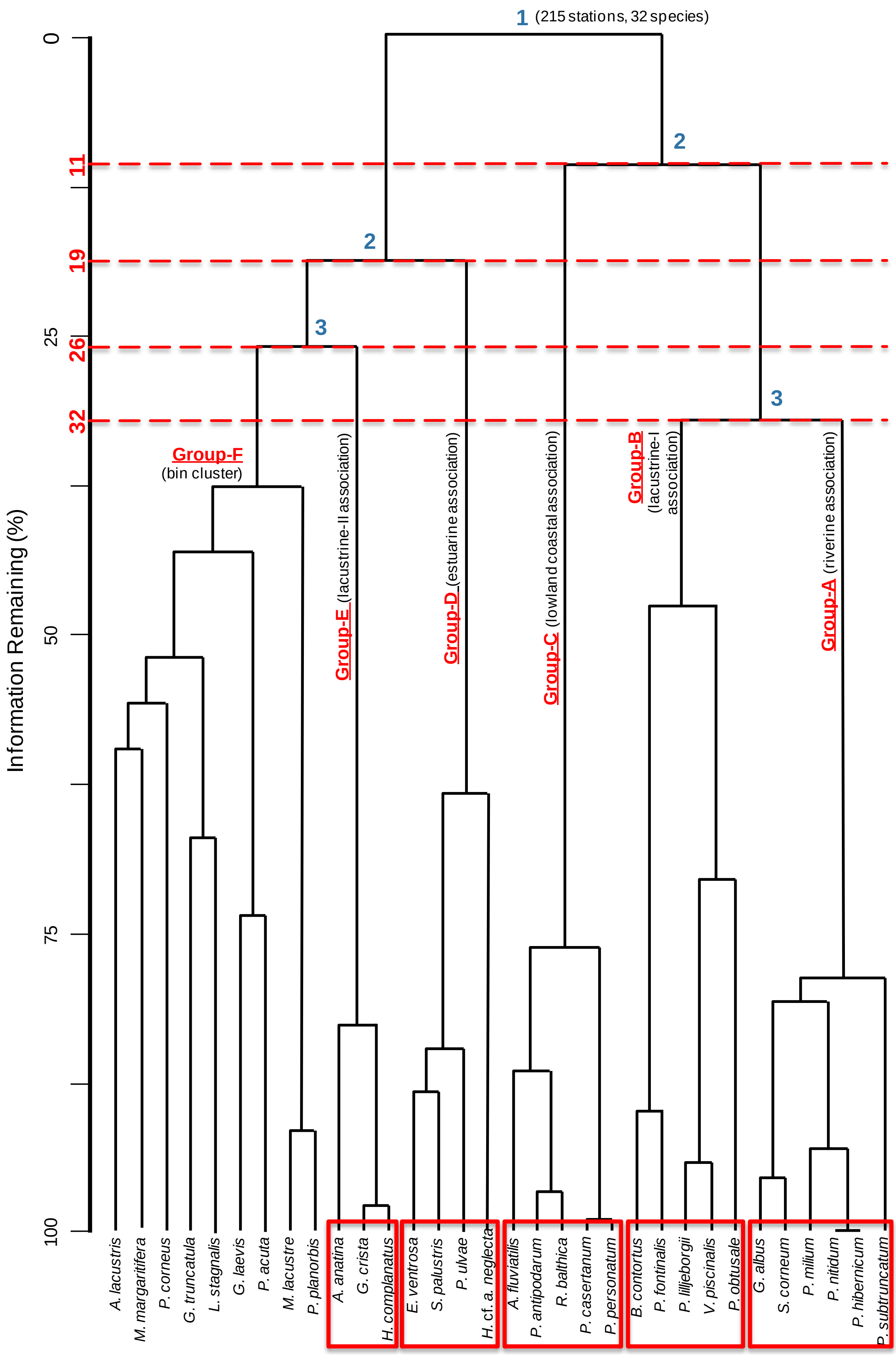

Fig. 27. Cluster Analysis (Ward's method) dendrogram 215 stations versus 32 mollusc species (species axis): third level dichotomous division with 6 groups details (groups A-F). Blue numbers refer to the subdivision level.

Group-E is another group including taxa with a pronounced affinity to lacustrine environments (lacustrine-II association): *H. complanatus, G. crista* and *A. anatina.* These species are commonly found in the medium-size lochs of the lowland area.

Group-F includes all the rest of the species falling on the same side of the plot but not strictly affiliated, highlighting the poor differentiation of these zoological entities by cluster analysis. This bin cluster effectively groups together taxa characterised by completely different ecological requirements, with no particular similarities. With respect to the groups already defined, the ecological affinities of Group-F are not strong enough to identify specific patterns at this dichotomous division.

The first dichotomous division on Matrix-2 (stations axis) splits apart two numerically similar groups (89 and 87 stations each), one mainly encompassing headwater running water systems, coastal streams and poor environments such as oligotrophic fens and bogs, and the other one grouping together a variety of mid-lowland habitats, including lochs, major rivers, mid-lowland streams, estuarine, etc.

The second dichotomous division splits at 25% similarity level the highland group (left side of the graph) into two other groups of 62 (Group-1bis-Group-2bis) and 27 stations (Group-3bis), better separating the well-defined high altitude and coastal streams habitat-types from stations which may have a less-distinct ecological characterization such as the stream stations sparse in the mid-highland sector. Concerning the lowland group (right side of the graph) this second branch of the second level division (40% similarity) allows a better partition among dominantly lentic or slowly flowing environments such as lochs, lower river reaches and estuaries (Group-4bis-Group-5bis, 66 stations) from a mixture of different habitats such as major rivers streams, lochans, etc. (Group-6bis, 21 stations).

The third dichotomous division generates 6 groups, as Group-3bis was already defined at the previous phyletic division.

Group-1bis (28 stations) mainly consists of lotic stations located in the coastal sector as well as streams flowing in the high hill range. From a faunistic point of view this group is characterised by the constant presence of *P. personatum*, indicating poor habitat conditions, relatively unfavourable for the settlement of other species.

Group-2bis (34 stations) is largely formed by lotic stations located in the middle-high hill range. These environments are typically colonised by the catholic association *P. casertanum-P. personatum*, the only molluscs capable to colonise prohibitive habitats such as those found along the up-hill tributaries of the main rivers.

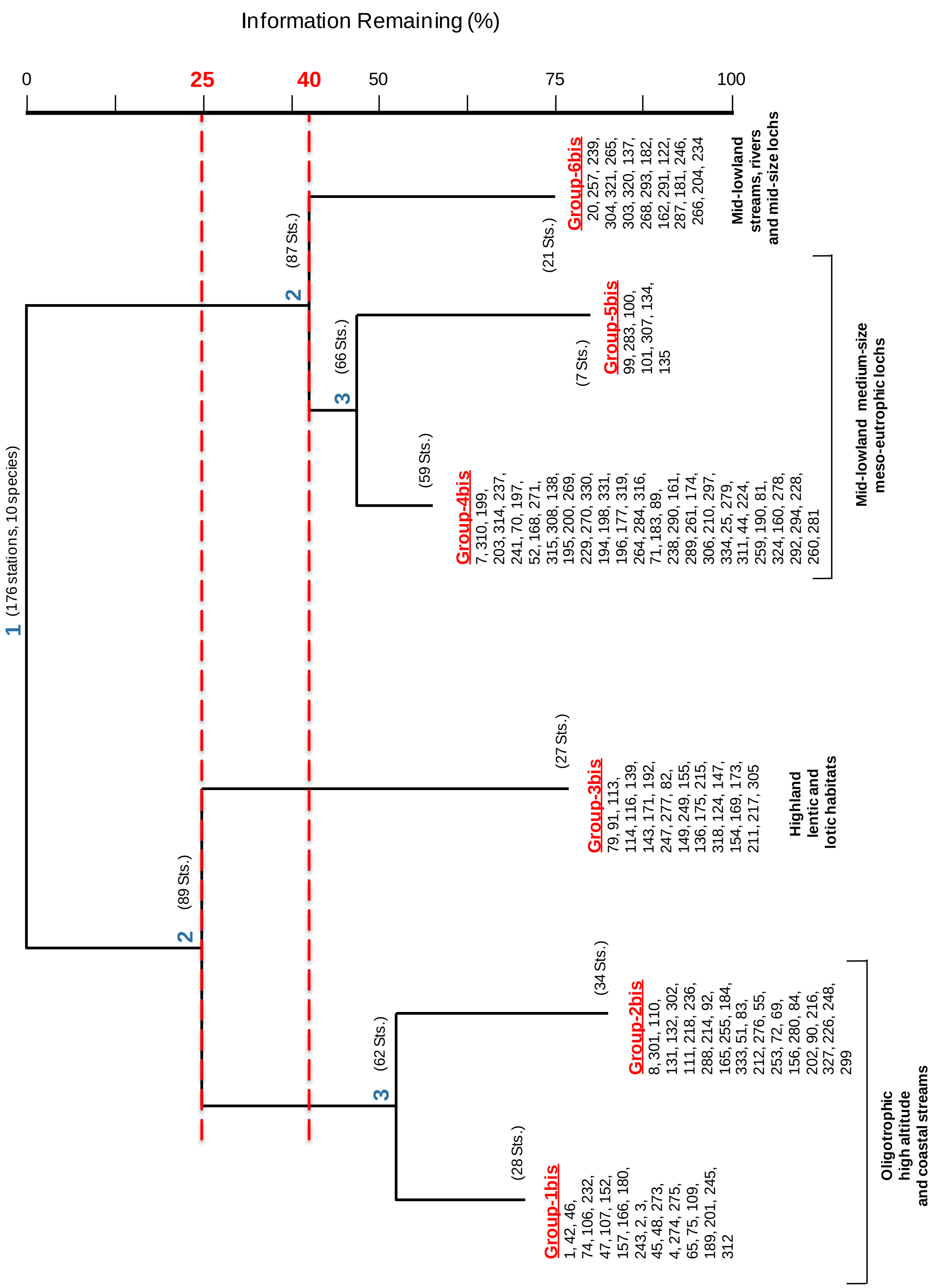

Fig. 28. Cluster Analysis (Ward's method) dendrogram 176 stations versus 10 Sphaeriidae species (stations axis): third level dichotomous division with six groups details (groups 1-6bis). Blue numbers refer to the subdivision level.

In the lowland sector *P. subtruncatum* is sometimes found together with *P. casertanum* and *P. personatum* such as in stations No. 8, 131 and 132. This group also includes the poor habitats characterised by the occurrence of *P. obtusale* generally found together with *P. personatum* and *P. casertanum,* such as Loch of Park (St. No. 226) and the Auchlossan lochan (St. No. 327).

Group-3bis (27 stations) is mainly represented by a number of lentic environments from the middle sector of the Dee but also by slow-flowing rivers and streams. *P. casertanum* is the most frequent Sphaeriidae representative.

Group-4bis (59 stations) is the less defined cluster of stations, consisting of lentic environments (frequently kettle-hole lochs but also bogs and fens) located in the lowland sector and in the mid Dee valley. Rich and diversified communities of sphaeriids inhabit these lochs, quite often characterised by the following association: *S. corneum, P. nitidum, P. subtruncatum*, *P. milium,* and *P. hibernicum.*

Group-5bis (7 stations) is typically represented by lentic environments located in the midland sector, quite often men-made. These habitats are characterised by the recurrent presence of *P. hibernicum* populations, frequently associated with *P. lilljeborgii.*

Finally Group-6bis (21 stations) is represented by a number of riverine environments and also by a variety of lowland standing water bodies (artificial and glacial lochs, bogs, etc.).

The cluster analysis (Ward's method) performed on the transposed distance Matrix-2 (species axis) defines steadily the recurrent *P. casertanum-P. personatum* association (Group-Abis), widespread within the lowland sector and occasionally met in the river upper catchments (Fig. 29). This ecological consortium ubiquitously occurs all along the coastal streams system, generally accompanied by catholic gastropods such as *R. balthica, A. fluviatilis* and *P. antipodarum.* In the upper hydrographic systems this is the only mollusc association regularly found.

The second dichotomous level (22% similarity level) clearly identifies two clusters respectively of 4 species (Group-Bbis) and 3 species (Group-Cbis) along with *M. lacustre,* all belonging to different aquatic habitats. *M. lacustre* segregates already at 22% arbitrary similarity level suggesting a tendency to colonise lowland habitats independently from the other sphaeriid associations. Group-Bbis *(P. subtruncatum, P. nitidum, P. milium* and *S. corneum)* is mainly found in riverine systems, whilst Group-Cbis *(P. lilljeborgii, P. hibernicum* and *P. obtusale)* is dominantly met in lentic habitats. More in detail *P. lilljeborgii* and *P. obtusale* live exclusively in standing waters, whilst *P. hibernicum* can be found in both lentic and lotic waters.

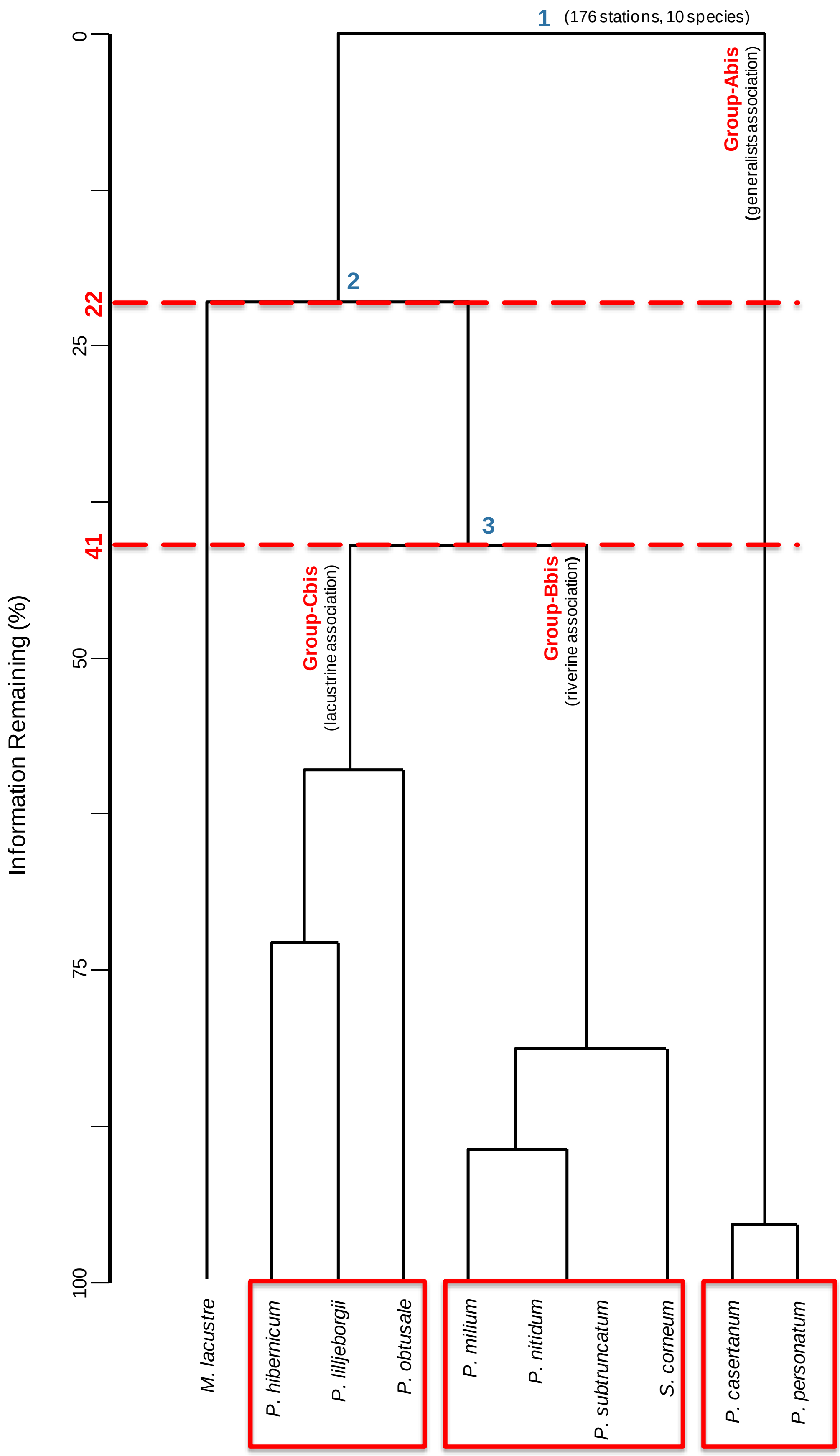

Fig. 29. Cluster Analysis (Ward's method) dendrogram 176 stations versus 10 Sphaeriidae species (species axis): third level dichotomous division with 3 groups details (groups Abis-Cbis). Blue numbers refer to the subdivision level.

A summary of the habitat preference for each sphaeriid species is given in the figure below:

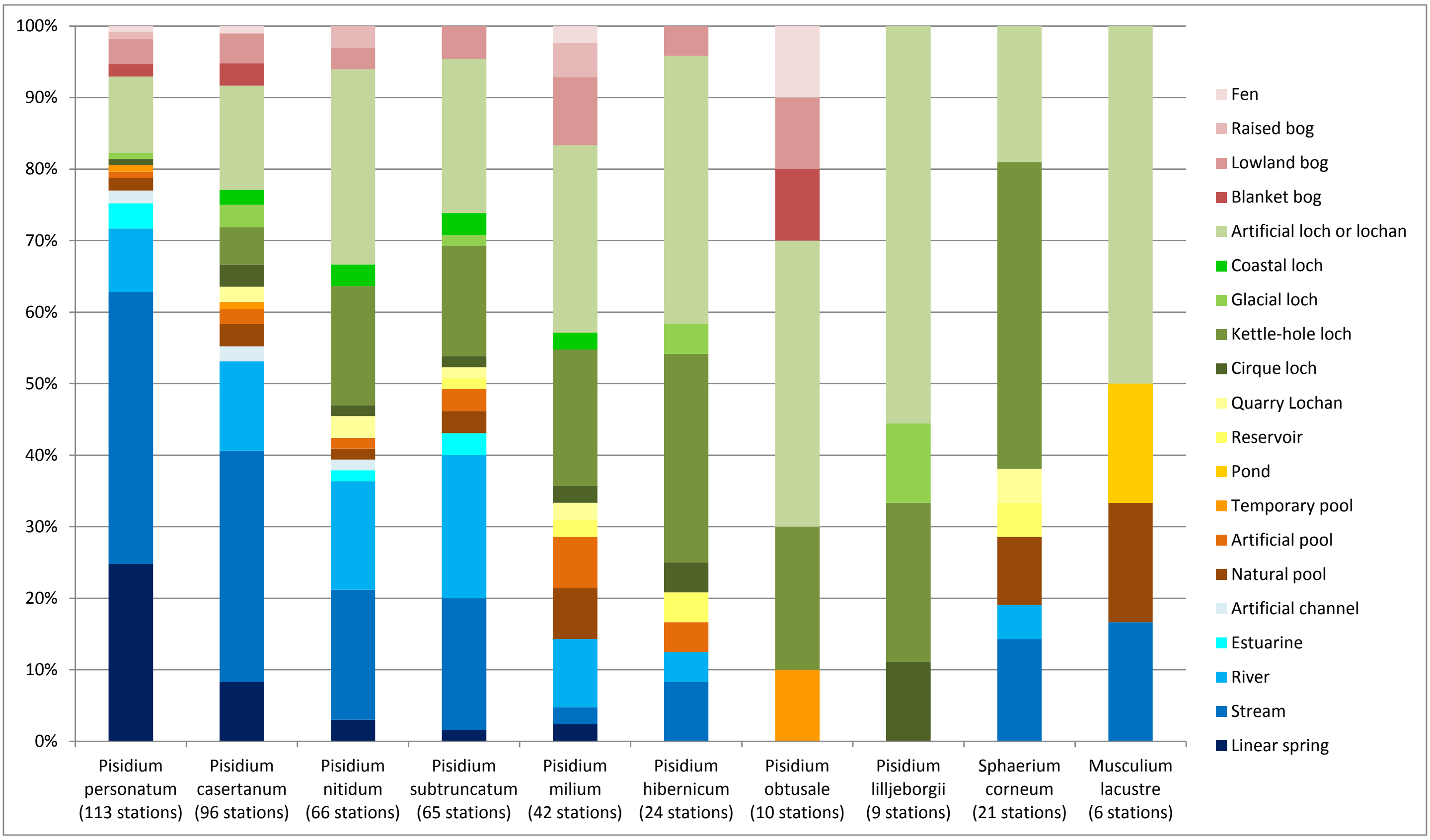

Fig. 30. Sphaeriid habitat preference by species.

It is worth to notice the strong preference for running waters (Fig. 30, blue colour scale) for Group-Abis, (*P. personatum* 77% and *P. casertanum* 55%) and to a lesser extent for the riverine species of Group-Bbis: *P. nitidum* (39%), *P. subtruncatum* (43%). *P. milium* and *S. corneum* clearly privilege medium-size lochs (Fig. 30, green colour scale), but can occasionally be found in running waters (streams, blue colour in Fig. 30), although they remain confined to the quietest sides of the stream reaches, away from currents. Kasprzak (1975) identified *P. nitidum* as the commonest *Pisidium* species inhabiting flowing waters in Poland, together with *P. subtruncatum, P. hibernicum, P. milium* and more rarely *P. casertanum* and *P. personatum*. Group-Cbis includes species occasionally found in riverine domains as in the case of *P. hibernicum,* which is more commonly met in a variety of medium-size standing water bodies (Fig. 30, brown, green and purple colour scales) and less often in running waters (13%). On the other hand neither *P. obtusale* nor *P. lilljeborgii* populations have been identified in running waters during this survey. According to Kuiper (1987), *P. obtusale* does not belong to the fauna of rivers and streams; it is reported living in a variety of confined standing water habitats, most commonly: ponds, drainages, forest ditches with rotting leaves, temporary pools, marshy prairies, peats, bogs, swamps, densely vegetated tarns, etc. *P. lilljeborgii* clear preference for clean standing waters and sandy substrata has been convincingly demonstrated by Combes *et al.*, (1971) during an ecological survey performed on a series of small lakes in the Pic Carlit area (French Pyrenees).

S. corneum and *M. lacustre* clearly privilege medium-size lochs (Fig. 30, green colour scale), but can occasionally be found in running waters (streams, blue colour in Fig. 30), although they tend to live in sheltered environments of the stream reaches, away from currents.

Bray-Curtis ordination was performed on Matrix-1 and Matrix-2, with the aim of verifying the validity of the species groups previously defined through cluster analysis. Group-C *(P. personatum, P. casertanum, R. balthica, A. fluviatilis* and *P. antipodarum),* the mollusc association of the lowland coastal sector, is nicely defined at the bottom of the cross-plot (Fig. 31).

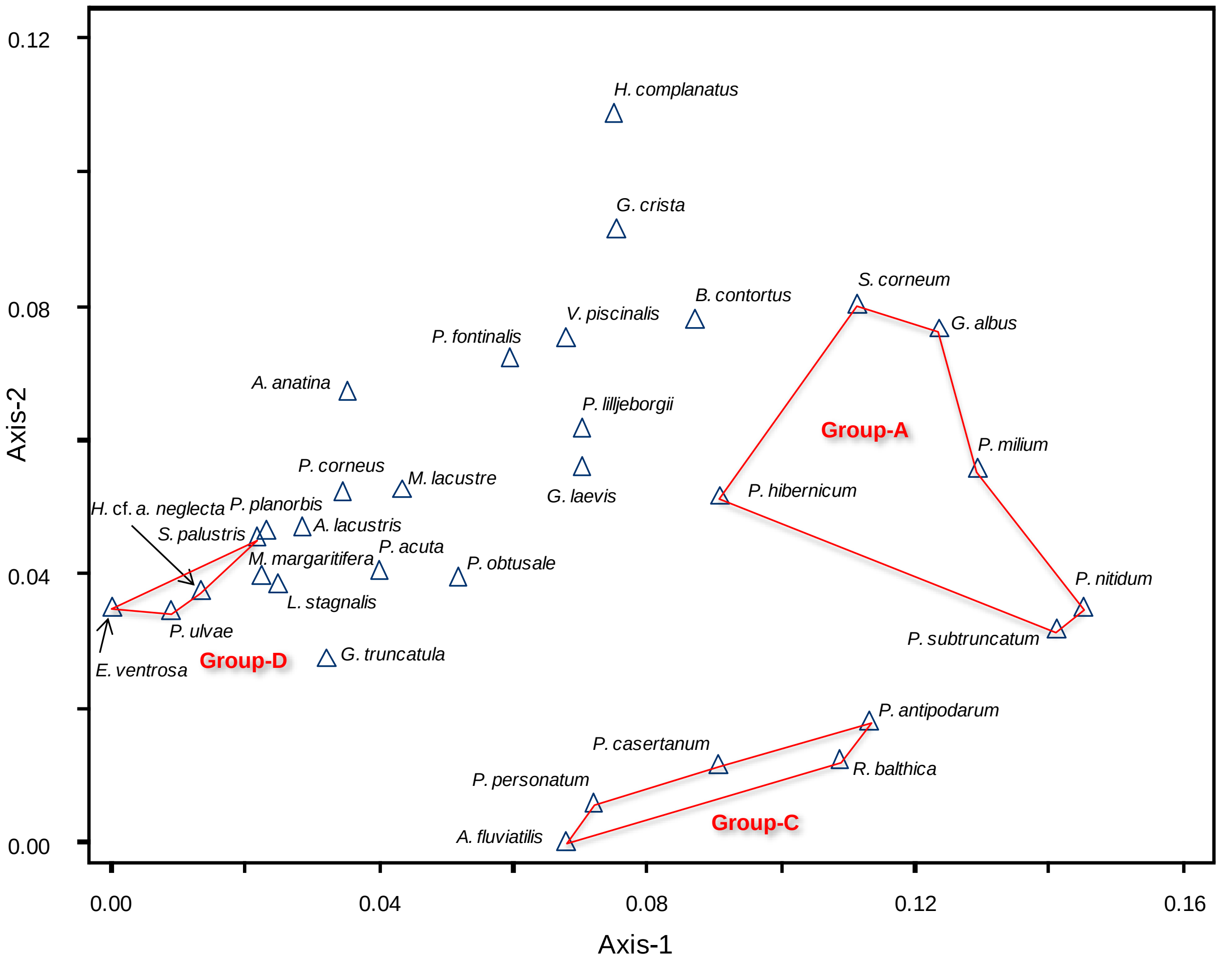

Fig. 31. Matrix-1 Bray-Curtis ordination on the same similarity matrix used for cluster analysis. Red polygons refer to groups previously defined (Fig. 27).

Group-D is composed of euryhaline hydrobiids together with *S. palustris;* it occupies the left side of the graph. Group-A includes the typical riverine sphaeriid association *(P. subtruncatum, P. nitidum, P. milium* and *P. hibernicum)* found in the lower reaches and in sizeable lochs together with *S. corneum* and *G. albus,* typical components of standing waters. This group is well defined to the right side of the cross-plot. Results convergence between classification (cluster analysis, Ward's method) and ordination (Bray-Curtis) indicates that the associations defined are real (Field *et al.*, 1982).

Bray-Curtis ordination analysis performed on distance Matrix-2 (Fig. 32) shows a similar group definition as previously observed in the cluster analysis dendrogram.

Group-Abis (generalist association) is clearly defined at the bottom of the graph, whilst Group-Bbis (riverine association) falls on the left side of the graph.

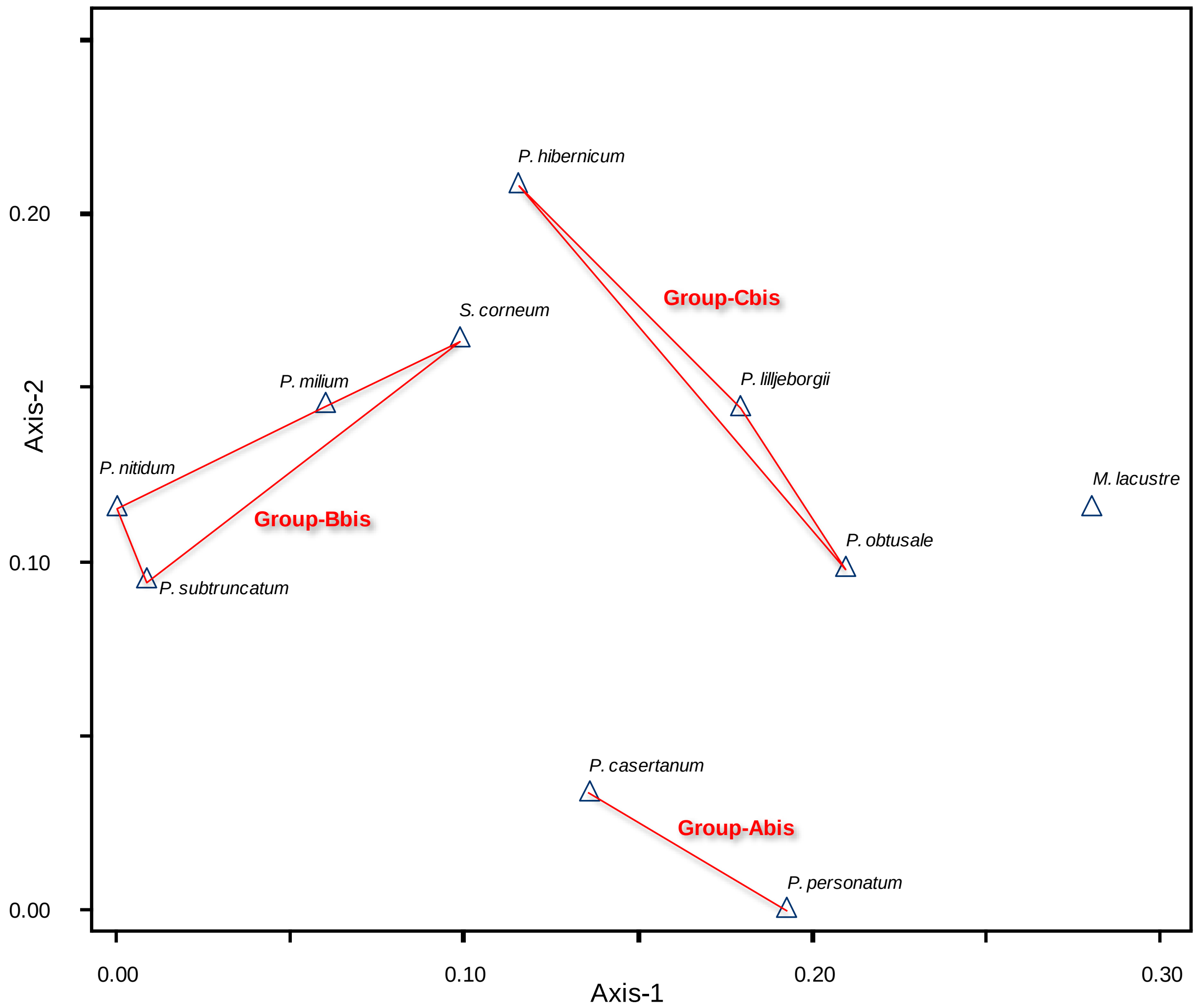

Fig. 32. Matrix-2 Bray-Curtis ordination on the same similarity matrix used for cluster analysis. Red polygons refer to groups previously defined (Fig. 29).

It is worth to notice the close relationship between *P. subtruncatum* and *P. nitidum* in both classification and ordination analyses. These two species are frequently found cohabiting together in a variety of lentic and lotic environments (43 common stations compared to 65 *P. subtruncatum* stations and 66 *P. nitidum* stations, Fig. 30). Finally *P. lilljeborgii* and *P. obtusale* falls in the central-right side. These two species of *Pisidium* share the same preference for standing waters frequently associated with P. hibernicum (Group-Cbis, lacustrine association).

4.5.2. MULTIPLE LINEAR REGRESSION

Multiple linear regression (MLR) was applied to Matrix-3 (mollusc species abundances, including null values, versus ecological parameters) and Matrix-4 (sphaeriid species abundances, including null values, versus ecological parameters), with the objective to test the null hypothesis H_0 (no dependency exists between mollusc diversity/abundance and ecological variables) and to reduce the number of independent variables, only including those which better explain the dependent variable (species abundance).

These are the initial assumptions used for the MLR:

- null hypothesis H_0 — $ß_1 = ß_2 = \ldots = ß_k = 0$
- alternative hypothesis H_a — at least one $ß_i \neq 0$
- MLR linear equation — $y = ß_0 + ß_1 * x_1 + ß_2 * x_2 + ß_k * x_k + \varepsilon$

Twelve environmental variables (T, pH, Eh, conductivity, salinity, O_2 concentration, O_2 saturation, substrate size, current speed, altitude, latitude, longitude) were tested through multiple linear regression with back elimination, using a 94% confidence level.

The goodness-of-fit of the model was assessed analysing the regression statistics, ANOVA and regression coefficients reported in Tabs. 5-6 with a level of confidence = 94% ($\alpha \leq 0.06$).

<u>Matrix-3</u>

Matrix-3 was first analysed through MLR. Multiple R = 0.52 suggests a fair fit to the linear model, whilst the adjusted R square indicates that the variation of y-values (dependent variable) around the mean are explained by the x-values (explanatory variables) in only 25% of the cases.

F value is 18.4 which is higher than the F critical value = 2.04. This result demonstrates that the regression has overall significance and we can reject the null hypothesis.

The small value of the Significance F (3.4E-18 $\leq$ 0.06) indicates that the regression output is not by chance.

Regression coefficients were analysed to verify the rejection of the null hypothesis.

Six variables were found significant ($\alpha \leq 0.06$) to explain species abundances (in order of significance): altitude, temperature, pH, O_2 saturation, current speed and conductivity.

Altitude appears to be the most important variable, with a negative relationship to temperature and pH. These three parameters are deeply interrelated and maintain similar relationships throughout the year: temperature and pH generally increase with decreasing altitude and molluscan abundance generally raises proceeding towards lowlands.

Regression statistics				
Multiple R	0.52			
Adjusted R Square	0.25			
Standard Error	8.31			
Observations	306			
ANOVA	**df**	**F**	**Significance F**	
Regression	6	18.40	3.40E-18	
Residual	299			
Regression	**Coefficients**	**Standard error**	**t-Statistic**	**P-value**
Intercept	4.187	3.255	1.286	0.19936423
Altitude	-0.013	0.002	-5.971	0.00000001
Temperature	0.478	0.102	4.690	0.00000416
pH	1.272	0.406	3.135	0.00188983
O_2 saturation	-0.040	0.013	-3.074	0.00230526
Current speed	-0.696	0.250	-2.786	0.00567644
Conductivity	-0.001	0.000	-1.899	0.05851491

Tab. 6. Matrix-3 MLR summary results.

Beside these physical factors, O_2 saturation and conductivity appear significant to explain mollusc abundance variations, mainly in relation to water productivity and to the trophic level. The current speed plays also an important role, favouring the development of rheophile species in fast river reaches or lentic species on soft substrata in habitats characterised by moderate or no currents.

All retained independent variables have t-stat values > 1.56 or < -1.56 (critical value of a two tailed t-distribution for $\alpha = 0.06$), indicating that the coefficient is significant with 94% confidence.

Furthermore P-values of the explanatory variables are all < 0.06, which confirm that the null hypothesis H_0 can be rejected for all retained independent variable.

Finally residuals where calculated to determine whether or not they fit the assumption of a normal distribution. The residuals scatter-plot does not show any particular trend; therefore the robustness of the regression output is confirmed. Moreover in Matrix-3, 84% of the residuals are small ($-10 < r < 10$) with only few points randomly distributed.

<u>Matrix-4</u>

Matrix-4 MLR provided slightly worse results of Matrix-3 for the regression statistics, with a multiple R = 0.42, still suggesting a questionable fit to the linear model (Tab. 7). The measure of the explanatory power provided by the adjusted R square is 16% only.

Regression statistics				
Multiple R	0.42			
Adjusted R Square	0.16			
Standard Error	5.20			
Observations	306			
ANOVA	**df**	**F**	**Significance F**	
Regression	7	9.12	3.24E-10	
Residual	298			
Regression	**Coefficients**	**Standard error**	**t-Statistic**	**P-value**
Intercept	2.141	2.049	1.045	0.2968
Temperature	0.211	0.064	3.297	0.0011
pH	0.772	0.254	3.037	0.0026
Current speed	-0.468	0.164	-2.849	0.0047
Conductivity	-0.001	0.000	-2.626	0.0091
Altitude	-0.004	0.001	-2.544	0.0115
O_2 saturation	-0.020	0.008	-2.488	0.0134
Substratum size	-0.244	0.124	-1.967	0.0501

Tab. 7. Matrix-4 MLR summary results.

However F value is 9.12, higher than the F critical value = 1.96. This result indicates that the regression has overall significance; consequently the null hypothesis can be rejected.

The small value of the Significance F (3.24E-10 ≤ 0.06) reinforces the validity of the regression results. Moving to the regression coefficients table, seven independent variables (temperature, pH, current speed, conductivity, altitude, O_2 saturation and substratum size) were retained after back elimination, meaning that these parameters were found significant ($\alpha \leq 0.06$) to explain species abundance.

Temperature and pH appear to be the most significant variables, with a positive relationship to sphaeriid abundance. On the other hand current speed and substratum size show a negative relationship to sphaeriid presence and abundance, clearly suggesting that those habitats characterised by fine-grained substrata and slow currents are commonly preferred by sphaeriids. Conductivity, altitude and O_2 saturation all show a slightly negative relationship to the dependent variable, possibly suggesting an erratic estimate of the coefficients due to multicollinearity (e.g. altitude vs. conductivity).

All explanatory variables have t-stat values > 1.56 or < -1.56 (critical value of a two tailed t-distribution for $\alpha = 0.06$), confirming that regression coefficients are significant with 94% confidence. Moreover P-values are all < 0.06, allowing rejecting the null hypothesis H_0 for all selected independent variables.

In the last step residuals where calculated to verify the validity of the linear model. No trends can be identified in the residuals scatter-plot, confirming the robustness of the regression result. Lastly 94% of the residuals are small ($-10 < r < 10$) with only few scatter points erratically distributed.

4.5.3. Ordination (Canonical Correspondence Analysis)

Once the ecological variables that best explain molluscan abundance have been defined, Canonical Correspondence Analysis (CCA) was run on both the species abundance matrix and the environmental variables matrix. CCA is a direct gradient investigation method based on the concomitant analysis of a pair of matrices, producing two types of site scores (Ter Braak, 1986).

According to Hill (1977), a ponderate selection of environmental variables should minimize the number of species with complex canonical distributions. CCA works essentially on unimodal models (i.e. Gaussian distribution) and it would not work if a large number of species follows different distributions (e.g. bimodal). As a consequence extra care is required for the independent variables choice.

Canonical correspondence analysis results are displayed in an ordination diagram with species represented by crosses, and ecological variables represented by arrows (e.g. Fig. 33).

The graph is subdivided clockwise into four quadrants (quads), progressively numbered from the top right.

<u>Matrix-1 and Matrix-5</u>

CCA was run on both mollusc species abundance matrix (Matrix-1) and the relevant environmental variables matrix created after MLR (Matrix-5).

Species points and ecological variable arrows jointly explain the species distributions along each of the environmental variables. For example *P. lilljeborgii* and *P. casertanum* roughly follow the altitude gradient, in fact they are mostly found in the Cairngorms range within the range 401-1300 m AMSL. This also applies for the *P. obtusale* and *P. hibernicum* association, frequently found in lentic environments in the highland sector. The conductivity vector possibly explains hydrobiids distribution *(P. ulvae, E. ventrosa* and *H.* cf. *acuta neglecta),* a typical molluscan assemblage only found in estuarine environments. The lowland coastal association represented by *P. casertanum, P. personatum, R. balthica, A. fluviatilis* and *P. antipodarum* clusters together in quad-4 and quad-3. This is a very common molluscan assemblage virtually present in every stream system flowing across the coastal area. Another characteristic association is represented by the sphaeriid riverine association *(P. subtruncatum* and *P. nitidum)* and to a lesser extent *P. milium,* grouped closely in quad-1, following the pH arrow.

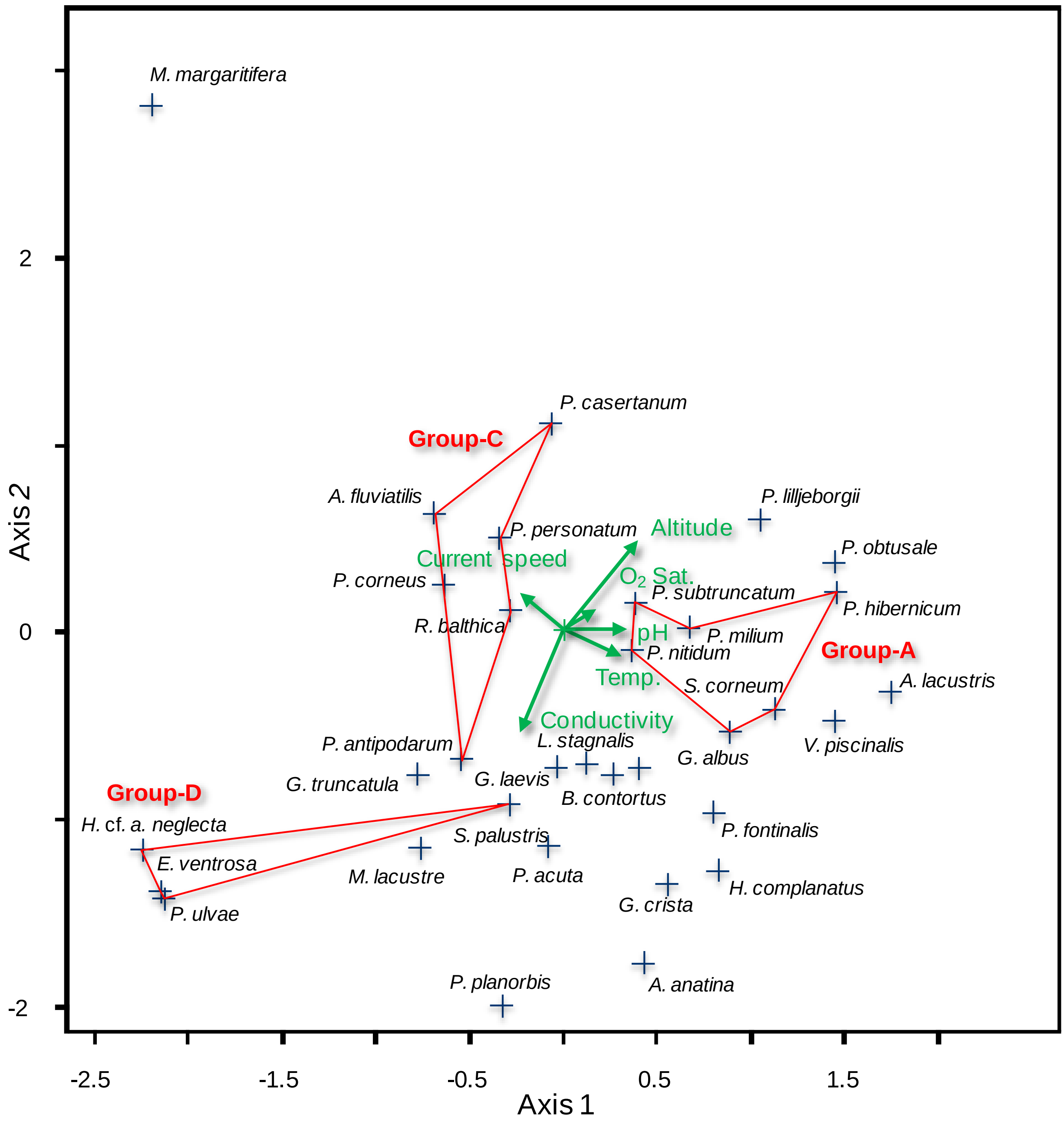

Fig. 33. Cross-plot of the Matrix-1/Matrix-5 Canonical Correspondence Analysis (species axis). Species are represented by crosses and ecological variables by arrows. Red polygons refer to groups previously defined through cluster analysis performed using Ward's method (Fig. 27).

This molluscan assemblage is frequently found along the lower river reaches, where water is generally eutrophic and pH is slightly alkaline due to aquatic plant photosynthesis.

The CCA crossplot relevant to the species axis is displayed in Fig. 34. The first three groups of stations previously defined after the first dichotomous division of the cluster analysis (Ward's method) are highlighted in the graph. The two high altitude and conductivity gradients approximately separate the graph into two regions: the upper part (quad-1 and 4) dominated by oligotrophic ecotypes located in the highland area, whilst the lower part (quad-2 and 3) includes most of the meso-eutrophic lowland habitats, characterised by higher conductivity, pH and water temperature.

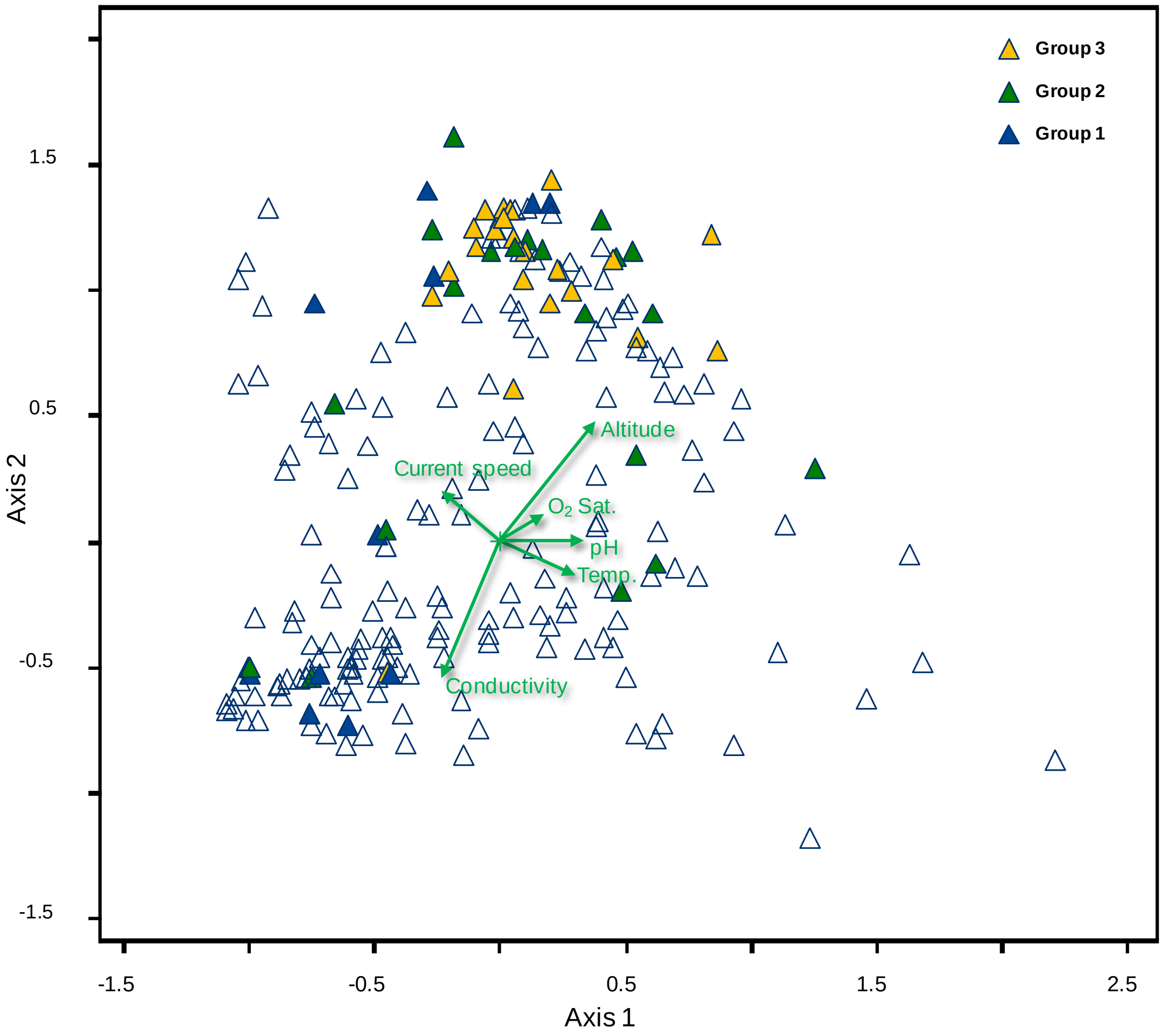

Fig. 34. Cross-plot of the Matrix-1 and Matrix-5 Canonical Correspondence Analysis (stations axis). Stations are represented by triangles and ecological variables by arrows. Groups-1 to 3 previously defined with cluster analysis (Fig. 26) are highlighted with colours.

Group-1 (blue colour) shows a symmetrical distribution in relation to the centroid position because it includes different stations located in high altitude and coastal sectors. Group-2 stations (green colour) are mainly distributed in the upper and central parts of the graph, mostly following the high altitude gradient.

Both Group-1 and Group-2 are clearly formed by stations belonging to different ecotypes. However current speed, substrate size and O_2 content are quite comparable, as the general stream configuration of the two ecosystems, represented by step and pool reaches, appears similar. The major difference among these two ecosystems is in the ion content of the water, which is directly related to the conductivity value: very low in the upper river catchments and high to very high in the coastal stream system. On the other hand the trophic level (most of the time oligotrophic) may be similar in several cases, as in both ecotypes there is a significant contribution from groundwater.

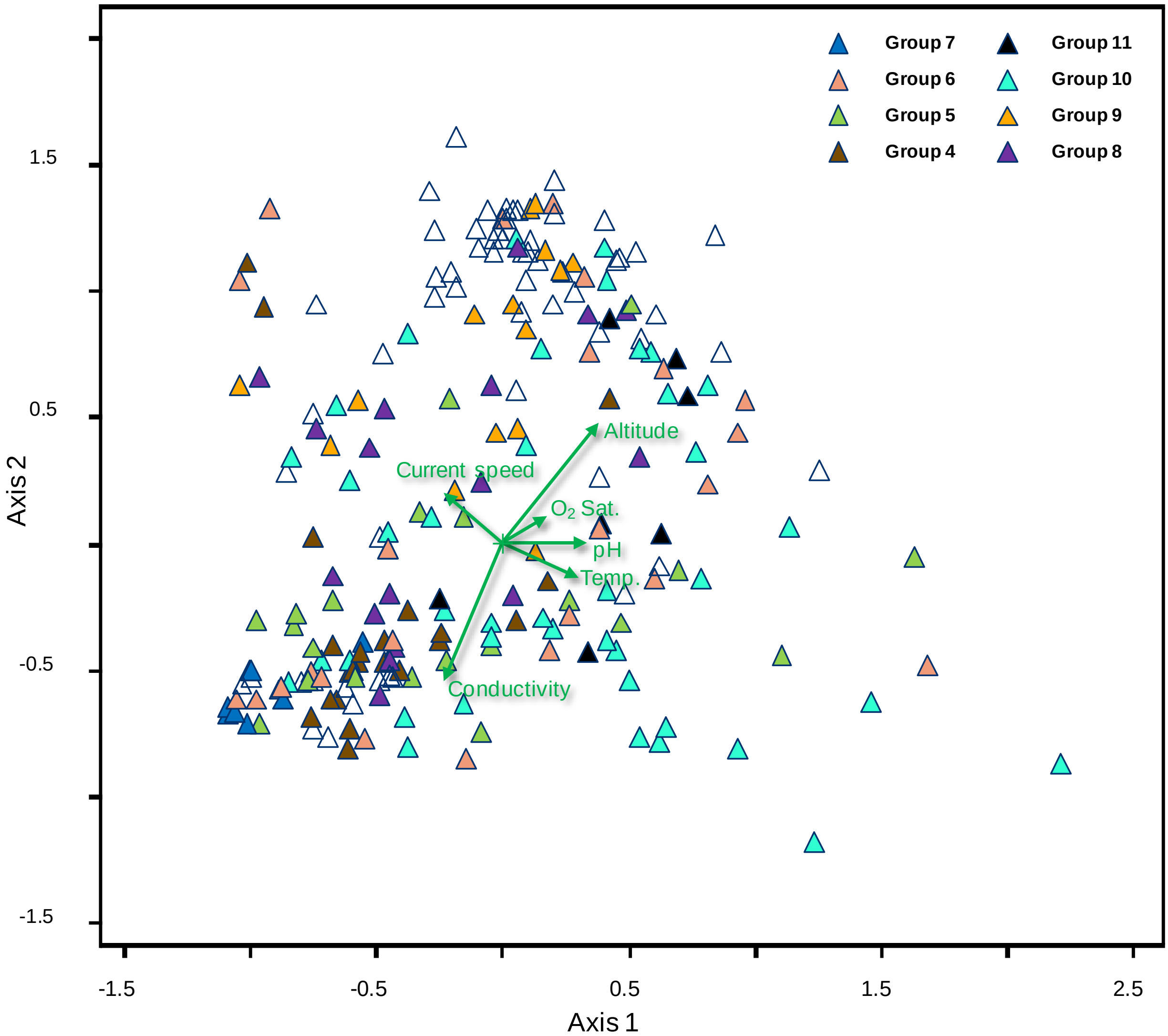

Fig. 35. Cross-plot of the Matrix-1 and Matrix-5 Canonical Correspondence Analysis (stations axis). Stations are represented by triangles and ecological variables by arrows. Groups-4 to 11 previously defined with cluster analysis (Fig. 26) are highlighted with colours.

The longitudinal profile of these stream systems is generally very steep, frequently represented by step and pool reaches with turbulent flow and coarse bottom sediments. For this reason Group-1 and Group-2 show some ecological similarities, despite being located in different geographical contexts, which allow the survival of highly tolerant species (e.g. *P. casertanum* and *P. personatum)* able to live in environments usually hostile to the majority of molluscs.

Group-3 dominantly falls in the uppermost part of the graph (quad-1 and quad-4), coherent with the poor type of oligotrophic lentic environments found at medium to high altitudes.

The other 8 groups of stations belonging to the second branch of the first dichotomous division are reported in Fig. 35.

Group-4, Group-5 and Group-6 include a variety of lotic (rivers, streams and linear springs) and lentic (lochs and lochans) stations mostly located in the lowland area (lowermost region of the graph).

Group-7 is nicely distributed along the lowermost left half of the graph (quad-3), as it would be expected by estuarine ecotopes located in the lowland sector and affected by strong marine influence (high conductivity-salinity).

Group-8 is largely composed of rivers and streams stations located in the lowland sector. Most of the stations fall in quad-3, following the conductivity gradient.

Group-9 includes rivers and streams stations situated in the highland area. As such they are all located in the upper part of the graph (quad-1 and quad-4), strongly influenced by the current speed and altitude gradients.

Group-10 encompasses the majority of the mid-lowland medium-size meso-eutrophic lochs. Because of the high heterogeneity of such environments, this group is not clearly defined in the CCA plot. It is worth to notice that differently from the other groups containing lentic lowland habitats, part of the Group-10 stations falls in quad-2, strongly influenced by pH, temperature and conductivity. Typically these are the lentic environments found in eutrophic conditions, which host the most abundant and diversified mollusc populations (e.g. St. No. 196 Loch Davan, St. No. 198 Bishop Loch, St. No 199 Corby Loch and St. No. 200 Lily Loch).

Finally Group-11 comprises a number of oligotrophic fens and bogs environments located in the midland sector. Most of the stations fall in quad-1 and quad-2, depending first on the altitude and secondly on the trophic level.

In order to explore the relationship between mollusc species abundances and ecological variables, a summary of the CCA numerical results is reported in Table-8. Eigenvalues of Axis-1 and Axis-2 of the CCA were 0.201 and 0.180 respectively, only explaining 5.8% of the overall variance (Tab. 8). This is related to the generally common coexistence of all mollusc taxa in the majority of habitats, and clearly to the absence of true specialists (except for the halophile group), which become dominant in specific environments such as the estuarine.

	Axis-1	Axis-2	Axis-3	
Eigenvalues	0.201	0.180	0.080	
Variance explained %	3.100	2.800	1.200	
Cumulative variance explained %	3.100	5.800	7.100	
Species-environment Pearson correlation	0.647	0.655	0.470	
Species-environment Kendall (Rank) correlation	0.404	0.496	0.362	
Total inertia in the species data				6.552

Tab. 8. Results of Canonical Correspondence Analysis of Matrix-1 and Matrix-5 (all mollusc species).

Although the poor overall variance explained by the first 2 axis suggests that the predictive variables have a limited interaction with mollusc abundance, canonical coefficients and correlation coefficient can be tentatively used to interpret the ordination axes (Tab. 9).

	Standardized canonical coefficients			Correlation coefficients		
Predictive variables	Axis-1	Axis-2	Axis-3	Axis-1	Axis-2	Axis-3
Altitude	0.572	0.376	0.177	0.575	0.737	-0.279
Temperature	0.126	-0.337	0.097	0.456	-0.214	0.674
Conductivity	0.328	-0.196	0.309	-0.353	-0.847	0.066
pH	0.441	-0.081	-0.017	0.500	-0.006	0.687
Oxygen Saturation	0.100	0.154	0.334	0.258	0.164	0.783
Current speed	-0.434	0.371	0.325	-0.353	0.299	0.756

Tab. 9. Summary of the canonical and correlation coefficients of Matrix-1 and Matrix-5. Correlation coefficients correspond to 'intraset correlations' of Ter Braak (1986).

By looking at the signs and relative magnitudes of these two types of coefficients, it could be possible to infer the relative importance of each environmental variable for predicting the community composition and the species prevalence. The predictive variables with the highest correlation coefficients in Axis-1 are altitude and pH (respectively 0.575 and 0.500 in Table-9). This result is in general agreement with the MLR results, which ranked altitude as the most significant independent variable, followed by temperature and then by pH. Axis-1 roughly identifies the trophic level, with the current speed pointing towards the negative side of the axis and pH, temperature and O_2 saturation increasing towards the opposite direction. Altitude maintains the highest score in Axis-2 (0.737) even if conductivity has the highest negative value (-0.847), confirming the negative relationship which links the two predictors. Axis-2 broadly defines the hydrographic longitudinal gradient identified by the altitude and conductivity vectors.

Matrix-2 and Matrix-6

A second CCA was run on both the sphaeriid-only species abundance matrix (Matrix-2) and the environmental variables matrix (Matrix-6). The relevant ordination crossplot is shown in Figure-36.

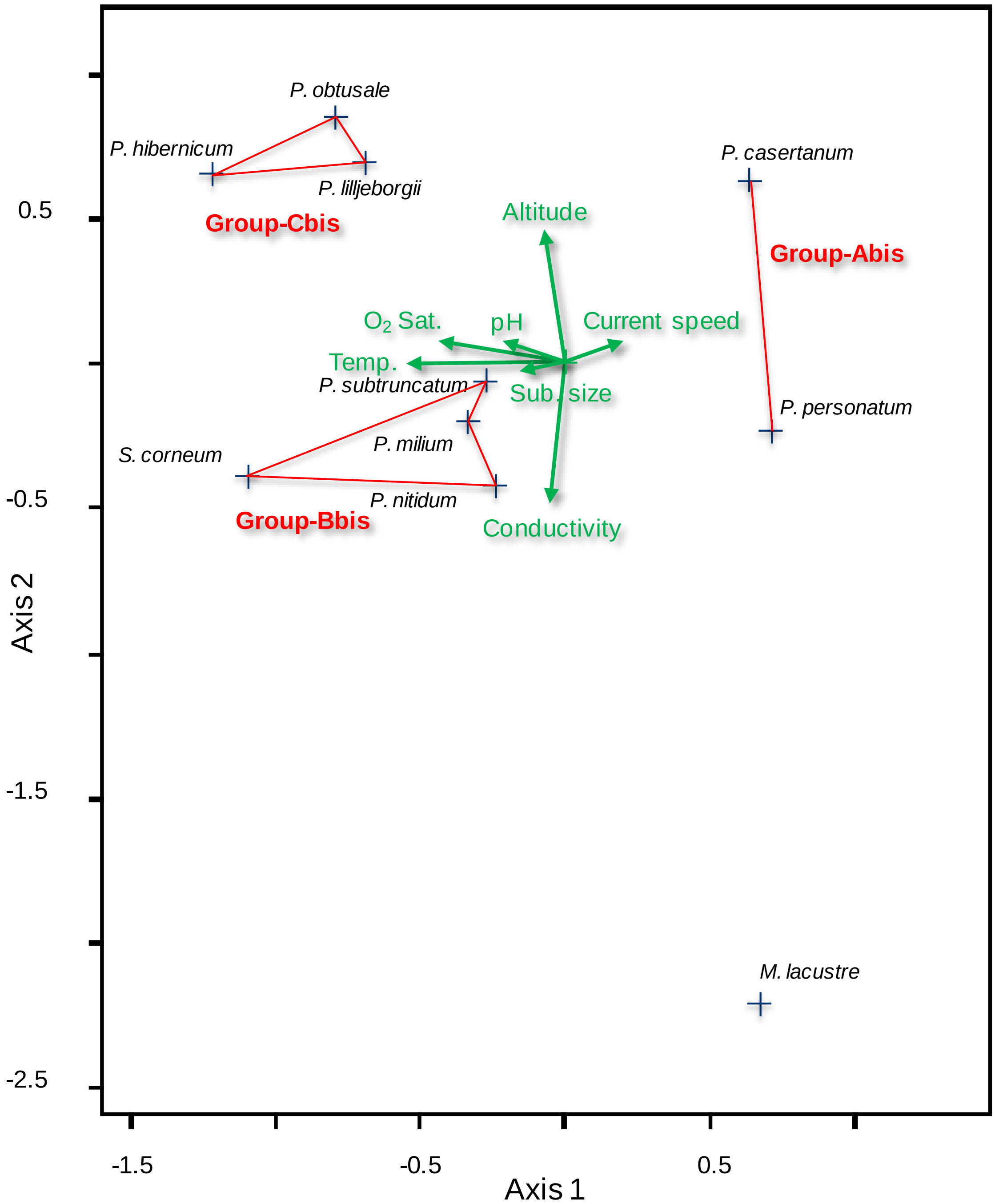

Fig. 36. Summary of the Matrix-2/Matrix-6 Canonical Correspondence Analysis (species axis). Species are represented by crosses and ecological variables by arrows. Red polygons refer to groups defined through cluster analysis (Fig. 29).

The altitude influence is shown in quad-1 and quad-4 (along Axis-2), where the typical sphaeriid associations leaving in the mountainous sector appear.

P. casertanum lies in quad-1, because this species is generally found in lotic habitats of the Cairngorms range, where current speed plays an important role for contrasting mollusc active dispersal along the longitudinal gradient.

On the left side (quad-4) another association of high altitude sphaeriids is found: *P. lilljeborgii* and *P. hibernicum*. These two species are occasionally found in the Cairngorms area, where they generally live in sizeable lochs. Also *P. obtusale,* which has been exclusively found in standing waters, may sporadically colonise poor habitats located along the mountain crest system (e.g. St. No. 248, St. No. 330 and St. No. 216). *P. subtruncatum, P. nitidum* and *P. milium* clusters together in the barycentre of the cross-plot, where all the ecological variables are simultaneously present with moderate effects, as expected in lower river reaches, mostly located in the lowland sector. *M. lacustre* lies at the very bottom of quad-2, indicating a strong preference for high conductivity waters, typically found in eutrophic bodies within the lowland area. Also *P. personatum* is located in quad-2 but it is less affected by conductivity increasing. This species is in fact a broad generalist and it is commonly found in poor environments, where ecological niches are available due to molluscan rarefaction. Finally *S. corneum* falls in quad-3, in a region of the cross-plot mostly explained by substrate size and temperature.

The summary of the CCA numerical results is reported in Table-10.

Eigenvalues of the CCA Axis-1 and Axis-2 were 0.176 and 0.075 respectively, explaining 8.6% only of the overall variance. As already observed in Matrix-1/Matrix-5 this result indicates that the independent variables marginally explain sphaeriid abundance.

	Axis-1	Axis-2	Axis-3	
Eigenvalues	0.176	0.075	0.029	
Variance explained %	6.000	2.600	1.000	
Cumulative variance explained %	6.000	8.600	9.600	
Species-environment Pearson correlation	0.559	0.445	0.307	
Species-environment Kendall (Rank) correlatic	0.327	0.353	0.191	
Total inertia in the species data				2.926

Tab. 10. Results of Canonical Correspondence Analysis (CCA) on Matrix-2 and Matrix-6 (sphaeriid only species).

Axis-2 generally expresses the altitude gradient, with mountain sphaeriid assemblages located in the upper quadrants (quad-1 and quad-4) and lowland taxa in the lower quadrants (quad-2), following the conductivity vector.

Axis-1 mostly explains the stream current variation, with *P. casertanum-P. personatum* association frequently found in lotic habitats (quad-1 and quad-2) and on the opposite side taxa inhabiting eutrophic environments characterised by slow current and high pH levels (e.g. *S. corneum).*

	Standardized canonical coefficients			Correlation coefficients		
Predictive variables	Axis-1	Axis-2	Axis-3	Axis-1	Axis-2	Axis-3
Altitude	-0.494	0.335	0.508	-0.104	0.876	-0.294
Temperature	-0.415	-0.038	-0.003	-0.849	-0.017	0.265
Conductivity	-0.475	-0.185	0.571	-0.086	-0.927	0.251
pH	-0.159	0.084	-0.033	-0.681	0.145	0.316
Oxygen Saturation	-0.125	0.122	0.209	-0.324	0.144	0.542
Substrate size	0.061	-0.179	-0.083	-0.232	-0.058	0.273
Current speed	0.221	0.133	0.402	0.312	0.135	0.839

Tab. 11. Summary of the canonical and correlation coefficients of Matrix-2 and Matrix-6. Correlation coefficients correspond to 'intraset correlations' of Ter Braak (1986).

The highest correlation coefficients in Axis-1 are those of temperature (-0.849) and pH (-0.681 in Table-11). These two vectors define together a trophic level gradient progressively increasing towards quad-3 and quad-4, opposite to the current speed vector. The significance of temperature and pH was already highlighted by MLR analysis.

Axis-2 could possibly define a physical gradient where the conductivity arrow points towards the bottom side of the graph (-0.927, quad-2 and quad-3) and the altitude to the opposite side (0.876, quad-1 and quad-4).

The *P. casertanum-P. personatum* generalists association (Group-Abis) appears related to current speed. This association is in fact found along the stream headwater complexes as well as in the coastal stream sector, where the water speed is usually high.

The riverine association (Group-Bbis, *P. subtruncatum, P. nitidum, P. milium,* and *S. corneum)* is located in quad-3 of the graph, principally influenced by conductivity, temperature and pH. The riverine association typically inhabits slow-flowing river reaches, where the organic load is high and silty-sandy substrata can be found away from the main current axis.

The lacustrine association (Group-Cbis, *P. lilljeborgii, P. obtusale* and *P. hibernicum)* is located on the top left of the graph, following the altitude gradient. This association is in fact most frequently found across lentic habitats of the mid-highland sector, quite often under meso-eutrophic conditions. This is consistent with the pH and O_2 saturation gradients increasing towards Group-Cbis.

M. lacustre lies at the bottom of quad-2, confirming the results of the cluster analysis (Ward's method), which separated this taxon at 22% arbitrary similarity level. *M. lacustre* appears to follow the conductivity gradient; all populations have been found in the lowland sector, in lentic environments usually located in densely cultivated areas. Water conditions area generally eutrophic.

4.5.4. CONCLUDING REMARKS

Lentic and lotic environments have been dealt together using a work flow combining multiple linear regression and multivariate analysis, with the benefit of having a unique data set. This approach avoided an arbitrary distinction among these two ecosystems, considering the high number of habitats showing intermediate characters between standing and flowing waters. In this sub-section the evidences described in the 4.1-4.5 sections is reviewed and integrated in an *excursus* describing the key features of each major ecosystem.

The running waters of the Grampian Area show recurrent regularities in the distribution of the benthic assemblages, nicely expressed by the concept of the 'river continuum' (Vannote *et al.*, 1980). The river systems examined in this study showed consistent similarities in the distribution of the molluscan assemblages all along the river longitudinal profiles. Estuarine habitats only occur where the topography and the marine influence are capable of generating tidal flats invaded by low-salinity waters. These are the cases of the major estuaries such as the ones formed by the rivers Ythan or Dee, where euryhaline species (e.g. *Peringia ulvae* and *Ecrobia ventrosa)* are well-adapted to the habitat variable conditions.

Moving upstream the rivers generally show large channels quite often meandering in confined alluvial plains. These lower reaches (potamon) are constantly characterised by a huge rate of flow and deep pools located on the external sides of the meanders (Group-4 in the stations versus all mollusc species Matrix-1 cluster analysis, stations axis, Fig. 26). The ion content is relatively high (conductivity typically beyond 200 µS/cm, Figs. 10, 11), together with a high trophic level (generally eutrophic) and pH values higher than 8 (Figs. 13-14). The oxygen content is generally high because of the rich macrophytic community (Fig. 15). These habitats are densely populated by rheophile sphaeriids such as *Pisidium subtruncatum, P. nitidum* (Group-Bbis, in the Matrix-2 cluster analysis ward's method species axis, Fig. 29) and *P. milium,* frequently accompanied with the ubiquitous *P. casertanum* and *P. personatum.* Among the gastropods the most frequent species is *Bathyomphalus contortus,* frequently found in calm pools together with *Radix balthica* and *Potamopyrgus antipodarum. Ancylus fluviatilis* is found everywhere, with a strong preference for fast-flowing reaches.

Once above the lower river plains the water current becomes stronger, and as a consequence the average size of the bottom sediments dramatically increases. This is the rhithron domain, where pools become rarer and the river bottoms are generally represented by gravelly-pebbly sizes classes, sometimes extensively covered with boulders. The ion content is generally poor (conductivity lower than 200 µS/cm), pH tends to be neutral (i.e. 7) and the oligo-mesotrophic level depends on the nutrient load supplied by tributaries. This river sector generally represents a hostile habitat for molluscs, with the exception of *Margaritifera margaritifera,* which prefers well-oxygenated, fast-flowing waters with a low content of dissolved ions. Among the other molluscs only *A. fluviatilis* and *P. casertanum* are able to penetrate upstream through this type of environment. *A. fluviatilis* also requires a minimum level of dissolved carbonates to survive, which tends to drastically drop upstream. The uppermost station of *A. fluviatilis* (and also *P. antipodarum*) along the River Dee is located below the bridge of Aboyne (St. No. 318). Beyond this point only scattered specimens of *P. casertanum* can be found, migrating longitudinally according to the flood regime (e.g. St. No. 154, medium-upper sector of Glen Dye), highlighting the dynamic nature of the benthic assemblage. A similar rarefaction in the distribution is observed in the lateral tributaries, where the current is generally faster as the topographic gradient is higher.

On the other hand once above the medium-high sector of the hydrographic system, roughly coinciding with the steep U-shaped glacial erosion, the upper tributaries flow in the highland plateau range, characterised by gentle gradient and slow flow. These two sectors are generally separated by waterfalls or step and pool reaches, which provide a formidable barrier to the upstream migration of any benthic invertebrate. The high plateaux are often flooded during the wet season and blanket bogs frequently occur, extensively fed by meteoric and groundwater. According to the Illies & Botosaneanu (1963) river zonation, these upper catchments correspond to the crenon zone. These are extreme environments as waters are virtually devoid of nutrients, and ice may cover the quietest pools for a few months, causing extensive winter killing of invertebrates (Group-3 in the Matrix-1 cluster analysis Ward’s method, stations axis, Fig. 26). Conductivity is regularly found below 100 µS/cm (Figs. 10-11), with high-oxygen content (quite often in excess of 10 mg/l, favoured by the low temperatures, Fig. 16) and pH generally neutral or slightly acidic (Figs. 12-13). Only the sphaeriid assemblage *P. casertanum* and *P. personatum* (Group-Abis in the Matrix-2 cluster analysis Ward’s method, species axis, Fig. 29) can survive in these habitats, frequently found in the upper tributaries pools.

Moving to the highest water pools, only *P. casertanum* can be found, attaining the maximum altitude record among the British freshwater molluscs. *P. personatum* seems to be more sensitive to cold temperatures and becomes progressively rarer upstream.

Close to the sea is the coastal stream system, characterised by short and fast lotic environments, frequently characterised by step and pool reaches (Group-1 and Group-2 in the Matrix-1 cluster analysis Ward’s method stations axis, Fig. 26).

Conductivity is generally high (higher than 300 μS/cm, Figs. 10-11), because of the interaction with sea spray and general ion content enrichment of surface waters; the oxygen content tends to be high as well (frequently in excess of 12 mg/l, Figs. 16-17) in relation to the turbulent flow due to the steep longitudinal gradient. On the other hand the trophic level tends to be moderate (oligo-mesotrophic, pH in the range 7-8, Figs. 12-13), as the coastal stream is mostly fed by subterranean waters. Moreover the nutrient content (nitrates and phosphates) is generally poor although could locally reach high trophic level in ditches draining cultivated fields located on top of the coastal cliff edges.

This is a peculiar environment because despite the turbulent flow and the frequently exposed bedrock along the channels, the molluscan populations are generally abundant and regularly represented by the same faunistic assemblage (Group-C in the Matrix-1 cluster analysis species axis, Fig. 27).

The *P. casertanum-P. personatum* association is regularly met together with the constant presence of *R. balthica* and *A. fluviatilis* among the pulmonates and the invasive *P. antipodarum* prosobranch. The highly successful colonisation showed by lowland species of molluscs is essentially related to the relatively high content of dissolved ions in the water, as the streams are directly fed by groundwater from the lowland aquifer.

The standing waters in the Grampian Area are a very common hydrological feature represented by a highly diversified mosaic of different habitats. Some general trends have been recognised using ecological parameters and species distribution. Peatlands are generally poor environments, especially those located in the hill range (e.g. blanket bogs, groups 2 and 3 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26), characterised by low-ion content (conductivity usually lower than 100 μS/cm, Figs. 10-11), acidic pH (frequently within the range 4-6, Figs. 12-13) and moderately oxygenated waters (Figs. 16-17). Only adaptable species (i.e. generalists) can be occasionally found in this type of environment (e.g. *P. casertanum* and *P. personatum)* together with species adapted to live in poor habitats (e.g. *P. obtusale).*

On the other hand lowland bogs (mostly in groups 3 and 10 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26) hold a richer and diversified fauna. The trophic level is generally oligo-mesotrophic, although in some cases it may become eutrophic (e.g. St. No. 215, bog near Dinnet) with pH values well beyond 8. The dissolved-oxygen content can also reach high concentration in presence of dense vegetation cover (e.g. St. No. 299, bog near Tarfside: 19.31 mg/l). *R. balthica* frequently occurs together with rich communities of sphaeriids such as

P. casertanum, P. personatum, P. subtruncatum and *P. nitidum* (groups A and C in the Matrix-1 cluster analysis Ward's method species axis, Fig. 27).

Lowland lochs of glacial or anthropogenic origin (mostly groups 5, 6 and 10 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26) are all quite affected by eutrophication, being constantly fed by agricultural runoff. The pH usually falls within the 7-9 range, depending on the overall content of organic matter particulate and on the invertebrate densities of the ecotope (Figs. 12-13). The ion content is highly variable (conductivity range 100-200 μS/cm in average, Figs. 10-11)) depending on the nature of the water feeding the basin and on the nature of the rocks outcropping in the area. Such environments are densely invaded by aquatic plants and by a large variety of macrophytes, offering adequate shelter and source of nutrients to the molluscan communities. The oxygen content is generally very high during the day, because of photosynthesis (in some cases higher than 12 mg/l, Figs. 16-17), quickly falling during the night due to animal respiration. These lochs generally hold the highest number of molluscs, both quantitatively and qualitatively, in terms of species diversity (Loch Davan, St. No. 196; 13 species).

Highland standing waters such as cirque lochs stand on the opposite side of the plot to lowland lochs, being characterised by the absence of fauna or by the monopolistic presence of *P. casertanum* (e.g. groups 3, 9 and 10 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26). These waters are generally extremely oligotrophic and acidic (pH range 3-6 in average, Figs. 12-13), being generally fed by meteoric water and melted snow. The oxygen content is generally high because of the low temperatures (8-12 mg/l, Figs. 16-17), particularly in proximity to the inlets and outlets, where the environment tends to be more lotic. The ion content is extremely poor (less than 50 μS/cm, Figs. 10-11), because of the nature of the rocks generally outcropping in the Cairngorms (mainly granites and mica-schists) and of the high rate of meteoric precipitation, which does not allow concentrations of elements in water bodies. Loch Vrotachan (St. No. 177, Group-10 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26) represents an exception among this category, being the habitat with the highest mollusc diversity found within the hill range (8 species). This is related to the peculiar location of this loch, which sits on a variety of carbonate-rich sedimentary rocks belonging to the Ballachulish Subgroup, enriching the water ion content, an essential condition for the development of non-generalist (intolerant) molluscs.

4.6. VERTICAL RANGE MOLLUSC DISTRIBUTION

The vertical distribution of molluscs is a complex phenomenon which is the result of interaction among several ecological parameters with the adaptability of species to hostile environments. The vertical range of the Grampian Area is between 0 and 1,309 m AMSL, reached at the top of Ben Macdui, the second highest mountain of the British Isles after Ben Nevis.

Four main vertical zones can be identified in the area: the lowland sector (0-150 m AMSL), the midland sector (151-400 m AMSL), the hill range (401-800 m AMSL) and the mountain range (801- m AMSL).

It is clear that a general trend of rarefaction affects all the freshwater molluscs correlated with altitude. This is mainly related to two main parameters: temperature and ion content. This is because the temperature of the water bodies decreases with the altitude, causing icing conditions or temperature close to 0°C for relatively long periods during winters. These are hostile conditions for the majority of aquatic fauna, particularly molluscs, where only a few extremely tolerant species can survive. The low ion content typical of the water of the hill and mountain ranges represents another severe obstacle to molluscan life, organisms which require a minimum level of calcium to build up their shells. The calcium level in water increases in the presence of calcareous soils, which are quite rare in the highland zone, therefore representing refuge areas for aquatic faunas when present. This is the case for Loch Vrotachan (St. No. 177) and Loch Kander (St. No. 306) respectively located along the south-western slope of Carn Aosda and at the base of the north-eastern cliffs of Carn an Tuirc. The hill and mountain ranges are less-studied ecosystems, for this reason all research focusing on this type of environment has an opportunity to reveal new information. During this study for example, despite the high number of scattered observations followed by detailed researches carried out by Stelfox (1946, 1952) and Dance (1972) in different mountain ranges of the British Isles, four new maximum altitude records have been documented among different species of the genus *Pisidium*.

Sub-section 4.6.1 provides an historical perspective of the existing literature on the matter to understand the evolution of the knowledge since mid 19th century.

Sub-section 4.6.2 describes the vertical distribution patterns specific to the Grampian Area, as ascertained by this study. A number of references to the literature completes this picture, trying to examine all the possible variables which may interfere with the adaptive capabilities of molluscs studied in this survey.

4.6.1. HISTORICAL PERSPECTIVE

Very little is known about the vertical distribution of freshwater molluscs within the Scottish Highlands. This is mostly due to the scarcity of records available for the area and to the restricted number of studies that directly focused on this matter.

One of the earliest observations dealing with rambles in search of plants and a wide range of organisms in a mountain range is reported by Macgillivray in 1855. He spent a few days during August 1850 in Castletown [=Castleton, Braemar] organizing daily excursions to the highest summits of the Cairngorms. On one of these trips he expressly mentioned the lack of Mollusca in Loch Aun [=Loch Avon] and Loch Etagan [=Loch Etchachan], after having surveyed their shores. A consistent number of malacological surveys conducted at the end of the 19th and beginning of the 20th century in the Perthshire mountainous sector represents the first attempts to reconstruct habitat requirements in relation to spatial distribution of terrestrial and freshwater molluscs.

The exceptional record of *Pisidium personatum* in a lochan on Cru-y-Ben in the Tarmachan range near Killin found by Evans (1918), still represents today the highest population of this species found in the British Isles (3,000 ft = 914 m AMSL).

During the 40's Stelfox specifically addressed his attention to this matter, publishing a series of articles dealing with molluscs living in Irish (1945, 1946) and Scottish (1952) mountain environments. One of these studies (Stelfox, 1946) deals with sphaeriids found at altitudes between 1,600 (488 m AMSL) and 1,900 ft (579 m AMSL) in the Galtee Mountains (Co. Tipperary South), providing useful information relevant to the environment and the shell characters of four *Pisidium* species *(P. casertanum, P. nitidum, P. subtruncatum* and *P. hibernicum)*. Field work was carried out on Ben Lawers, a very productive area located in Perthshire characterised by a rich and diversified community of molluscs. The Stelfox contribution (1952) represents a fundamental study of the area, which led to the completion of more accurate field surveys such as those performed by Dance (1972) and Marriott & Marriott (1992).

In 1956 Hunter & Hunter described a population of *Ancylus fluviatilis* living at about 440 m AMSL in Loch Coire Uaigneich (Isle of Skye). This population is mostly represented by small individuals and the breeding season was found to be delayed about nine weeks. In 1971 Dance for the first time tried to compile a list of altitude records for the whole group of non-marine British molluscs. This list, despite its provisional character, represents an important milestone outlining the vertical range of terrestrial and freshwater taxa occurring in the British Isles. A year later (1972) another work by the same author appeared, dealing with the vertical distribution of molluscs on Ben Lawers in Perthshire. The author found a high-spired population of *Radix balthica* in Lochan nan Cat at 701 m AMSL, together with *Pisidium lilljeborgii*, *P. casertanum* and *P. nitidum*. A higher population of *P. lilljeborgii* was later found by Bishop in Loch Vrotachan, upper Glen Clunie (Kerney, 1974; see Tab. 12). Similarly *P. nitidum* has been found at 716 m AMSL in Llyn y Cwn in Snowdonia (Dance, 1972) and *Pisidium casertanum* in a pool at 1,006 m AMSL on the Ben Lawers in a habitat which freezes completely during winter. This represents the highest British record for this species, being the second one located in Ffynnon Felen, a mountain lake located at 732 m AMSL in the hollow of Cwm Glas in Snowdonia (cited as *P. cinereum* in Boycott, 1936). *Lymnaea peregra [=Radix balthica]* was also found in Lochan an Tairbh-uisge (Tarmachan group, west of Ben Lawers) at 760 m AMSL by Smith in 1963 (Dance, 1972).

In 1977 Bishop performed a study of the molluscs inhabiting the Central Highlands of Scotland using field data combined with existing information from the Conchological Society's mapping scheme. The data were collected following the 10 x 10 km squares grid and organized in frequency classes based on the number of species occurrences. A major group of molluscs characterised by the widest possible ecological tolerance was identified: *L. peregra [=R. balthica], L. truncatula [=Galba truncatula], Pisidium casertanum, P. personatum* and *P. obtusale*. On the other hand *Pisidium lilljeborgii* was recognized as a species particularly adapted to the highland environment and relatively uncommon in calcareous lowland. The conclusions of the author were that the waters of the region are all more or less deficient in calcium and that the freshwater mollusc distribution is largely controlled by substratum and water flow.

The last survey on Ben Lawers, carried out by Marriott & Marriott (1992), mostly addressed the terrestrial molluscs, although mention is made of *L. truncatula [=Galba truncatula]*. This latter species was found on An Stùc at 900 m AMSL representing the highest record for the British Isles.

4.6.2. VERTICAL PATTERNS IN THE GRAMPIAN AREA

In the Grampian Area a general rarefaction of freshwater mollusc distribution with increasing elevation is observed. Despite the modest altitude reached by the highest peaks in the Cairngorms range, which rarely exceed 1,300 m AMSL (e.g. Ben Macdui, 1,309 m), alpine conditions are extensive over 900 m AMSL.

All the water bodies found along the hill crests are frequently covered by ice from December to February, including the surface of the deeper corrie lochs. The majority of the blanket bogs located in natural depressions are normally quite shallow (< 0.5 m) and tend to completely freeze during the cold season, leaving no free water available to the benthic fauna.

Winter killing is an extremely selective process, which dramatically reduces the number of environments available to the establishment of new colonies of freshwater molluscs. On the other hand sphaeriids seem to be quite tolerant to low temperatures as ascertained by Olsson (1981), who recorded a total of 57% of *Pisidium* spp. specimens survived after a prolonged 5 months exposure under laboratory conditions at -4°C. The same author also reported the occurrence of live *Pisidium* spp. specimens after the melting of a completely frozen river bottom covered by ice in the north Swedish river Vindelälven. In addition the Cairngorms and the Lochnagar areas are mainly characterised by granite and metamorphic schists, rocks extremely resistant to weathering, which only release a limited amount of ions to running waters.

The majority of the cirque lochs located in the upper sectors of the major rivers is in oligotrophic conditions, allowing only the colonisation of pioneer species. On the other hand the few lochs found at high altitude (i.e. over 650 m AMSL) but located in sedimentary rock basins, hold a surprisingly diversified community of organisms, primarily sphaeriids. In these lochs mesotrophic conditions are frequently met (Loch Vrotachan). Only in a few cirque lochs located on granite, the occurrence of freshwater molluscs has been documented, and always with a limited number of individuals. In the tarn located at the base of the north-east cliffs of Carn an t-Sagairt Beag, on the northern side of the Lochnagar massif (St. No. 173, 846 m AMSL), only one specimen of *Pisidium casertanum* was found near the outlet, with the valves deeply corroded by the acidic environment (pH 5.92). The loch occupies a glacial cirque and is surrounded by rocky outcrops of grey and pink medium to coarse-grained leucogranite. Loch Phàdruig (St. No. 169, 685 m AMSL) is located in a similar glacial cirque, on the western slope of Meall an t-Slugain, where the same Lochnagar granite outcrops. Another deeply corroded specimen of *P. casertanum* was found near its outlet (pH 6.04), confirming the occasional and rare occurrence of this catholic species.

The lochans located on rich soils, such as sandstone or limestones (e.g. those belonging to the Dalradian Supergroup), are characterised by slightly alkaline waters with a higher content of ions than the lochans on granites and schists. These conditions are sufficient for the successful establishment of cold stenothermophilous species such as *P. lilljeborgii, P. hibernicum* and even *P. milium,* frequently found associated in the still water bodies occurring within the hill range. Loch Vrotachan is located on the south-western slope of Carn Aosda (St. No. 177, 750 m AMSL). It represents a remarkable example of an environment situated on sedimentary rocks, where seven species of *Pisidium* together with *Radix balthica* occupy the same ecological niche. Five of these *Pisidium* populations *(P. lilljeborgii, P. hibernicum, P. milium, P. nitidum* and *P. subtruncatum)* represent the highest found in the British Isles (Tab. 12). The pH is heavily alkaline (8.35) with a moderately low conductivity (64 μS/cm), which in any case is more than double (e.g. 25 μS/cm in St. No. 169) or the triple (e.g. 16 μS/cm in St. No 173) of the granite loch waters. Loch Vrotachan is placed in a large glacial cirque excavated in phyllite and limestone of the Ballachulish Subgroup (Dalradian Subgroup).

Another example is Loch Kander, situated at the base of the north-eastern cliffs of Carn an Tuirc (St. No. 306, 677 m AMSL). This is a further cirque loch excavated in the Glas Maol Schist (graphitic mica-schist with interbedded quartzite and limestone levels) and characterised by slightly acidic (pH 6.79) waters of low conductivity (27 μS/cm). In this loch three species of *Pisidium (P. casertanum, P. subtruncatum* and *P. milium)* occur together with *Ancylus fluviatilis* and *Radix balthica,* an unusual association for a high altitude environment.

A variety of small standing waters do occur in the higher altitudinal range starting from 650 m AMSL, generally falling in two major categories: blanket bogs and ice-melt pools. The first category is represented by shallow pools resting in natural depressions, quite often found on the cols separating broad summits. These environments are normally covered by ice during the winter months, although free water may be found if an outlet drains the water. This is the case for the occasional mollusc records found in this type of environments. In the blanket bog situated on the col between Creag an Loch and Carn an t-Sagairt Mòr (St. No. 171, 727 m AMSL) a few individuals of *P. casertanum* were found in proximity to the little outlet draining the water. The area is mostly characterised by Lochnagar granite outcrops. Quite often blanket bogs do not hold molluscs such as in the case of station No. 117, situated on the southern ridge of Loch Muick at an altitude of 728 m AMSL. In this environment the water is very acidic (pH 4.17) because of the nature of the substratum (coarse-grained biotite granite of the Lochnagar complex) and the dense heather moor covering the area. Conductivity is moderately low (45 µS/cm) indicating meteoric water input as recorded in several other cases located at comparable altitude.

Sometimes unusual habitats can be established as a consequence of natural perturbations of normal conditions, as in the case of the pool located along the Allt an t-Slugain upper sector (St. No. 84, 585 m AMSL). In this place a shallow pool formed by the running water dammed by an old landslide occurs, hosting a rich community of sphaeriids *(P. casertanum* and *P. personatum)* which is not found along the adjacent stream reaches. Quartzite largely outcrops in the area although the most common lithotype on the valley slopes is represented by flaggy quartzo-feldspathic psammite. The pH is slightly alkaline (7.39) and the conductivity is low (23 µS/cm). In this pool a permanent flow is caused by the slow infiltration of the water through the landslide body, which leaves the downstream stream channel permanently dry.

Ice-melt pools are a widespread common feature above 800 m AMSL, frequently found adjacent to the residual snow fields in late spring-early summer. These are the favourite environments chosen for spawning by *Rana temporaria.* These pools start forming after the ice melt and rapidly develop to an interconnected system of bogs and trickles of increasing importance moving downhill. Many of them are ephemeral and subject to desiccation during the summer, leaving an area filled by soft mud and vegetal debris. No freshwater molluscs have been recorded so far in these biotopes above 650 m AMSL, in relation to the extremely adverse environmental conditions.

In respect to the running waters only the slow-flowing reaches belonging to the first order streams associated with broad and flat headwaters may support colonies of freshwater molluscs. In meandering reaches (frequently established along high plateaux) these organisms are only found in quiet muddy-silty pockets located on the meander point bar, opposite the main stream current.

In a riffle and pool system sphaeriids are occasionally found in the quieter pools, where turbulence is moderate or absent. These waters are mostly neutral with a pH ranging between 6.24 (St. No. 124, 872 m AMSL) and 7.27 (St. No. 165, 748 m AMSL), in relation to the geological nature of the substratum. Conductivity is typically low, just over 30 µS/cm, as expected in a system dominantly fed by meteoric water.

Only two generalist sphaeriids are capable of survival in so dynamic and demanding environment: *Pisidium casertanum* and *P. personatum.* The two species are often found in sympatric populations (e.g. St. No. 55, upper sector of the Glen Lee), although *P. casertanum* seems to tolerate slightly worse conditions, being present in biotopes moderately higher than those reached by *P. personatum* (e.g. St. No. 124, flooding depression of the Glas Allt Mòr). These observations are in accordance with the highest records found in the malacological literature for the British Isles, where *P. casertanum* is documented at a maximum altitude of 1,006 m AMSL, whilst *P. personatum* only reaches 914 m AMSL (Tab. 12). A similar conclusion was also established following a field work in the Italian central Apennine mountain range, where *P. casertanum* is the only sphaeriid reaching the highest pools at about 1,400 m AMSL, whilst *P. personatum* does not exceed the 1,000 m AMSL contour line (Pettinelli, unpublished data).

Species	Literature			This study	
	Locality	Altitude	Reference	Locality	Altitude
Pisidium casertanum	Pool on col between Beinn Ghlas and Ben Lawers (Scotland)	1006	Dance, 1972	St. No. 124	872
Pisidium personatum	Tarn on Cru-y-Ben, Tarmachan, near Killin (Scotland)	914	Evans, 1918; Dance, 1971	St. No. 55	780
Galba truncatula	An Stùc NN641430 (Scotland)	900	Marriott & Marriott, 1992	St. No. 285	327
Radix balthica	On the col dividing Lochan nan Cat from Yellow Corrie, Ben Lawers (Scotland)	823	Stelfox, 1952; Dance, 1971	St. No. 177	750
Pisidium lilljeborgii	Loch Vrotachan (Scotland)	750	Kerney, 1974	St. No. 177	750
Pisidium hibernicum	Ireland	701	Dance, 1971	St. No. 177	750*
Pisidium milium	Scotland	701	Dance, 1971	St. No. 177	750*
Pisidium nitidum	Llyn y Cwn, near Cwm Idwal in Snowdonia (Wales)	716	Dance, 1972	St. No. 177	750*
Pisidium subtruncatum	Wales	587	Dance, 1971	St. No. 177	750*
Pisidium obtusale	Scotland	701	Dance, 1971	St. No. 248	546
Ancylus fluviatilis	Ireland	701	Dance, 1971	St. No. 306	677
Bathyomphalus contortus	Scotland	488	Dance, 1971	St. No. 99	137
Sphaerium corneum	Wales	488	Dance, 1971	St. Nos. 194 & 331	363
Gyraulus albus	Wales	442	Dance, 1971	St. No. 330	365
Acroloxus lacustris	Wales	412	Dance, 1971	St. No. 241	107
Potamopyrgus antipodarum	Wales	401	Dance, 1971	St. Nos. 194 & 331	363
Hippeutis complanatus	Wales	400	Dance, 1971	St. No. 271	126
Musculium lacustre	Wales	381	Dance, 1971	St. No. 269	105
Stagnicola palustris	England	378	Dance, 1971	St. No. 235	136
Valvata piscinalis	England	375	Dance, 1971	St. No. 196	176
Lymnaea stagnalis	England	375	Dance, 1971	St. No. 266	49
Physa fontinalis	England	375	Dance, 1971	St. No. 239	199
Gyraulus crista	England	375	Dance, 1971	St. No. 271	126
Gyraulus laevis	Wales	296	Dance, 1971	St. No. 234	243
Anodonta anatina	England	213	Dance, 1971	St. No. 314	89
Planorbarius corneus	Wales	153	Dance, 1971	St. No. 264	55
Peringia ulvae	Scotland	<31	Dance, 1971	St. Nos. 189 & 190	2
Ecrobia ventrosa	Wales	<31	Dance, 1971	St. No. 190	2
Physella acuta	?	?	Dance, 1971	St. No. 295	108
Margaritifera margaritifera	?	?	Dance, 1971	St. No. 300	78
Planorbis planorbis	?	?	Dance, 1971	St. No. 311	21
Hydrobia cf. *acuta neglecta*	-	-	-	St. No. 223	1

Tab. 12. Comparison between historical and present study altitude records. The asterisk indicates the new maximum elevation recorded for the considered species within the British Isles during this research project.

4.7. PASSIVE DISPERSAL

For nearly two centuries occasional field observations and anecdotal evidences were the only arguments available in literature to qualitatively prove the existence of passive dispersal mechanisms operating on a variety of animal taxa. A list of literature records describing passive transport events, subdivided in categories either related to the transporting mechanism or to the nature of the host is reported in Appendix-V. 595 documented accounts in 451 short notes, scientific articles and books covering the period 1694-2016 give an idea of the strong interest sparked by this matter among a number of malacologists, ornithologists, entomologists, herpetologists, carcinologists and more generally naturalists.

One of the most important contributions in this field was provided by Kew in 1893, who collated nearly a century of observations in an accurate Victorian-style catalogue. The same author wrote another monography on the capacity of molluscs in spinning mucous threads, another important adaptative behaviour to free movements along the water column (Kew, 1900). Other occasional accounts were documented during the first part of the 20th century, mostly dealing with birds found with snails attached to their feathers. In 1928 Schlesch wrote a detailed description of all the new taxa appearing in different continents as result of passive dispersal through a variety of vectors and accidental introductions due to human activities. More recent overviews concerned amphibian dispersal (Rees, 1952), insect-borne dispersal (Fernando, 1954) and aerial dispersal more in general (Rees, 1965; van Gemert & Schipper, 2013).

Other researchers studied dispersal mechanisms frequently occurring in restricted taxonomic groups such as Sphaeriidae (Mackie, 1979) or a single taxon such as *Potamopyrgus antipodarum* (NZMS, 2007; Alonso & Castro-Diéz, 2008).

It is only during the last 15 years that the topic was reviewed from different perspectives (field studies, laboratory experiments, genetic analyses, etc.). Major contributions are those of Wesselingh *et al.* (1999), Bilton *et al.* (2001), Figuerola & Green (2002), Kappes & Haase (2012) and van Leeuwen (2012). Mitochondrial DNA sequencing of geographically isolated gastropod populations, sometimes located on different continents, allowed the origins of common ancestors to be established. Furthermore genetically related populations appear to be located along major migratory bird routes, suggesting that these migrants play a primary role in dispersing molluscs.

Genetic similarities linked to bird migration paths or commercial ship routes have been highlighted by several researchers: Wilson *et al.* (1999) for *Dreissena rostriformis bugensis* in

North America, Gittenberger *et al.* (2006) for the genus *Balea* in the Pacific area, Haase *et al.* (2010) for *Ecrobia grimmi* in Iraq, Hershler *et al.* (2010) for *Potamopyrgus antipodarum* in Idaho and van Leeuwen *et al.* (2013) for *Physa [=Physella] acuta* in southern Spain.

4.7.1. MOLLUSCS HOSTS IN THE GRAMPIAN AREA

In the study area molluscs can be found in all varieties of waters, even in the most isolated and remote sites. This is particularly true for the sphaeriids, which are frequently found in the majority of river upper catchments, suggesting the existence of a common dispersal host responsible for their fragmented but ubiquitous distribution. Vast plateaux are quite often found in the hydrographic upper sectors, where local favourable conditions for the development of sphaeriid communities are frequently met. These catchments are normally separated from lowlands by a fast-running stream segment, in many cases represented by a gorge with an exposed rocky substratum or at least by a step and pool system, in both cases a formidable barrier for the upstream migration of lowland benthic fauna.

Amphibians represent the best candidate hosts for the dispersal of freshwater molluscs in the area, particularly sphaeriids. In the Grampian area four different species belonging to this phylum of vertebrates are found (Taylor, 1963; Swan & Oldham, 1993; Arnold, 1995; Arnold & Ovenden, 2002; NBN Gateway): the common frog *Rana temporaria* Linnaeus, 1758, the common toad *Bufo bufo* (Linnaeus, 1758), the palmate newt *Lissotriton helveticus* Razoumowsky, 1789 and the smooth newt *Lissotriton vulgaris* (Linnaeus, 1758). The presence of the crested newt *Triturus cristatus* (Laurenti, 1768) in Deeside needs confirmation, although the species occurs just outside the study area (nearby Elgin). *B. bufo, L. helveticus* and *L. vulgaris* (this latter quite rare according to NBN Gateway records) are commonly found within lowland sectors including the coastal area, whilst *R. temporaria* is widespread, having been frequently found from river estuaries up to the highest temporary water bodies of the Cairngorms. *R. temporaria* normally breeds in seasonal ponds or temporary ditches, where large egg masses are frequently found during the spawning season. It is common to find a *R. temporaria* specimen moving from different water bodies across the moorland in the Cairngorms range, suggesting that a significant population inhabits the area. An attempt to compare distribution maps of freshwater molluscs and amphibians in the study area has been made in order to identify possible relations between them. It has been noticed that a direct correlation exists between sphaeriid and *R. temporaria* distributions, suggesting a possible interaction. High altitude sphaeriid populations are regularly found in places where adult specimens, tadpoles or egg masses of *R. temporaria* are spotted nearby. *R. temporaria* is in fact able to colonise a wide range of environments, especially those subject to desiccation or icing: deadly conditions for any type of mollusc.

Despite this common distribution, during this survey no amphibians have been identified with molluscs of any type clamped or stuck on their bodies.

Regardless of this lack of evidence, *R. temporaria* remains the most likely vector for sphaeriid passive transport in the Cairngorms.

The contribution of birds or aquatic insects to mollusc dispersal can be significant, as documented and discussed in literature. Birds in particular may play a dominant role in passive transport within the coastal lowlands, where a number of wetlands are regularly visited by thousands of migratory birds and seabirds during spring. Should this happen the number of accidental introductions of molluscs trapped between the feathers and released in new environments could be very high. For instance the estuarine environments occurring in the region hold similar associations of hydrobiids, suggesting cross transport by seabirds. The passive dispersal of sphaeriids by birds is a very rare event, only documented in a couple of cases (Chapman, 1884; Coates, 1922a). The major limitation resides in the clamping mechanism, which is the same as that described for amphibians and insects, but it does not have the same rate of success in birds as they have bigger and rougher feet (also a smooth bill). Furthermore it is quite likely that young specimens trapped between the feathers fall during flight, as the surface of the shell is very smooth and does not offer any point of anchorage.

In respect of aquatic insects there are no particular elements which may help in understanding their effective role in passive dispersal of mollusc within the study area. Large beetles are more frequently found in lowlands suggesting that insect passive transport may be more effective in this sector. Within the highlands in fact the limited size of the insects (and their fragility), mainly represented by Plecoptera and Ephemeroptera, does not seem amenable to mollusc transport.

5

DISCUSSION

The origin of the British fauna is quite recent if compared to those living in mainland Europe. It is believed that the Quaternary glaciations caused the total extinctions of the British pre-glacial fauna, for this reason few endemic taxa occur in Great Britain. During the strongest glacial phases such as the Anglian, the Wolstonian and the Devensian, it is thought that the ice sheet covered the whole island. There are some suggestions on the possible existence of small refuge areas free from the ice in southern England, but Scotland was certainly fully covered by a thick ice sheet. Therefore the current British fauna is the result of a continuous immigration process started since the last post-glacial, which began 10,000 years BP or at most at the beginning of the Windermere Interstadial (13,000 years BP). This latter hypothesis is valid only if we assume that during the Loch Lomond Readvance (11,000-10,000 years BP) large areas of the Grampian Area were not occupied by ice sheets.

The origin of the Scottish fauna

The freshwater mollusc list identified during the present research amounts to 20 species of gastropods and 12 bivalves of which 10 are sphaeriids. This fauna is quite comparable to that traditionally reported for the area, amounting to 17 gastropods and 14 bivalves of which are 12 sphaeriids.

The actual fauna presumed to inhabit the area currently amounts to 21 gastropods (*Anisus leucostoma* not confirmed in this study) and 14 bivalves (*Pisidium pulchellum* and *P. amnicum* presence not confirmed), all typical Palaearctic and Holarctic exponents.

All these species are commonly found in mainland Europe including *P. lilljeborgii,* which is a cold immigrant, today confined to some residual lochs of post-glacial origin spread across the Holarctic region.

Considering that the role of the Loch Lomond Readvance (11,000-10,000 BP) along the Deeside is still unclear, the age of the isolated populations of *P. lilljeborgii* and perhaps *P. hibernicum,* found in several kettle-hole lochs (e.g. Loch Vrotachan & Loch Davan), may date back at the beginning of the Windermere Interstadial (13,000 years BP).

The extremely diversified populations of *P. hibernicum* identified in the Pronie and Witchock lochs, located on the slope of the Baderonoch Hill near Dinnet, suggest a long persistence of such an environment, where the speciation process began earlier than in other places. The peculiar specimens identified in these lochs (e.g. Plate-30, Figs. a-f), which differ from all the other *P. hibernicum* populations identified in the area, could sustain such hypothesis.

Additional elements which could support the survival of sphaeriid populations since last stadial come from the distribution patterns of Holarctic and Palaearctic species. This is the case of *P. conventus* Clessin 1877 (occurring outside the studied area) and *P. lilljeborgii,* which show a general rarefaction trend towards the south, the opposite of all other sphaeriid species becoming progressively rarer to the north. In more detail *P. conventus,* a truly Arctic species (Holarctic circumpolar), is in fact virtually absent in England, whilst in Scotland is confined to the profundal zone of large lakes (e.g. Loch Rannoch, Dance, 1957; Loch Lomond, Hunter & Slack, 1958), sometimes at considerable depth (e.g. Loch Ness, -230 m, Martin *et al.,* 1993, Loch Morar -300 m, Kerney, 1999b). The distribution of the *P. lilljeborgii* populations, a Subarctic species (Holarctic circumpolar), follows a similar pattern, only occurring in North England and in isolated populations in the high plateaux of Snowdonia, Wales.

Finally *P. hibernicum,* a Palaearctic species frequently associated with *P. lilljeborgii,* is the only sphaeriid rather homogeneously widespread in the British Isles, suggesting that the population's origin may be the result of two different events: the southernmost ones could have immigrated from the continent, whilst those located to the north may be relicts from the last stadial.

Some genetic investigations are required to clearly establish the origin of the post-glacial radiation within the British Isles.

From an ecological point of view both *P. conventus* and *P. lilljeborgii* can be considered specialists, because of their patent preference for cold still waters, particularly the first one, that survives today in the profundal range of the major Scottish lakes.

Conchological characters

With respect to the sphaeriid morphological characters and their possible adaptations under specific ecological conditions, the density and the distribution of the shell internal pores have been investigated. These structures are believed to be used to improve gas exchange and waste removal through the shell wall (Burky, 1983).

Comparing distinct *P. obtusale* populations living in different habitats, it was noticed that pore density changed according to ecological characteristics, therefore it does not appear as a specific morphological character as suggested by several authors (Korniushin, 2000; Slugina, *et al.,* 2006, etc.). For instance the *P. obtusale* population living in the Tarfside bog (St. No. 299, Pl. 17, Figs. a-i), shows a higher density of pores on the internal side of the shell if compared to specimens belonging to the same species inhabiting the Witchock Loch (St. No. 330, Pl. 18). The Tarfside bog is characterised by a muddy substratum covered by a thick layer of vegetable debris, whilst the Witchock Loch has a sandy-gravelly substratum locally covered by a thin layer of vegetable debris. The increased pore density visible on the specimens living in the Tarfside bog could be related to the low-oxygen content at the water-sediment interface, which may favour the evolution of a morphotype with a higher number of canals to improve external exchanges.

Similar evidence is obtained comparing a *P. casertanum* population living in a low-oxygen environment characterized by abundant production of vegetable debris (Loch of Park, St. No. 226, Pl. 10) with a typical lotic population from a well-oxygenated gravelly river bed (St. No. 318, River Dee, Pl. 7, Figs. g-l).

Grigorovich *et al.* (2000) achieved similar conclusions whilst studying *P. moitessierianum* specimens living in different mud and sand substrata in the lower Great Lakes region (North America).

Relationships between ecological variables and molluscan abundance

The classification analyses (cluster analysis, Ward's method) performed on all mollusc and sphaeriid-only species matrices (Matrix-1 and Matrix-2), indicate a clear distinction in phyletic groups for both sampling stations and species axes, even if in some cases the occurrence of 'bin groups' (e.g. Group-F in Matrix-1 cluster analysis species axis, Fig. 27) in the dendrogram, does not allow a full understanding of the direct relationship habitat-taxon. This is more evident in lowland habitats, where the highest number of species is found, as the ecological parameters are usually suitable for the majority of the specialist and generalist species.

In more detail the cluster analysis (Ward's method) performed on the stations versus all mollusc species matrix shows in some cases a good separation among phyletic groups of zoological taxa (Matrix-1, species axis, Fig. 27), with a good correspondence with the molluscan associations identified in the field.

The Group-C *(P. personatum, P. casertanum, R. balthica, P. antipodarum* and *A. fluviatilis)* is already defined at the second dichotomous division level (11% arbitrary similarity), identifying a well-established association commonly found in the coastal lowland stream system.

Similar evidence can be possibly inferred from the Matrix-1/Matrix5 CCA, where Group-C falls in the left side of the cross-plot, stretching along the hydrographic longitudinal gradient identified by the altitude and conductivity vectors (Axis-2, Fig. 33). *P. antipodarum* is in fact located in quad-3, following the conductivity gradient, whilst *P. casertanum* falls in quad-4, directly influenced by the altitude and current speed gradients.

These species are quite often associated with Group-A taxa such as *P. subtruncatum* and *P. nitidum,* species frequently met in riverine systems. Group-A comprises a typical riverine association inhabiting a variety of mid-lowland lotic environments. The other components of this association are: *P. hibernicum, P. milium, S. corneum* and *G. albus*. This group is located on the right side of the Matrix-1/Matrix5 CCA cross-plot, along the trophic gradient expressed by Axis-1 (pH, temperature and O_2 saturation).

Group-B (lacustrine-I) is a typical lacustrine association, including a number of species which are frequently found in the lowland loch system, typically represented by eutrophic and well-oxygenated waters, generally supporting a consistent macrophytic community. *P. obtusale* and *P. lilljeborgii* are exclusively found in lentic environments (Fig. 30), the former generally found in poor-quality environment, whilst the latter is generally met in well-oxygenated waters and clean silty-sandy substrata, avoiding stagnant conditions. The other taxa belonging to Group-B are *V. piscinalis, P. fontinalis* and *B. contortus,* all found in a number of medium-size lochs, generally characterised by dense macrophytic communities.

Also Group-E (lacustrine-II) typically inhabits mid-lowland meso-eutrophic lochs of medium-size such as those included in Group-10 stations. This association is composed of: *H. complanatus, G. crista,* and *A. anatina.*

Group-D (estuarine association) is nicely defined after the second dichotomous division at 19% similarity level. This group is essentially composed by halophile hydrobiids *(P. ulvae, E. ventrosa* and *H.* cf. *a. neglecta),* which are specialist molluscs adapted to survive to euryhaline environments. *S. palustris* belongs as well to this group as it is occasionally found in such transitional environments.

Eventually Group-F includes a heterogeneous number of species characterised by a weak degree of affinity, generally found together in a wide variety of environments ranging between mid-lowland lochs to fens and bogs. This is a bin group, mostly composed by rare species (e.g. *A. lacustris, M. margaritifera)* or by species found in a different range of habitats, not specifically associated to other taxa (e.g. *G. truncatula).*

The *P. casertanum-P. personatum* association (Group-Abis in Matrix-2 cluster analysis Ward's method species axis, Fig. 29) represents a typical component of the benthos living in poor environments, where other less tolerant species cannot survive. For this reason these two species are commonly found at the two habitat extremes of the Grampian Area: in the running and standing waters of the hills and mountain ranges up to the highest peaks of the Cairngorms and in the coastal stream systems. These two species of *Pisidium* are the commonest found in the area and can colonise a wide range of environments because they are both generalist molluscs. Differently from *P. personatum, P. casertanum* is able to colonise the highest habitats in the area (headwater streams, blanket bogs, etc.), competing with severe ecological conditions, particularly during winter, when all mountain populations are at risk of extinction. These high altitude environments mostly fall within Group-2 and Group-3 of the Matrix-1 cluster analysis (Ward's method) stations axis (Fig. 26). This dual distribution of *P. casertanum* and *P. personatum* in highland and lowland habitats is also visible in the Matrix-2/Matrix-6 CCA, where they fall on opposite sides of the graph (Fig. 36), following the hydrographic longitudinal gradient (Axis-2).

The ability of broad generalists to survive in these extreme habitats can be considered to mark the limit of their ecological range and not as a specific adaptation to a particular ecological niche (typical of specialists). Both *P. casertanum* and *P. personatum* show a ubiquitous distribution, but the highest densities are recorded in those environments left free by specialists, where there is no competition. On the other hand specialists are more effective at competing with other stress-tolerant organisms, in those habitats characterised by more favourable conditions such as well-oxygenated, calcium-rich waters with large colonies of macrophytes, pushing generalists out of their favoured ecological niches.

Along the coastal stream system, conductivity is definitely higher than in the highland habitats, due to the contribution of the subterranean waters as well as to the proximity of the sea (Group-1 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26). Also the pH is neutral tending to basic and the nutrient content higher because of the vegetable debris deposited in the finer sediment pockets.

Temperatures only occasionally drop to around 0°C and only for very short periods, for this reason icing does not bring a restriction in this type of environment.

Nevertheless these running systems generally show a step and pool configuration and the rate of flow is extremely variable, being directly influenced by meteoric precipitation. Many of these habitats may pass from a low rate of flow to total quiescence and during drought the water can completely disappear. For this reason these environments are not suitable for sphaeriids more adapted to riverine systems such as *P. subtruncatum* and *P. nitidum* (Group-Bbis in Matrix-2 cluster analysis Ward's method species axis, Fig. 29).

Only Group-Abis which includes species tolerating desiccation *(P. casertanum)* or capable of surviving in poor environments *(P. personatum),* can permanently colonise such ecotopes.

Group-Bbis (*P. subtruncatu*m, *P. nitidum, P. milium* and *S. corneum)* is a well-defined association frequently found in large rivers, together with the species of the Group-Abis *(P. casertanum* and *P. personatum)* and some of the Group-Cbis such as *P. hibernicum*.

Group-Bbis distribution in the Matrix-2/Matrix6 CCA cross-plot (Fig. 36) is mostly explained by the trophic gradient, possibly expressed by pH, temperature and conductivity vectors.

Group-Cbis includes species which frequently compose assemblages of the lowland systems (lacustrine association). *P. obtusale, P. lilljeborgii* and *P. hibernicum* are typical components of this sphaeriid association, frequently occurring in major lowland lochs, together with a variety of other species such as *P. subtruncatum, P. nitidum* and *P. milium* (Group-Bbis). However *P. obtusale* and *P. lilljeborgii* are also present in the highland sector (respectively St. No. 248 Craig Vallich and Pannanich Hill blanket bog; St. No. 177 Loch Vrotachan), where they can compete against *P. casertanum* and *P. personatum* for the same ecological niche if the ecological requirements are not too restrictive. It is also worth to notice that *P. obtusale* and *P. personatum* are both frequently found in poor habitats, where they can survive better than other sphaeriids in waters with low oxygen concentrations, with the bottom layered by fine particulate organic matter. *M. lacustre* separates already at the second dichotomous level (22% arbitrary similarity, Fig. 29) from the other clusters, indicating strong species specificity. This sphaeriid is in fact related to environments situated in proximity of urban settlements, quite often deeply altered by human interventions and characterised by high water conductivity. Its presence could be related to accidental introduction and subsequent successful settlement in different type of environments, regardless of its specific habitat requirements. *M. lacustre* is found at the very bottom of quad-2 in the Matrix-

2/Matrix-6 CCA (Fig. 36), because of the high conductivity characterising Group-6 and Group-10 environments, where it is usually found.

The molluscan distribution is highly dependent on a number of ecological parameters as a consequence of the specific habitat requirements of each species. The water ion content (particularly calcium), well-represented by the conductivity parameter, is certainly one of the most important factors affecting molluscan life. Every mollusc needs a minimum level of calcium in the water to build its shell and even species preferring soft water (calcium content 1-20 mg/l, Boycott, 1936) such as *Margaritifera margaritifera,* cannot survive below a certain minimum threshold. Soft waters are also quite poor in terms of nutrient load, such as nitrates and phosphates. These components are normally associated with the biodegradation chain of animal and vegetable substances, which availability is directly related to the water current.

Multiple linear regression (MLR) run on both Matrix-3 (all mollusc species) and Matrix-4 (sphaeriid-only species) allowed the rejection of the null hypothesis (no dependency exists between mollusc diversity/abundance and ecological variables) and to rank the independent variables that best explain mollusc species abundance.

In the case of all mollusc species abundance, altitude appeared to be the most significant explanatory variable, with a negative relationship to temperature and pH (Tab. 6). These three ecological variables are tightly interrelated and keep these relationships throughout the year. Temperature and pH (but also conductivity) increase with decreasing altitude, together with molluscan diversity and abundance. O_2 saturation and conductivity are significant variables to explain molluscan abundance variations, mainly in relation to water productivity and to the trophic level. Also the current speed is an important ecological factor, clearly limiting mollusc settlement in those waters characterised by strong currents and turbulent flow. Only well-adapted mollusc to stream currents can colonise such environments (e.g. *A. fluviatilis* and *M. margaritifera).*

A similar result was achieved by MLR run in Matrix-4. Temperature and pH appeared to be the most significant variables explaining sphaeriid abundances, together with current speed and substratum size (Tab. 7). Sphaeriids are in fact sensitive to the type of substratum, avoiding coarse-grained sediments swept by strong currents and favouring low-energy habitats characterised by fine-grained sediments.

The pH is an important key parameter which reflects the ion composition and the presence of organic matter in sediment. Generally speaking pH increases with the eutrophication process, as it is related with sediment load and vegetation growth. The pH tends to augment with decreasing altitude, reaching the highest values (8-9) in the altitudinal zone between 150 m and sea level (Figs. 13-14). The only exception is represented by the limestone-rich areas of the Cairngorms, where the pH may attain high values (e.g. Loch Vrotachan, pH 8.35). The minimum pH is reached among the water bodies distributed along the hill-mountain range, where the nature of the bedrock (granite), combined with the water chemistry (water with poor ion content, reflecting rainfall composition) and the constant presence of silicophile plants (heather), favour acidification. Examples of this type of environment are Lochnagar (pH 5.82; conductivity 20 μS/cm) and Dubh Loch (pH 4.97; conductivity 21 μS/cm), both located on the slopes of the Lochnagar Massif. Proceeding downstream both running and standing waters start carrying a high load of ions and nutrients, favouring the development of algal mats and macrophytes. These environments may fall within the eutrophic class because of the constant presence of highly vegetated shores and the consequent heavy production of organic matter concentrated at the water bottom. This is the case of lochs Davan and Kinord (Group-5 and Group-10 in the Matrix-1 cluster analysis Ward's method stations axis, Fig. 26), which share the same origin and are currently in an eutrophic stage, offering refuge to a variety of animals in a region still very close to the hill range. In lowland water bodies transparency is generally very limited, even in running waters and nearly anoxic conditions can be easily reached at the sediment-water interface. Sphaeriids can survive at low oxygen levels, avoiding penetration into the deep sediment. *P. obtusale* and *P. personatum* are typical inhabitants of such an environment, which may represent an unfavourable habitat for other species. On the other hand, macrophytes offer excellent support for those species that prefer crawling on firm surfaces, such as Lymnaeidae, Physidae and Planorbidae. In this microhabitat the oxygen content is considerably higher during daylight as a consequence of photosynthesis but drops quickly overnight. These fluctuations reflect the diel movement cycles of pulmonates gastropods, with a midday-to-early-afternoon grazing activity peak during the time of maximum photosynthesis (Lombardo *et al.*, 2010). Even prosobranch gastropods (generally less generalist than pulmonates) such as Bithyniidae and Valvatidae follow a similar trend, although they require a less eutrophic and polluted habitat to survive, with satisfactory levels of nutrients and oxygen.

The majority of lowland water bodies are of anthropogenic origin, essentially built as water storage for agricultural practices. Being located among cultivated fields, these environments are affected by high trophic levels, chiefly related to nitrates and phosphates brought-in by run-off water. During summer these shallow bodies are subject to intense solar warming, which, associated with prolonged photosynthetic activity, generate marked eutrophic conditions, with the development of thick algal mats. For this reason these lochans are mostly inhabited by generalist species such as Lymnaeidae and Group-Abis sphaeriids *(P. casertanum* and *P. personatum)* together with *M. lacustre*. This latter species appears to be a recent introduction to the area, only present in easily accessible basins altered by human intervention.

Altitude is a factor intrinsically related to chemical and physical parameters such as temperature, ion content, nutrient content, current speed and bottom sediment grain size. Increasing altitude is certainly a limitation to mollusc distribution, where only a few species are capable of survival. Turner *et al*. (1998), after having studied the distribution of freshwater molluscan associations along the Swiss Alps sector, concluded that both species number and abundance decrease markedly with increasing altitude.

Furthermore, Sturm (2007) noticed that water bodies at high altitude are dominated by generalist species, able to thrive in a wide variety of environmental conditions, whilst specialists can only occur where levels of submerged vegetation and nutrients are sufficiently high.

In Scotland the upper sectors of the catchment basins generally represent a hostile environment for molluscs, because of the steep topographic gradient invariably crossed by fast-running systems. For this reason it is quite difficult in the Grampian Highlands (above 400 m AMSL) to discover living populations of molluscs, with the exception of some plateaux areas that may break the river longitudinal profile and create refuge areas. These plateaux are generally crossed by meander reaches, where deposition of fine sediments may occur in the quietest pools (Group-3, Fig. 26). For this reason these environments may host populations of Group-A species *(P. casertanum* and *P. personatum),* where suitable conditions for the survival of suspension feeders such as the sphaeriids can be found.

Another important parameter conditioning mollusc ecology is certainly the temperature, which may considerably limit their survival above the 800 m AMSL contour line, where icing during winter months frequently occurs. Once again only generalist species such as those from Group-Abis can be found beyond this limit, because they can survive in moist soil or even in the complete absence of water after ice formation (Olsson, 1981).

Finally, salinity is a fundamental parameter driving molluscan distribution along estuaries. The majority of freshwater molluscs are generally very sensitive to salinity and quickly disappear in the oligohaline domain (0.5-5 salinity). The most resistant species belong to the Lymnaeidae family, which may sometimes reach the estuarine environment during floods and survive for a while. This is the case in the River Ugie, where the short length of the estuary easily promotes the accidental introduction of specimens of *R. balthica* into an oligohaline environment (1.10 salinity). Among the sphaeriids only *P. personatum* occurs in an estuarine habitat, sometimes accompanied with *P. subtruncatum* (e.g. St. No. 246, Water of Cruden; St. No. 287, River North Esk) or more rarely with *P. nitidum* (St. No. 190, River Ythan), the latter species only found in river reaches still greatly influenced by freshwater.

With respect to the prosobranchs, the Grampian Area estuaries reveal an unexpectedly rich hydrobiid fauna, with three species living simultaneously in different microhabitats across the same ecotope.

Peringia ulvae is certainly the commonest British inhabitant of estuaries, tolerant of a wide range of salinity (1.5-33‰ according to Fretter & Graham, 1978), although it is most common where salinity rises to 10‰ or more. It is a typical component of tidal flats and intertidal banks, where it lives on the surface of firm or soft muds, stones and on weeds such as *Ulva* and *Zostera*. Even if *P. ulvae* can be found in the sublittoral zone down to depths of 20 m, it is mostly found in the upper third of the estuary, tolerating a minimum salinity of 1.5‰.

Ecrobia ventrosa has been recorded for the first time in North-East Scotland, probably because of its cryptic presence among the huge populations of *P. ulvae* (thousands of individuals per m^2), which it is generally associated with. *E. ventrosa* certainly prefers waters with lower salinities than *P. ulvae* and microhabitats not directly connected to the sea, such as those found in shallow tidal channels and quiet pools. *E. ventrosa* is mostly found on muddy substrata, stones or on weeds such as *Ulva* and *Ruppia*.

The presence of *Hydrobia* cf. *acuta neglecta* has been tentatively indicated for the River Ugie estuary, but it needs to be verified on anatomical characters as soon as living specimens become available. The occurrence of *Hydrobia acuta* along the British coasts is still unclear due to the taxonomic confusion which affects this taxon because of its morphological similarity with other brackish water hydrobiids. According to the original description of *Hydrobia neglecta* (currently considered as a subspecies of *Hydrobia acuta)* by Muus (1963), this species is generally found in those environments covered by dense carpets of *Zostera* and *Potamogeton*. The salinity range indicated by Muus is between 10 and 24‰.

<u>Passive dispersal: possible mollusc hosts in the Grampian Area</u>

The uppermost sectors of the river watersheds are difficult to reach through active dispersal, because they are separated from the lowland sectors by high energy step and pool reaches difficult to bypass.

In the case of the freshwater molluscs these steep river reaches (quite often with waterfalls) represent an impassable obstacle for upstream dispersal and the origin of the populations identified above this zone can only be explained through passive dispersal mechanisms.

The European common frog *(Rana temporaria),* a common visitor to virtually any kind of water environment in the hill-mountain range, is the most likely vector for sphaeriids passive transport.

Also the common toad *(Bufo bufo)* may represent another possible carrier, especially among water bodies located at a lower altitude, such as glacial and kettle-hole lochs. A full overview of the role of *R. temporaria* and other amphibians in carrying bivalves is discussed extensively in sub-section 4.7.1.

Furthermore birds using the Cairngorms water bodies during their regular migrations can transport specimens and eggs of molluscs facilitating their spreading.

<u>Geology versus molluscan abundance</u>

Other refuge areas within the hill-mountain range are related to surface geology.

The large outcrop area of meta-sedimentary formations of the Islay, Easdale and Crinan subgroups belonging to the Argyll Group, mostly located along a NE-SW band crossing the Glass Maol-Loch Callater area, is a clear example of a close association between rocks and water chemistry. In this area the richest water bodies of the whole Cairngorms range are found, such as Loch Vrotachan (St. No. 177), which holds the most diversified sphaeriid community (7 sympatric species of *Pisidium,* Fig. 25) discovered during this project.

Another example is the Allt an t-Slugain, flowing through a series of calcareous-siliciclastic rocks belonging to the Grampian Group, extensively outcropping along the southern slope of the Meall an t-Slugain. This stream is inhabited by sphaeriid populations of Group-Abis *(P. casertanum* and *P. personatum),* quite an unusual occurrence within the vast area between Ben Avon and Braemar, dominated by large outcrops of granites of the Cairngorm suite. This area only represents a minor part of the Cairngorms range, largely occupied by granitic intrusions. Surface waters located in those sectors characterised by igneous rocks (mostly granite), show more acidic pH, reduced ion content (comparable to rainfall) and a minimum level of nutrients, essentially concentrated in standing water bodies such as blanket bogs. This is the most hostile environment for freshwater molluscs and their sporadic presence can only be considered accidental and temporary (e.g. upper sector of the Glas Allt Mòr, St. No. 124).

Another example of direct interaction between terrain and water chemistry is represented by the Red Loch located at the back of the Holocene dune belt of Fraserburgh. In this area the bedrock is represented by granitic rocks, covered by a complex system of coastal dunes (of siliciclastic composition) and colonised by a fir wood with large fern patches. The combination of these factors produce severe acidification (pH 4.39), rarely observed within the lowland sector. This loch despite its geomorphological similarity with other basins such as Loch of Strathbeg (Fraserburgh) and Cotehill Loch (Collieston) shows completely different water chemistry, bringing it into the category of the acidic lochs.

CONCLUSIONS

For the first time the Grampian Area has been fully investigated during a single research project with extensive field sampling for a total of 334 stations recorded over a large variety of environments belonging to different ecosystems.

A detailed review of the historical malacological records reported in the area has been performed and all the results integrated in an ArcGis database, which is a core part of this project.

A distribution map for each species integrating historical records and data from this study has been created, following Ordnance Survey grid square references and GPS site coordinates.

Taxonomical analyses have been performed on the whole set of specimens collected during field work. Detailed SEM observations have been carried out on selected specimens with the aim to document intraspecific variation among minute conchological details. Teratological individuals have been described and for some of the identified malformations (e.g. diphyoidy) possible causing mechanisms are discussed (Appendix-IV).

The standardised sampling methodology applied during field work allowed the use of bivariate and multivariate analyses to cross correlate ecological parameters with species habitat requirements. Distribution patterns have been carefully examined and compared with the statistical and analytical data to better clarify the interaction between ecological parameters and surface geology.

The main aims of this study have all been achieved and developed:

- Mollusc species distribution
  - The most complete data set to date concerning historical records within the area has been compiled and organized in a list of references in chronological order (Appendix-I).
  - An updated freshwater mollusc list for the Grampian Area using the data from this study has been produced (Appendix-II).
  - A set of mollusc distribution maps referring to each taxon occurring in the area (21 gastropods and 14 bivalves) has been generated (Appendix-III) and commented on the individual descriptive cards reported in section 4.4.

- Taxonomy
  - The huge intraspecific variability among the Sphaeriidae family has been explored; a number of lines of evidence have been documented in plates 1-32 and commented on the individual descriptive cards reported in paragraph 4.4.1.2 (Bivalvia).

– Conchological characters of sphaeriids have been studied in detail with the aim to establish if any relation exists between morphological features and ecological parameters. A review of the function of the internal shell pores and possible pattern evolutionary adaptation under specific ecological conditions is discussed in paragraph 4.4.1.2.

- Mollusc ecology

– The null hypothesis H_0 that no dependency exists between mollusc diversity/abundance and ecological variables has been tested and rejected with Multiple Linear Regression.

– Molluscan distribution and diversity have been studied in relation to ecological parameters, through bivariate and multivariate analyses. An iterative methodology, based on a similar approach used by Field *et al.* in 1982 to investigate nematode distributions in an estuarine environment, has been adopted. Similarity (distance matrices using Bray-Curtis equation) followed by classification (cluster analysis, Ward's method) and ordination (Bray-Curtis) analyses were first run to explore grouping among species and habitats. MLR was then performed in order to identify the predictive variables which best explain mollusc distribution and to retain only those which appeared significant. Altitude, temperature and pH for all mollusc species and temperature, pH and current speed for sphaeriid species were identified as most significant independent variables. CCA was finally run and the results compared with the previous achievements. The good concordance of results achieved through different techniques indicates that the species and habitat associations are real. For example Group-C *(R. balthica, A. fluviatilis, P. antipodarum, P. casertanum and P. personatum),* the lowland coastal association defined through cluster analysis (Ward's method), is a well-defined species assemblage ubiquitously found in the majority of streams along the coast. Analogously, Group-Abis *(P. casertanum* and *P. personatum),* the generalists association, is typically found in the coastal stream complex and in remote highland habitats, quite often representing the only molluscs living in such demanding environments. Species associations identified through multivariate analyses correspond adequately to the actual assemblages recognised on the field, which are affected by specific ecological variables. The results are discussed in section 4.5.

– A historical review of the existing altitude records for freshwater molluscs has been performed with the aim of comparing new findings with historical ones. The main explanatory ecological variables related to the hydrographic longitudinal gradient, have been analysed through bivariate and multivariate analyses. The results are presented and discussed in sections 4.5 and 4.6.

- Possible relationships between surface geology and molluscan distribution and diversity have been investigated through water chemistry characterisation in relation to the lithological nature of the substratum. Results are discussed in the individual descriptive cards reported in section 4.4.
- A critical revision of the literature describing the evidence of passive transport through a variety of vectors has been reviewed to support the theory of accidental introduction caused by resident and migrant fauna. The results are presented and discussed in section 4.7 and Appendix-V.

All raw data will be transferred to the Conchological Society of Great Britain & Ireland to update the national mapping scheme, as well as to the NBN Gateway scheme, consisting of an interactive online database which covers the whole Animalia Kingdom.

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Front plate: Linn of Dee.
From: Gibb A., Hay J. M., 1884 - The scenery of the Dee, with pen and pencil
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APPENDIX I - HISTORICAL RECORDS

PRE-1950 RECORDS (Cosgrove, 1997 *M. margaritifera* grid reference data are encrypted)

1. Rivers Dee and Don
Boethii (Boecius), 1527
Conchis margaritis (+)

2. Water of Kelly at the junction with the Ythan
Leg. Jamieson, presented to King James VI in 1620 by Thomas Menzies of Cults (in Keith, 1811 and Manson, 1845)
Pearl (rr)

3. On the banks of the Ythan
Earl of Melrose, 1622 (in Stewart, 1909)
Pearls (+)

4. The Ythan
Mr. Tower, 1750 (in Keith, 1811)
Quantity of pearls (+)

5. River Ythan in the Parish of Fyvie
Leg. Anonymous during 1762-1763 (in Manson, 1845)
Pearls frequently found in years 1762-1763 (c)

6. River Ythen [=Ythan] [1]
Pennant, 1771
Pearl muscle (+)

7. 'L'Écosse, dans la riviere ou fleuve Doone' [=River Don]
Desallier d'Argenville, 1780a
'Cheval-moule, qui produit de belles perles rondes' [horse-mussel, which produces beautiful round pearls] (+)

8. River Ythan in its lower extremity
Keith, 1811
Pearl mussels (+)

9. In the Inverury [=Inverurie] Canal
Collected in 1841 (Macgillivray, 1855)
Pisidium amnicum (+)

10. Hilton Quarries, Stuart Park [=Stewart Park]
Leg. Marian Macgillivray, 1841, Museum of the University of Aberdeen (in Booth, 1913c)
Limnæa truncatula (+)

11. Two shells without the animal were found among shell sand on the beach, between the mouth of the Dee and the Don
Leg. W. Macgillivray, 1842; leg. P. Macgillivray, 1842 (in Macgillivray 1855)
Neritina fluviatilis (r)

12. Below Bridge of Dee
October 1843, Wm. [leg. William Macgillivray?], Museum of the University of Aberdeen, (in Booth, 1913c)
Limnæa palustris (+)

13. Loch of Strathbeg and St Fergus Canal, etc.
Museum of the University of Aberdeen, no date, presumably before 1843 (in Booth, 1913c)
Planorbis contortus (+)

14. Crimond, Strathbeg
Museum of the University of Aberdeen, no date, presumably before 1843 (in Booth, 1913c)
Anodonta cygnea anatina (+)

15. Cruden
Museum of the University of Aberdeen, no date, presumably before 1843 (in Booth, 1913c)
Limnæa peregra lacustris (+)

16. Keith, and Strathbeg
Museum of the University of Aberdeen, 20th September 1843 (in Booth, 1913c)
Limnæa palustris (+)

17. It occurs plentifully in the Loch of Skene; in pools of the Dee; in a mill pond near the base of the Hill of Fare; Powis Burn at Old Aberdeen; Ditches with running water near the same place; Burn of Cruden; Auchmedden
Macgillivray, 1843
Limnæus pereger ovatus (a), *Limnæus pereger communis* (c), *Limnæus pereger limosus* (+),

18. At Don-mouth; in pools, lakes, marshy places, and streams, in the maritime and lower inland tracts
Macgillivray, 1843
Limnæus palustris (+)

19. Generally distributed, occurring abundantly in pools, rivers, brooks and rills; as in Hilton Quarries, the mill-pond near the New Bridge of Don, the Inverury [=Inverurie] Canal, and similar places, from the coast far into the interior
Macgillivray, 1843
Limnæus truncatulus (a), *Limnæus truncatulus oblongus* (c), *Limnæus truncatulus fossarius* (c), *Limnæus truncatulus minutus* (+)

20. In vast profusion in the Loch of Skene; in a pool in the Dee; in the Don, near Seaton
Macgillivray, 1843
Physa fontinalis (a)

21. On aquatic plants, and on the mud, in a ditch with stagnant and rather putrid water, in the hollow between Aberdeen and the Spital, where it is abundant
Macgillivray, 1843
Planorbis Vortex (a), *Planorbis Vortex crassulus* (+)

22. In a ditch at Banner Mill, near Aberdeen, where it exists in great profusion, among *Ranunculus aquatilis,* and other plants
Macgillivray, 1843
Planorbis Vortex Spirorbis (a)

23. In a pool in the Old Aberdeen Links; in a small pond in the garden of the Professor of Medicine of King's College, where it is very abundant on the grass and decayed leaves of trees; in a stripe of the Don, near Seaton House; in the Loch of Skene, the Inverury [=Inverurie] Canal, and subsequently in many other localities, it being generally distributed in the lower tracts
Macgillivray, 1843
Planorbis contortus (a)

24. In the Aberdeen Canal
Macgillivray, 1843
Planorbis albus (a)

25. Aberdeenshire undefined locality
Macgillivray, 1843
Planorbis imbricatus (+)

26. Abundant in brooks and rivers, on stones and plants, especially potamogetons; occurs also in pools, as in those of the granite quarries of Rubislaw and Hilton, and in mill-dams
Macgillivray, 1843
Ancylus fluviatilis (a)

[1] Pennant also made specific reference to the mouth of the Ythan as prolific sites for mussels: 'Muscles are also much used for bait, and many boats loads are brought for that purpose from the mouth of the Ythen.', although probably intending the blue mussels (*Mytilus edulis* Linnaeus, 1758) beds still covering the lower reaches of the estuary today. Thereafter other authors (e.g. G. J., 1829) misinterpreted the original sentence from Pennant, believing that he was referring to pearl mussels, distorting completely the original observation (without even quoting the source): 'Many boat-loads of a river muscle *(Ùnio margaritífera* Turton) are taken from the mouth of the Ythen, a river not far from Aberdeen, and employed in the fisheries of cod and ling established near Peterhead.'

27. A dead shell was found on the beach near the mouth of the Dee; another at Torrie [=Torry]
Macgillivray, 1843
Paludina vivipara (rr)

28. Two specimens were found on the beach near the mouth of the Dee
Macgillivray, 1843
Bythinia tentaculata (r)

29. Two shells without the animal were found on the beach, between the mouth of the Dee and the Don
Macgillivray, 1843
Neritina fluviatilis (r)

30. In great profusion, along with *Littorina tenebrosa,* in a small salt-marsh, near Newburgh, on the Estuary of the Ythan
Macgillivray, 1843
Rissoa ulvæ (a)

31. In the St. Fergus Canal, and near Fraserburgh (leg. A. Murray); near Peterhead (leg. Gray)
Macgillivray, 1843
Anodon anatinus (+)

32. In the Dee, the Don, the Ythan, the Ugie, and the Doveran [=Deveron], in muddy and gravelly places
Macgillivray, 1843
Alasmodon margaritiferus (c)

33. In the Loch of Skene
Macgillivray, 1843
Cyclas flavescens (a)

34. In a ditch near the Links of Old Aberdeen, in still water, full of decayed vegetable matter, in a small neglected pond, and especially in a ditch near it, in the garden of the Professor of Medicine of King's College;
Macgillivray, 1843
Pisidium Joannis (+)

35. In the clear running water of a ditch, filled with plants, and especially *Callitriche verna,* near Old Aberdeen; in clear, but stagnant water, in a ditch, in gravelly ground with peaty soil, between Aberdeen and the Spital; in the Bishop's Loch; in Aberdeenshire and Kincardineshire; in Banffshire; in the district of Buchan; from the Canal near Aberdeen;
Macgillivray, 1843
Pisidium Jenynsii (+)

36. In the mud and sand of a mill-pond near the New Bridge of Don;
Macgillivray, 1843
Pisidium pulchellum (a)

37. In a mill-pond, near the New Bridge of Don, where it occurs rarely, along with *Pisidium pusíllum,* and *P. pulchellum*
Macgillivray, 1843
Pisidium nitidum (r)

38. In a mill-pond, near the New Bridge of Don
Macgillivray, 1843
Pisidium pusillum (a)

39. In the Inverury [=Inverurie] Canal
Macgillivray, 1843
Pisidium amnicum (+)

40. Loch of Skene
Leg. Dickie, 1843 (in Macgillivray, 1855)
Valvata piscinalis (+)

41. A single specimen found among minute shells gathered on the beach at the mouth of the Dee
Collected in 1844 (Macgillivray, 1855)
Valvata cristata (rr)

42. A single specimen found among minute shells gathered at the mouth of the Dee, close to the pier
Collected in 1844 (Macgillivray, 1855)
Planorbis nitidus (rr)

43. Loch of Strathbeg
Museum of the University of Aberdeen, no date, presumably before 1844 (in Booth, 1913c)
Planorbis nitidus (+)

44. River Ythan in the Parish of Logie-Buchan
Cruden, 1845
Pearl muscle (+)

45. River Ythan in the Parish of Methlic
Whyte, 1845
Pearl fishery (+)

46. Mouth of the Ythen [=Ythan]
Johnston, 1850
Unio margaritiferus (a)

47. Aberdeenshire and Kincardineshire
Taylor, 1853
Limnæus pereger (c); *Planorbis vortex* (c) on aquatic plants, as potamogetons; *Pisidium Jenynsii* (c) in all clear stagnant water, both in pools and ditches; *Pisidium pulchellum* (c) in muddy and sandy pools and ditches; and most beautiful specimens occur among sphagna in pools of water among the hills; *Pisidium nitidum* (u) together with the last; *Planorbis imbricatus* (+), *Paludina vivipara* (+), *Bithinia tentaculata* (+) found not alive

48. Loch Skene; pools on the banks of Dee
Taylor, 1853
Limnæus pereger ovatus (a)

49. Marshy places, at Old Aberdeen and Bay of Nigg
Taylor, 1853
Limnæus pereger limosus (c)

50. In pools and streams, near the sea, and in the low districts
Taylor, 1853
Limnæus palustris (u)

51. Found in the pool of Belhelvie Links; Hilton quarries
Leg. Wilson (in Taylor, 1853)
Limnæus truncatulus (r)

52. In ditches at Nether Banchory; on *Lemna minor* and potamogetons in the ditches or streams that run into the Dee and Don
Taylor, 1853
Physa fontinalis (c)

53. In a ditch at Banner-mill, and in the links, where it is found on *Poa fluitans, Ranunculus aquatilis,* &c.
Taylor, 1853
Planorbis spirorbis (a)

54. In ditches and pools, upon grass and decayed leaves, in the Old-town links and at Nether Banchory
Taylor, 1853
Planorbis contortus (u)

55. On the leaves of potamogetons in the canal near Aberdeen
Taylor, 1853
Planorbis albus (r)

56. On stones in streams, and the rivers Dee and Don
Taylor, 1853
Ancylus fluviatilis (c)

57. In a pool at Morrison bridge [=Shakkin' Briggie]
Leg. Ewan (in Taylor, 1853)
Cyclas cornea (rr)

58. In the Loch of Skene, ten miles to the west of Aberdeen
Taylor, 1853
Cyclas flavescens (c)

59. In many places, as in a mill-pond near the new bridge of Don
Taylor, 1853
Pisidium pusillum (a)

60. In the canal and the Hilton quarries
Leg. Clark (in Taylor, 1853)
Pisidium amnicum (r)

61. In the St. Fergus canal, Banff
Taylor, 1853

Anodon anatinus (c)

62. In the Dee and the Don, and discovered in great plenty in the burn of Canry [=Canny], at Upper Banchory
Leg. Ewan (in Taylor, 1853)
Alasmodon margaritiferus (c)

63. River Donovan [=Deveron]
Gordon, 1854
Unio margaritiferus (+)

64. Along the shores and on the sandy bottom of the Loch of Skene, in the Loch of Park
Macgillivray, 1855
Cyclas cornea (a)

65. Knæckleith [=Knockleith], Auchterless
Macgillivray, 1855
Pisidium obtusale (+)

66. Widely distributed in Aberdeenshire; inhabiting both still and running water
Macgillivray, 1855
Pisidium pulchellum (a)

67. In a millpond near the new bridge of Don
Macgillivray, 1855
Pisidium nitidum (+)

68. In a millpond near the new bridge of Don
Macgillivray, 1855
Pisidium pusillum (+)

69. St. Fergus canal and near Fraserburgh, Loch of Strathbeg and near Banff
Macgillivray, 1855
Anodonta cygnea (+)

70. In the Dee, the Don, the Ythan, the Ugie and the Doveran [=Deveron], in muddy and gravelly places
Macgillivray, 1855
Unio margaritiferus (c)

71. Dead shells found on the beach near the mouth of the Don, probably derived from ballast
Macgillivray, 1855
Paludina Listeri (+)

72. Dead shells found on the beach near the mouth of the Don, probably derived from ballast
Macgillivray, 1855
Bythinia tentaculata (+)

73. In the Loch of Skene, the Don, and the Dee
Macgillivray, 1855
Physa fontinalis (+)

74. In a ditch filled with stagnant and rather putrid water, in the hollow between Aberdeen and the Spital
Macgillivray, 1855
Planorbis vortex (+)

75. In a ditch at Banner mill, near Aberdeen. In a ditch at the Loch of Strathbeg
Macgillivray, 1855
Planorbis spirorbis (+)

76. Generally distributed in the lower tracts (Aberdeenshire undefined localities)
Macgillivray, 1855
Planorbis contortus (c)

77. On *Potamogeton* in the Aberdeen canal
Macgillivray, 1855
Planorbis albus (+)

78. Aberdeenshire undefined locality
Macgillivray, 1855
Planorbis nautileus? (P. glaber) (+)

79. Common and general (Aberdeenshire undefined localities)
Macgillivray, 1855
Limnæus pereger (c)

80. Generally distributed, and abundant in pools, rivers, brooks and rills, from the coast far into the interior
Macgillivray, 1855
Limnæus truncatulus (a)

81. In pools, lakes, marshy places, and streams; in the maritime and lower inland tracts
Macgillivray, 1855
Limnæus palustris (+)

82. In brooks and rivers; on stones and plants, especially potamogetons
Macgillivray, 1855
Ancylus fluviatilis (a)

83. River Isla, River Deveron in Banff; River Don, River Ythan, River Dee in Aberdeen
Von Hessling, 1859
Unio margaritifer (+)

84. Cruden
Leg. Dawson, 1860, in the Arbuthnot Museum, Peterhead (in McMillan, 1960)
Planorbis vortex? (Planorbis leucostoma det. McMillan) (r)

85. Aberdeenshire
Dickie, 1860
Pisidium pulchellum (+) occurs at 1742 feet, along with *Limneus pereger* (+); the *Pisidium* is also found at 2400 feet

86. Don district
German merchant named Unger, 1861 (in A.W.C.H., 1890 and in Kunz & Stevenson, 1908)
Scottish pearls (+)

87. Muddy or gravelly places of the Dee, though not unfrequent farther down
Crombie, 1861
Pearl mussel (r)

88. Here and there upon stones in the more muddy streams [Dee Basin]
Crombie, 1861
Oval-lid shell *[=Ancylus fluviatilis]* (+)

89. Upon boulders in still water [Dee Basin]
Crombie, 1861
Wandering mud shell *[=Radix balthica]* (+)

90. In ditches and pools of the Dee
Crombie, 1861
Bubble shell [?] (u), *Pisidium* (u), contorted coil shell *[=Bathyomphalus contortus]* (u)

91. Frazerburg [=Fraserburgh] in Aberdeenshire
Jeffreys, 1862
Bythinia tentaculata (+)

92. The most northern limit in these islands appears to be Aberdeenshire
Jeffreys, 1862
Planorbis albus (+)

93. On water-cresses and other aquatic plants in running brooks, as well as in slow rivers, canals, and ditches everywhere in Great Britain, as far north as Aberdeenshire
Jeffreys, 1862
Physa fontinalis (+)

94. Marshes, ditches, and shallow pools everywhere from Aberdeenshire to the Channel Isles
Jeffreys, 1862
Limnæa palustris (+)

95. On stones and rocks in shallow rivers and streams everywhere from Aberdeenshire to the Channel Isles
Jeffreys, 1862
Ancylus fluviatilis (a)

96. In slow rivers, lakes, canals, marshes, and ponds throughout the greater part of the kingdom as far north as Aberdeenshire
Jeffreys, 1862
Ancylus lacustris (+)

97. In a ditch near Aberdeen
Fide Macgillivray (in Tate, 1866)
Pisidium pulchellum (+)

98. It attains an elevation of 1742 feet on the Aberdeenshire mountains
Tate, 1866
Limnæa peregra Burnetti (+)

99. River Ythan, Aberdeenshire
Brodie, 1867
Mussels (+)

100. River Don
Lovell, 1867
Unio margaritiferus (+)

101. Loch of Skene, Loch of Park
Dawson, 1870
Sphærium corneum (+)

102. In the old Inverurie Canal
Leg. Macgillivray (in Dawson, 1870)
Pisidium amnicum (+)

103. In slow streams and standing water of the counties of Aberdeen & Banff
Dawson, 1870
Pisidium fontinale (c)

104. In mossy springs near Collieston, and in similar places in the counties of Aberdeen & Banff
Dawson, 1870
Pisidium pusillum (+), *Pisidium nitidum* (r)

105. St. Fergus canal
Dawson, 1870
Pisidium nitidum (c)

106. Morayshire collection
Fide Jeffreys (in Dawson, 1870)
Pisidium roseum (+)

107. In all our rivers in the counties of Aberdeen & Banff
Dawson, 1870
Unio margaritifer (c)

108. In the Loch of Strathbeg and St. Fergus Canal
Dawson, 1870
Anodonta cygnea (a)

109. One at Aberdeen, probably from ballast
Dawson, 1870
Neritina fluviatilis (rr)

110. One at Aberdeen, one at Torry
Dawson, 1870
Paludina vivipara (rr)

111. Fraserburgh (fide Jeffreys) and Aberdeen probably from ballast
Leg. Macgillivray (in Dawson, 1870)
Bythinia tentaculata (+)

112. On the beach between the Dee and Don
Leg. Macgillivray (in Dawson, 1870)
Valvata cristata (rr)

113. Strathbeg, St. Fergus canal, &c.
Dawson, 1870
Planorbis nitidus (c)

114. Loch of Cortes, and a small loch on Cruden Links
Dawson, 1870
Planorbis nautileus (c)

115. Sand Loch of Slains, &c.
Dawson, 1870
Planorbis albus (+), *Planorbis lævis* (+)

116. In stagnant water of the counties of Aberdeen & Banff
Dawson, 1870
Planorbis spirorbis (c), *Planorbis vortex* (c)

117. Loch of Strathbeg, &c.
Dawson, 1870
Planorbis contortus (c)

118. Loch of Skene, River Don at Kittock's Mills [=Kettocks Mill], on water plants
Leg. Macgillivray (in Dawson, 1870)
Physa fontinalis (+)

119. In ditches and pools of the counties of Aberdeen & Banff
Dawson, 1870
Limnæa peregra (c)

120. In Loch of Strathbeg, &c.
Dawson, 1870
Limnæa palustris (c)

121. In ditches everywhere in the counties of Aberdeen & Banff
Dawson, 1870
Limnæa truncatula (c)

122. In streams in the counties of Aberdeen & Banff
Dawson, 1870
Ancylus fluviatilis (c)

123. St. Fergus canal, on aquatic plants
Dawson, 1870
Ancylus lacustris (a)

124. In estuaries in the counties of Aberdeen & Banff
Dawson, 1870
Hydrobia ulvæ (c)

125. Aberdeen, in shallow slow running streams and stagnant water
Buchanan White, 1874
Planorbis vortex (u)

126. In muddy ponds and streams from Aberdeenshire South
Buchanan White, 1874
Lymnæa palustris (c)

127. Found as far north as Aberdeenshire, living in ponds and adhering to the stems and leaves of plants, as the water-lily, *Iris,* &c.
Buchanan White, 1874
Ancylus lacustris (+)

128. In canals and slow streams. Frazerburgh [=Fraserburgh], Aberdeenshire
Buchanan White, 1874
Bythinia tentaculata (+)

129. From Aberdeenshire and Lerwick
Leg. Jeffreys (in Buchanan White, 1874)
Sphærium corneum flavescens (+)

130. Aberdeenshire
Rimmer, 1880
Bythinia tentaculata (+), *Sphærium corneum flavescens* (+)

131. Inhabits lakes, ponds, and stagnant water as far north as Aberdeenshire
Rimmer, 1880
Planorbis albus (+)

132. Inhabits sluggish rivers, canals, ponds, &c. as far north as the counties of Banff and Perth
Rimmer, 1880
Anodonta cygnea (+)

133. River Don in Aberdeenshire
McKean, 1883
150 specimens from the River Don introduced in 1875 to the River Wandle, between Bridge House, Wallington, and Hackbridge
Unio margaritifer (+)

134. It is not found further north than Aberdeenshire
Adams, 1884
Ancylus fluviatilis (+)

135. Alford
Mason, 1885
Sphærium corneum (rr)

136. Forfarshire, Vice County 90
Taylor & Roebuck, 1885

Pisidium fontinale (+), *Pisidium pusillum* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Planorbis nautileus* (+), *Planorbis spirorbis* (+), *Planorbis contortus* (+), *Limnœa peregra* (+), *Limnœa truncatula* (+)

137. Forfarshire, Vice County 90
Taylor & Roebuck, 1889
Sphœrium corneum (+), *Pisidium pusillum* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Valvata piscinalis* (+), *Valvata cristata* (+), *Planorbis nautileus* (+), *Planorbis albus* (+), *Planorbis parvus* (+), *Planorbis spirorbis* (+), *Planorbis vortex* (+), *Planorbis contortus* (+), *Physa fontinalis* (+), *Limnœa peregra* (+), *Limnœa palustris* (+), *Limnœa truncatula* (+), *Ancylus fluviatilis* (+), *Ancylus lacustris* (+)

138. Kincardineshire, Vice County 91
Taylor & Roebuck, 1889
Limnœa truncatula (+)

139. Aberdeenshire South, Vice County 92
Taylor & Roebuck, 1889
Planorbis spirorbis (+), *Planorbis contortus* (+), *Limnœa peregra* (+), *Ancylus fluviatilis* (+)

140. Aberdeenshire North, Vice County 93
Taylor & Roebuck, 1889
Limnœa palustris (+)

141. Banffshire, Vice County 94
Taylor & Roebuck, 1889
Pisidium nitidum (+)

142. From three or four ponds situated in grounds belonging to the Banner Mills Co., at Aberdeen
Leg. Rae (in Jenkins, 1890)
Physa acuta (a), *Limnœa peregra* (+)

143. River Don, Waterton, near Aberdeen, Aberdeen S.
P. R. Shaw, 1890 (R. S. Coll. and C. Oldham coll.) (in Jackson, 1925)
Margaritana margaritifera (+)

144. Loch Strathbeg, Aberdeenshire
Scott, 1891
Limnœa truncatula (r), *Limnœa peregra* (c), *Pisidium pusillum* (c), *Planorbis spirorbis* (r)

145. Fraserburgh, Aberdeenshire
Fide White (in Roebuck, 1891a)
Bythinia tentaculata (+)

146. Loch Strathbeg near Fraserburgh, Aberdeen N.
Leg. T. Scott (in Roebuck, 1891a)
Planorbis nautileus (+), *Planorbis spirorbis* (+), *Limnœa peregra* (+)

147. Aberdeen (British Museum). Bridge of Don, in stomach of shoveller, Aberdeen S.
Leg. W. Evans (in Roebuck, 1891a)
Planorbis spirorbis (+)

148. Aberdeenshire, Aberdeen S.
Leg. W. Turner for S. C. Cockerell (in Roebuck, 1891a)
Planorbis contortus (+)

149. Aberdeen, Aberdeen S.; Braemar, Aberdeen S.
Leg. W. Nelson, leg. W. Evans (in Roebuck, 1891a)
Limnœa peregra decollatum (+)

150. In stomach of shoveller duck shot at Bridge of Don, Aberdeen S.; Huntly, Aberdeen N.; Loch Strathbeg, Aberdeen N.
Leg. W. Evans, leg. J. Conacher, leg. T. Scott (in Roebuck, 1891a)
Limnœa palustris (+)

151. Stonehaven, Kincardine; in stomach of shoveller shot at Bridge of Don, Aberdeen S.; Braemar, Aberdeen S.
Leg. W. Turner, leg. Evans (in Roebuck, 1891a)
Limnœa truncatula (+)

152. Aberdeenshire, Aberdeen S.; Braemar, Aberdeen S.
Leg. W. Turner, leg. W. Evans (in Roebuck, 1891a)
Ancylus fluviatilis (+)

153. St Fergus Canal near Peterhead, Aberdeen N.
Leg. W. Dawson for G. Gordon (in Roebuck, 1891a)
Ancylus lacustris (+)

154. Braemar, Aberdeen S.
Leg. W. Evans (in Roebuck, 1891a)
Pisidium fontinale (+), *Pisidium pusillum* (+)

155. From stomach of shoveller shot at Bridge of Don, Aberdeen S.
Leg. W. Evans (in Roebuck, 1891a)
Pisidium pusillum (+), *Pisidium pusillum obtusale* (+)

156. From stomach of shoveller shot at Bridge of Don, Aberdeen S.; Braemar, Aberdeen S.; Banffshire, Banff
Leg. W. Evans, leg. W. Evans, leg. A. M. Norman (in Roebuck, 1891a)
Pisidium nitidum (+)

157. R. Deveron (no site given)
Leg. Burnett, 1893 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

158. Loch Skene, South Aberdeenshire
Leg. G. A. F. Frank (in Roebuck, 1895)
Sphœrium corneum (+)

159. Forfar, Vice County 90
Adams, 1896
Planorbis nautileus (+), *Planorbis albus* (+), *Planorbis parvus* (+), *Planorbis spirorbis* (+), *Planorbis vortex* (+), *Planorbis contortus* (+), *Physa fontinalis* (+), *Limnœa peregra* (+), *Limnœa palustris* (+), *Limnœa truncatula* (+), *Ancylus fluviatilis* (+), *Velletia lacustris* (+), *Valvata piscinalis* (+), *Valvata cristata* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Sphœrium corneum* (+), *Pisidium fontinale* (+), *Pisidium pusillum* (+)

160. Kincardine, Vice County 91
Adams, 1896
Limnœa truncatula (+)

161. Aberdeen S., Vice County 92
Adams, 1896
Planorbis nautileus (+), *Planorbis spirorbis* (+), *Planorbis contortus* (+), *Limnœa peregra* (+), *Limnœa palustris* (+), *Limnœa truncatula* (+), *Ancylus fluviatilis* (+), *Sphœrium corneum* (+), *Pisidium fontinale* (+), *Pisidium pusillum* (+), *Pisidium nitidum* (+)

162. Aberdeen N., Vice County 93
Adams, 1896
Planorbis spirorbis (+), *Limnœa peregra* (+), *Limnœa palustris* (+), *Velletia lacustris* (+)

163. Banff, Vice County 94
Adams, 1896
Limnœa peregra (+), *Limnœa auricularia* (+), *Limnœa truncatula* (+), *Ancylus fluviatilis* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Pisidium nitidum* (+)

164. In a pond in Cullen House grounds, Rathven parish, Banffshire
Leg. J. Gowan, 1897 (in Roebuck, 1917a)
Planorbis crista lævigata (r), *Pisidium milium* (u)

165. In moss on Sandend Links, Fordyce parish, Banffshire
Leg. J. Gowan, 1897 (in Roebuck, 1917a)
Pisidium pulchellum (rr)

166. Aberdeen
Marshall, 1899
Hydrobia ulvæ tumida (+)

167. Aberdeen (38/90), Aberdeen South (92)
City of Liverpool Public Museums, before 1900 (in Kerney, 1971)
Hydrobia ulvae (+)

168. Forfarshire, Vice County 90
Taylor & Roebuck, 1901
Sphœrium corneum (+), *Pisidium fontinale* (+), *Pisidium pusillum* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Valvata piscinalis* (+), *Valvata cristata* (+), *Planorbis nautileus* (+), *Planorbis albus* (+), *Planorbis parvus* (+), *Planorbis spirorbis* (+), *Planorbis vortex* (+), *Planorbis contortus* (+), *Physa fontinalis* (+), *Limnœa peregra*

(+), *Limnæa palustris* (+), *Limnæa truncatula* (+), *Ancylus fluviatilis* (+), *Velletia lacustris* (+)

169. Kincardine, Vice County 91
Taylor & Roebuck, 1901
Limnæa truncatula (+)

170. Aberdeenshire South, Vice County 92
Taylor & Roebuck, 1901
Pisidium nitidum (+), *Planorbis spirorbis* (+), *Planorbis contortus* (+), *Limnæa peregra* (+), *Limnæa truncatula* (+), *Limnæa palustris* (+), *Ancylus fluviatilis* (+)

171. Aberdeenshire North, Vice County 93
Taylor & Roebuck, 1901
Limnæa palustris (+), *Velletia lacustris* (+)

172. Banffshire, Vice County 94
Taylor & Roebuck, 1901
Pisidium nitidum (+), *Limnæa peregra* (+), *Limnæa truncatula* (+)

173. 90 Forfar
Adams, 1902
Planorbis nautileus (+), *Planorbis albus* (+), *Planorbis parvus* (+), *Planorbis spirorbis* (+), *Planorbis vortex* (+), *Planorbis contortus* (+), *Physa fontinalis* (+), *Limnæa peregra* (+), *Limnæa palustris* (+), *Limnæa truncatula* (+), *Ancylus fluviatilis* (+), *Velletia lacustris* (+), *Valvata piscinalis* (+), *Valvata cristata* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Sphærium corneum* (+), *Pisidium fontinale* (+), *Pisidium pusillum* (+), *Pisidium nitidum* (+), *Pisidium milium* (+)

174. 91 Kincardine
Adams, 1902
Limnæa truncatula (+)

175. 92 Aberdeen S.
Adams, 1902
Planorbis nautileus (+), *Planorbis spirorbis* (+), *Planorbis contortus* (+), *Limnæa peregra* (+), *Limnæa palustris* (+), *Limnæa truncatula* (+), *Ancylus fluviatilis* (+), *Sphærium corneum* (+), *Pisidium fontinale* (+), *Pisidium pusillum* (+), *Pisidium nitidum* (+)

176. 93 Aberdeen N.
Adams, 1902
Planorbis spirorbis (+), *Limnæa peregra* (+), *Limnæa palustris* (+), *Velletia lacustris* (+)

177. 94 Banff
Adams, 1902
Limnæa peregra (+), *Limnæa auricularia* (+), *Limnæa truncatula* (+), *Ancylus fluviatilis* (+), *Unio margaritifer* (+), *Anodonta cygnea* (+), *Pisidium nitidum* (+)

178. In Ythan estuary
Simpson, 1903
Hydrobia ulvæ (a)

179. Aberdeen
Leg. Marshall (in Simpson, 1903)
Hydrobia ulvæ tumida (+)

180. Ythan estuary
Leg. Marshall, Simpson, 1903
Hydrobia ulvæ decollata (+)

181. In the Bannermill Dam, at Aberdeen
Simpson, 1905
Physa acuta (u), *Limnæa pereger* (+)

182. Rivers Dee, Don and Ythan in Aberdeenshire
Kunz & Stevenson, 1908
Unio margaritifera (a)

183. In the North and South Esk, in the Dee, Don, and Spey, in the Shin and other northern rivers
Stewart, 1909
Unio margaritifer (+)

184. River Ythan, throughout the lower reaches
Simpson, 1910
Unio margaritifera (a)

185. North Ugie Water [=River Ugie], in the vicinity of the fords near Ravenscraig and also between Middleton of Rora and the Mains of Buthlaw
Simpson, 1910 (also in Cosgrove, 1997)
Unio margaritifera (a)

186. The junction of the North and South Ugies as far up as Baluss Bridge
Simpson, 1910 (also in Cosgrove, 1997)
Unio margaritifera (a)

187. Inverugie
Leg. Booth, 1910 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

188. The Ythan, Aberdeenshire
Anonymous, 1913 (also in Woodward, 1994)
Pearls (+)

189. Aberdeen (B.M. 1912.12.5: 62-66); Banchory (R. Dee) (Maj. Connolly), Aberdeenshire North & South
Woodward, 1913
Pisidium casertanum (+)

190. Aberdeen (B.M. 42-9-30: 79-85), Aberdeenshire North & South
Woodward, 1913
Pisidium personatum (+)

191. In boggy ground between Cruden Bay and Old Castle of Slains, Aberdeenshire North
Booth, 1913a
Limnæa truncatula (r)

192. In moist places between Slains New Castle and Boddam, Aberdeenshire North
Booth, 1913a
Limnæa truncatula (c)

193. In a small pond at Sandend, south end of Cruden Bay; in small streams on the sandhills north of the Ugie River, Aberdeenshire North
Booth, 1913a
Limnæa peregra (c)

194. In marshy ground near the River Ugie and near Inverugie, Aberdeenshire North
Booth, 1913a
Pisidium pusillum (c)

195. Small pond at Sandend, south end of Cruden Bay, Aberdeenshire North
Booth, 1913a
Pisidium milium (u)

196. On boggy ground, Belhelvie golf-links, Aberdeenshire South
Booth, 1913b
Limnæa truncatula (c)

197. Small pond in brick-yard near Bridge of Don, Aberdeenshire South
Booth, 1913b
Limnæa peregra (c), *Planorbis crista* (+), *Planorbis crista imbricata* (+), *Pisidium fontinale* (+), *Pisidium pusillum* (+)

198. River Ugie, Aberdeen N
Booth, 1913c
Unio margaritifer (a)

199. A pond at the brick depôt near the Bridge of Don, Aberdeen
Booth, 1913c
Planorbis crista (+), *Limnæa peregra* (+), Pisidia (+)

200. In ditches and wet places, and was collected in every locality visited, along with Pisidia, which could be found in every pond, ditch, stream, or boggy ground in North of Scotland
Booth, 1913c
Limnæa truncatula (u), Pisidia (+)

201. In most places on the sloping banks near the Bridge of Don
Leg. J. Simpson (in Booth, 1913c)
Physa fontinalis (c)

202. In a mill pool in connection with the Banner Mills, Aberdeen

Leg. J. Simpson (in Booth, 1913c)
Physa acuta (a)

203. Among beech leaves in a ditch in Crannoch Wood, Cullen; In a ditch leading into mill-dam at Cruat's [=Cruats] Farm, Portknockie, Rathven parish, Banffshire
Leg. J. Gowan, 1917 (in Roebuck, 1917a)
Pisidium subtruncatum (c)

204. In a ditch at foot of Bin, Rathven parish, Banffshire
Leg. J. Gowan, 1917 (in Roebuck, 1917a)
Pisidium subtruncatum (c), *Pisidium pusillum* (u)

205. In a small weedy stream close to the sea near Cullen, Banffshire
Leg. J. Gowan, 1917 (in Roebuck, 1917a)
Limnæa peregra (u)

206. In a pond in Cullen House grounds, in the parish of Rathven, Banffshire (VC 94)
Leg. J. Gowan, 1917 (in Roebuck, 1917b)
Planorbis albus (a), *Planorbis contortus* (u),

207. On stones in the Loch of Aboyne, Aberdeenshire South (VC 92)
Leg. J. Gowan, 1917 (in Roebuck, 1917b)
Planorbis albus (rr), *Planorbis contortus* (a)

208. Lock of Loriston [=Loirston Loch], Kincardineshire
Leg. J. Simpson (in Roebuck, 1917c)
Limnæa pereger (a)

209. River Don
Leg. Boycott, 1919 (in Jackson, 1925)
Margaritana margaritifera (+)

210. Forfarshire, VC 90
Roebuck, 1921
Ancylus fluviatilis (+), *Ancylus lacustris* (+), *Limnæa peregra* (+), *Limnæa palustris* (+), *Limnæa truncatula* (+), *Planorbis albus* (+), *Planorbis glaber* (+), *Planorbis nautileus* (+), *Planorbis vortex* (+), *Planorbis leucostoma* (+), *Bathyomphalus contortus* (+), *Hippeutis fontanus* (+), *Physa fontinalis* (+), *Valvata piscinalis* (+), *Valvata cristata* (+), *Margaritana margaritifera* (+), *Anodonta cygnea* (+), *Sphærium corneum* (+)

211. Kincardineshire, VC 91
Roebuck, 1921
Limnæa peregra (+), *Limnæa truncatula* (+), *Margaritana margaritifera* (+)

212. Aberdeenshire South, VC 92
Roebuck, 1921
Ancylus fluviatilis (+), *Limnæa peregra* (+), *Limnæa truncatula* (+), *Planorbis albus* (+), *Planorbis nautileus* (+), *Planorbis leucostoma* (+), *Bathyomphalus contortus* (+), *Valvata piscinalis* (+), *Margaritana margaritifera* (+), *Sphærium corneum* (+), *Pisidium casertanum* (+), *Pisidium milium* (+), *Pisidium nitidum* (+), *Pisidium personatum* (+), *Pisidium subtruncatum* (+)

213. Aberdeenshire North, VC 93
Roebuck, 1921
Ancylus lacustris (+), *Limnæa peregra* (+), *Limnæa palustris* (+), *Limnæa truncatula* (+), *Planorbis nautileus* (+), *Planorbis leucostoma* (+), *Margaritana margaritifera* (+)

214. Banffshire, VC 94
Roebuck, 1921
Ancylus fluviatilis (+), *Limnæa auricularia* (+), *Limnæa peregra* (+), *Limnæa truncatula* (+), *Planorbis albus* (+), *Planorbis glaber* (+), *Planorbis nautileus* (+), *Planorbis leucostoma* (+), *Bathyomphalus contortus* (+), *Margaritana margaritifera* (+), *Anodonta cygnea* (+), *Pisidium casertanum* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+), *Pisidium personatum* (+), *Pisidium subtruncatum* (+)

215. R. Don at Monymusk, NJX--Y--
Leg. Smith, 1922 (in Cosgrove, 1997)
1 specimen
Margaritifera margaritifera (rr)

216. R. Don at Monymusk, NJXX-YY-
Leg. Stirton, 1922 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

217. R. Deveron nr Turiff [=Turriff]
Leg. Abernethy, 1922 (in Cosgrove, 1997)
Produced many
Margaritifera margaritifera (a)

218. R. Deveron nr Rothiemay
Leg. Abernethy, 1922 (in Cosgrove, 1997)
Produced many
Margaritifera margaritifera (a)

219. Forfar (90)
Leg. E. Crapper (in Boycott, 1923)
Pisidium casertanum (+), *Pisidium personatum* (+), *Pisidium subtruncatum* (+), *Pisidium nitidum* (+), *Pisidium milium* (+)

220. Forfar (90)
Leg. E. Crapper (in Boycott, 1924)
Paludestrina jenkinsi (+), *Pisidium hibernicum* (+)

221. Aberdeen N. (93)
Leg. F. Booth (in Boycott, 1924)
Pisidium milium (+), *Pisidium personatum* (+), *Pisidium subtruncatum* (+)

222. R. Dee at Arboyne [sic Aboyne], NOX--Y--
Leg. Bromehead < 1925 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

223. R Dee at Park, NOX--Y--
Mussels immediately below Park bri., probably more in deeper water (leg. Thomson, <1925, leg. Kellas, 1970 & leg. Williams, 1978). Mussels on North bank, East of bri and in a side channel, leg. Irvine 1970's (in Cosgrove, 1997)
Margaritifera margaritifera (+)

224. River Esk, Forfar
Edinburgh Mus. (in Jackson, 1925)
Margaritana margaritifera (+)

225. River Dee, near Park, Kincardine
Leg. Prof. J. Arthur Thomson (J. W. J. coll., ex Prof. J. H. Ashworth) (in Jackson, 1925)
Margaritana margaritifera (+)

226. River Dee, near Aberdeen, Aberdeen S.
R. S. coll. (in Jackson, 1925)
Margaritana margaritifera (+)

227. River Dee, near Aboyne, Aberdeen S.
Leg. C. N. Bromehead (in Jackson, 1925)
Margaritana margaritifera (+)

228. Braemar
Coates, 1925
Ancylus fluviatilis (+)

229. R. Don
Leg. Smith, 1926 (in Cosgrove, 1997)
10-15 miles from Aberdeen
Margaritifera margaritifera (+)

230. Banff, Banffshire
P. Burnett's Collection, Banff Museum (in Gowan, 1926)
Limnæa truncatula (+)

231. Deskford, Banffshire
Gowan, 1926
Limnæa truncatula (+)

232. Boyndie, Banffshire
P. Burnett's Collection, Banff Museum (in Gowan, 1926)
Limnæa peregra (+), *Ancylus fluviatilis* (+)

233. Cullen, Banffshire
Gowan, 1926
Limnæa peregra (+), *Planorbis albus* (+), *Planorbis contortus* (+), *Planorbis crista* (+), *Ancylus fluviatilis* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+), *Pisidium personatum* (+)

234. Portknockie, Banffshire
Gowan, 1926
Limnæa peregra lacustris (+)

235. Banffshire
Burnett's Collection, Banff Museum (in Gowan, 1926)
Planorbis leucostoma (+), *Planorbis glaber* (+), *Planorbis albus* (+), *Planorbis crista lævigata* (+)
All labelled *"P. spirorbis"*

236. Sandend, Banffshire
Gowan, 1926
Pisidium casertanum (+)

237. Throughout the British Isles, but not north of Aberdeen
Ellis, 1926
Valvata piscinalis (+)

238. In all fresh waters throughout the British Isles from Banff southwards
Ellis, 1926
Planorbis albus (+)

239. Is recorded from the counties of Fife, Banff and Elgin
Ellis, 1926
Limnæa auricularia (+)

240. Aberdeen
Ellis, 1926
Physa heterostropha (+)

241. Forfar
Ellis, 1926
Planorbis vortex (+)

242. Aberdeen S. (92)
Leg. C. Oldham (in Boycott, 1927)
Pisidium hibernicum (+)

243. Kincardine (91)
Leg. R. Waterston, (in Boycott, 1929)
Ancylus fluviatilis (+)

244. In dam on Luther water, Auchenblae, Kincardineshire
Waterston, 1929
Pisidium personatum (+), *Pisidium pulchellum* (+), *Limnæa truncatula* (rr)

245. In dam on Luther water and also in Bervie, Auchenblae, Kincardineshire
Waterston, 1929
Limnæa pereger (c)

246. Luther and its tributaries, also in the River Bervie, Auchenblae, Kincardineshire
Waterston, 1929
Ancylastrum fluviatile (c)

247. Aberdeen S. (92)
Leg. C. Oldham (in Boycott, 1930)
Ancylus lacustris (+), *Pisidium pulchellum* (+)

248. Kincardine (91)
Leg. J. E. Forrest & A. R. Waterston (in Boycott, 1935)
Paludestrina jenkinsi (+)

249. Aberdeen S. (92)
Leg. J. E. Forrest & A. R. Waterston (in Boycott, 1935)
Limnæa palustris (+), *Physa fontinalis* (+)

250. R. Don at Aberdeen, NJX--Y--
Leg. Kerny < 1937 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

POST-1950 RECORDS (Cosgrove, 1997 *M. margaritifera* grid reference data are encrypted)

251. Forfarshire, VC 90
Ellis, 1951
Valvata cristata (+), *Valvata piscinalis* (+), *Potamopyrgus jenkinsi* (+), *Lymnaea truncatula* (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Physa fontinalis* (+), *Physa* spp. (+), *Planorbis vortex* (+), *Planorbis leucostoma* (+), *Planorbis laevis* (+), *Planorbis albus* (+), *Planorbis crista* (+), *Planorbis contortus* (+), *Segmentina complanata* (+), *Acroloxus lacustris* (+), *Ancylus fluviatilis* (+), *Margaritana margaritifera* (+), *Anodonta cygnea* (+), *Sphaerium corneum* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+)

252. Kincardineshire, VC 91
Ellis, 1951
Potamopyrgus jenkinsi (+), *Lymnaea truncatula* (+), *Lymnaea peregra* (+), *Ancylus fluviatilis* (+), *Margaritana margaritifera* (+)

253. Aberdeenshire South, VC 92
Ellis, 1951
Valvata piscinalis (+), *Lymnaea truncatula* (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Physa fontinalis* (+), *Physa* spp. (+), *Planorbis leucostoma* (+), *Planorbis albus* (+), *Planorbis crista* (+), *Planorbis contortus* (+), *Acroloxus lacustris* (+), *Ancylus fluviatilis* (+), *Margaritana margaritifera* (+), *Sphaerium corneum* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+), *Pisidium pulchellum* (+)

254. Aberdeenshire North, VC 93
Ellis, 1951
Lymnaea truncatula (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Planorbis leucostoma* (+), *Planorbis crista* (+), *Acroloxus lacustris* (+), *Margaritana margaritifera* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+)

255. Banffshire, VC 94
Ellis, 1951
Lymnaea truncatula (+), *Lymnaea auricularia* (+), *Lymnaea peregra* (+), *Planorbis leucostoma* (+), *Planorbis laevis* (+), *Planorbis albus* (+), *Planorbis crista* (+), *Planorbis contortus* (+), *Ancylus fluviatilis* (+), *Margaritana margaritifera* (+), *Anodonta cygnea* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium subtruncatum* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+)

256. Loirston Loch, Cove, Kincardineshire
Hunter & Warwick, 1957
Potamopyrgus jenkinsi (+)

257. Saltings, River North Esk, Kincardineshire
Hunter & Warwick, 1957
Potamopyrgus jenkinsi (+)

258. Cruden Bay, Aberdeen North (93)
Leg. N. F. McMillan (in Ellis, 1957)
Potamopyrgus jenkinsi (+)

259. Loch of Strathbeg
McMillan, 1958 (unpublished data)
Potamopyrgus jenkinsi (+)

260. Cotehill Loch, Aberdeenshire North (v.-c. 93)
Leg. B. Garden (in Richter, 1959)
Potamopyrgus jenkinsi (+)

261. Loch of Strathbeg, Aberdeenshire North (v.-c. 93)
Richter, 1959
Potamopyrgus jenkinsi (+)

262. Cortes Loch, Aberdeenshire North (v.-c. 93)
Richter, 1959
Potamopyrgus jenkinsi (+)

263. Pool nr. Sandend, Banffshire (v.-c. 94)
Richter, 1959
Potamopyrgus jenkinsi (+)

264. Clattering Bridge, Kincardine (91)
Leg. A. D. Berrie (in Ellis, 1959)
Planorbis albus (+), *Planorbis contortus* (+)

265. Loch of Strathbeg, Aberdeen North (93)
Leg. N. F. McMillan (in Ellis, 1959)
Planorbis albus (+), *Segmentina complanata* (+)

266. Cullybhan [sic Cullykhan] Bay, Banff (94)
Leg. N. F. McMillan (in Ellis, 1959)
Potamopyrgus jenkinsi (+)

267. Loch of Strathbeg, Aberdeen North (93)
Leg N. F. McMillan (in Ellis, 1960)
Pisidium nitidum (+)

268. In a stream at Cruden Bay (Aberdeen North VC 93), also in a marsh behind the shingle bar which blocks the debouchure of the Torr Burn into Cullykhan Bay (Banff VC 94)
McMillan, 1960
Potamopyrgus jenkinsi (a)

269. Loch of Strathbeg, Aberdeen North (93)
McMillan, 1960
Planorbis albus (u), *Segmentina complanata* (u), *Pisidium subtruncatum* (+) det. Stelfox, *Pisidium nitidum* (+) det. Stelfox

270. R. Cowie, Stonehaven, NOX--Y--, map 45
Leg. Cuthbert, 1960's (in Cosgrove, 1997)
Live mussels not looked for, but dead shells washed d/s to Stonehaven
Margaritifera margaritifera (+)

271. R. Don at Boat of Kintore, d/s & just past island, NJXXXYYY
Fisherman pers. comm., 1960's (in Cosgrove, 1997)
Margaritifera margaritifera (+)

272. R. Ythan below bri at Methlic, d/s & on opposite bank from village-good pearl found
Leg. Carry, 1960's (in Cosgrove, 1997)
Now appears to be extinct (Cruickshank A. U. S. A, 1960's). No mussels 100 yds d/s to 20 yds up/s of Methlic bri (Williams, 1978)
Margaritifera margaritifera (+)

273. R. Ythan at Ellon
Leg. Cruickshank A. S. A. C., 1960's; leg. Garioch, 1965 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

274. Idoch Water, 38/770493, Aberdeen N.
Morgan & Egglishaw, 1965
Hydrobia jenkinsi (u)

275. R. Don at Dyce, NJXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)
Shells from fishing (1990)
Margaritifera margaritifera (+)

276. R. Don at Inverurie, NJXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

277. R. Don at Devils Rock, NJXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

278. R. Don at Fintray, NJXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

279. R. Ugie at Howes of Buchburn? (Howe of Buchan [Howe o' Buchan] on map), NKXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

280. R. Deveron at Turriff, NJXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)

Dead shells 1990
Margaritifera margaritifera (+)

281. R. Ythan at Fyvie, NJXX-YY-
Leg. Garioch, 1965 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

282. R. Dee at Crathes (nr), NOXX-YY
Leg. Garioch, 1965 & 1990 (in Cosgrove, 1997)
Margaritifera margaritifera (u)

283. Forfar, VC 90
Kerney, 1966
Hydrobia ulvae (+)

284. Kincardineshire, VC 91
Kerney, 1966
Planorbis albus (+), *Planorbis contortus* (+)

285. Aberdeenshire North, VC 93
Kerney, 1966
Potamopyrgus jenkinsi (+), *Planorbis albus* (+), *Segmentina complanata* (+), *Pisidium nitidum* (+)

286. Banffshire VC, 94
Kerney, 1966
Potamopyrgus jenkinsi (+)

287. R. Isla nr Rothiemay
Leg. Kerney, 1967 (in Cosgrove, 1997)
One dead shell found
Margaritifera margaritifera (rr)

288. Braco Burn, north of Keith, Banff (94)
Leg. E. Kellock (in Kerney, 1968)
Pisidium milium (+)

289. Knock, Banff (94)
Leg. E. Kellock (in Kerney, 1968)
Pisidium obtusale (+)

290. In Britain northwards to Aberdeen usually in running water, though sometimes in lakes or large ponds
McMillan, 1968
Physa fontinalis (c)

291. R. Dee at Blackhall, Banchory, NOX--Y--
Leg. Steve?, 1970's (in Cosgrove, 1997)
Mussel beds found by sub-aqua club
Margaritifera margaritifera (+)

292. R. Dee at Dinnet, NOX--Y--
Leg. Irvine, 1970's (in Cosgrove, 1997)
Margaritifera margaritifera (+)

293. Beltie B., trib of R. Dee (Pinned at Bri of Canny), NJX--Y--
Leg. Irvine, 1970's (in Cosgrove, 1997)
Margaritifera margaritifera (+)

294. Beltie B., trib of R. Dee (Pinned at Bri of Canny), NJXX-YY-
Leg. Irvine, 1970's (in Cosgrove, 1997)
A few mussels found
Margaritifera margaritifera (r)

295. R. Don above Cock Bridge on A939, NJX--Y--
Leg. McCormick, 1970's (in Cosgrove, 1997)
Local keeper & McCormick planted several hundred of them (from Spey, fate unknown since then)
Margaritifera margaritifera (a)

296. R. Ugie, NKX--Y--
Leg. McCormick, 1970's (in Cosgrove, 1997)
Several miles searched, almost extinct
Margaritifera margaritifera (+)

297. R. Don at Fintray, NJX--Y--
Leg. Craig, 1970's (in Cosgrove, 1997)
Margaritifera margaritifera (+)

298. River Ythan estuary
Anderson, 1971
Hydrobia ulvae (a)

299. R. Dee from tide to just above Arboyne [sic Aboyne]
Leg. McCormick 1972 (in Cosgrove, 1997)
Common in many parts
Margaritifera margaritifera (c)

300. Strathbeg, NK0--5--
Young, 1973 (unpublished data)
Potamopyrgus jenkinsi (+), *Lymnaea peregra* (+), *Acroloxus lacustris* (+)

301. Loch of Strathbeg
Bourne *et al.,* 1973
Potamopyrgus jenkinsi (a)

302. R. Don from Waterton to Kemnay, NJX--Y--
Leg. McCormick, 1973 (in Cosgrove, 1997)
Very scarce
Margaritifera margaritifera (r)

303. R. Ythan at Ellon bri to Michael Muir bri [=Bridge of Auchedly at Ythanbank] on B9005, NJX--Y--
Leg. McCormick, 1973 (in Cosgrove, 1997)
Almost extinct, 2 mussels
Margaritifera margaritifera (r)

304. R. Deveron from tide at Banff (Duff Ho) to Turiff [sic Turriff], NJX--Y---
Leg. McCormick [?], 1973 (in Cosgrove, 1997)
V scarce
Margaritifera margaritifera (r)

305. Strathbeg, NK0--5--
Young, 1974 (unpublished data)
Bathyomphalus contortus (+), *Gyraulus laevis* (+), *Gyraulus albus* (+), *Gyraulus crista* (+), *Hippeutis complanatus* (+)

306. River Don, Dyce, NJ8--1--
Young, 1974 (unpublished data)
Bathyomphalus contortus (+)

307. Loch Urotachan [sic Vrotachan], 37/1278, Aberdeen South (92)
Leg. M. J. Bishop (in Kerney, 1974)
Pisidium lilljeborgii (+)

308. Strathbeg, NK0--5--
Young, 1975 (unpublished data)
Ancylus fluviatilis (+)

309. Peterculter, 38/8204, Aberdeen South (92)
Leg. E. Kellock (in Kerney, 1975)
Potamopyrgus jenkinsi (+)

310. Loch of Strathbeg, 48/0758, Aberdeen North (93)
Leg. M. R. Young (in Kerney, 1975)
Planorbis laevis (+), *Planorbis contortus* (+)

311. Wells of Ythan, NJ6--3--
Young, 1975 (unpublished data)
Lymnaea peregra (+)

312. River Ythan, Logie Buchan, NJ9--2--
Young, 1975 (unpublished data)
Gyraulus albus (+)

313. River Ythan, Gight, NJ8--3--
Young, 1975 (unpublished data)
Potamopyrgus jenkinsi (+), *Ancylus fluviatilis* (+)

314. Corby Loch, NJ9--1--
Young, 1975 (unpublished data)
Physa fontinalis (+)

315. R. Dee at Peterculter, on big bend SW of Peterculter (just up/s)
Leg. M. R. Young, 1975 (in Cosgrove, 1997)
Dead shells
Margaritifera margaritifera (+)

316. B. of Gairn, above Candacraig, NOX--Y--, map 37
Leg. McCormick, 1975 (in Cosgrove, 1997)
None found [by Cosgrove?]. But search was made too far up/s. Shells were reported as scarce already
Margaritifera margaritifera (r)

317. R. Deveron, just below Turiff [sic Turriff]

Leg. McCormick, 1976 (in Cosgrove, 1997)
30 specimens
Margaritifera margaritifera (a)

318. Corby Loch, NJ9--1--
Young, 1976 (unpublished data)
Sphaerium corneum (+), *Lymnaea palustris* (+), *Gyraulus albus* (+)

319. Strathbeg, NK0--5--
Young, 1976 (unpublished data)
Sphaerium corneum (+), *Sphaerium lacustre* (+)

320. River Ythan, Gight, NJ8--3--
Young, 1976 (unpublished data)
Lymnaea peregra (+)

321. River Ythan, Auchterless, NJ7--4--
Young, 1976 (unpublished data)
Bathyomphalus contortus (+), *Ancylus fluviatilis* (+)

322. Tillycorthie Pond, NJ9--2--
Young, 1976 (unpublished data)
Gyraulus albus (+)

323. R. Dee at Park Ho, NOX--Y--
4 large mussel beds seen whilst diving at Park Ho, leg. Coroon 1977. Plenty at Park Ho in a shallow arm of river nr hut, leg. Williams, 1978. Still common with juv's, leg. Young & Hastie, 1996 (in Cosgrove, 1997)
Margaritifera margaritifera (a)

324. River Ythan
Davidson, 1977
Pisidium sp. (+), *Ancylus fluviatilis* (r), *Lymnaea peregra* (a), *Potamopyrgus jenkinsi* (a), *Planorbis contortus* (c)

325. Little Water, River Ythan left tributary
Davidson, 1977
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (a), *Ancylus fluviatilis* (r)

326. Loch of Strathbeg
Forteath, 1977
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (a), *Lymnaea palustris* (r), *Planorbis albus* (r), *Planorbis laevis* (a), *Planorbis contortus* (a), *Planorbis crista* (c), *Segmentina complanata* (r), *Acroloxus lacustris* (r), *Anodonta anatina* (r), *Sphaerium corneum* (r), *Sphaerium lacustre* (r), *Pisidium nitidum* (a), *Pisidium subtruncatum* (a), *Pisidium casertanum* (a), *Pisidium amnicum* (r)

327. Loch Muick, NO2--8--
Young, 1977 (unpublished data)
Lymnaea peregra (+)

328. Corby Loch, NJ9--1--
Young, 1977 (unpublished data)
Potamopyrgus jenkinsi (+), *Lymnaea peregra* (+)

329. Tillycorthie Pond, NJ9--2--
Young, 1977 (unpublished data)
Potamopyrgus jenkinsi (+), *Lymnaea peregra* (+), *Gyraulus crista* (+)

330. Pitfour Loch, NJ9--4--
Young, 1977 (unpublished data)
Potamopyrgus jenkinsi (+), *Gyraulus albus* (+), *Planorbarius corneus* (+)

331. Culter Dam, NJ8--0--
Young, 1977 (unpublished data)
Sphaerium corneum (+), *Potamopyrgus jenkinsi* (+), *Lymnaea peregra* (+), *Gyraulus laevis* (+), *Gyraulus albus* (+), *Ancylus fluviatilis* (+)

332. Afforsk Pond, NJ6--1--
Young, 1977 (unpublished data)
Sphaerium corneum (+), *Lymnaea peregra* (+), *Gyraulus albus* (+)

333. Feugh at Birse, NO5--9--
Young, 1977 (unpublished data)
Lymnaea peregra (+), *Ancylus fluviatilis* (+)

334. River Dee Cults, NJ9--0--
Young, 1977 (unpublished data)
Potamopyrgus jenkinsi (+), *Lymnaea peregra* (+), *Ancylus fluviatilis* (+)

335. Botany Gardens Aberdeen, NJ9--0--
Young, 1977 (unpublished data)
Lymnaea peregra (+)

336. Loch of Strathbeg, 48/0759, Aberdeen North (93)
Leg. M. R. Young (in Kerney, 1977)
Anodonta anatina (+), *Sphaerium corneum* (+), *Sphaerium lacustre* (+), *Pisidium amnicum* (+), *Pisidium casertanum* (+)

337. River Don at Parkhill Bridge, Mains of Dyce
Raeburn, 1978
Lymnaea peregra (a), *Ancylus fluviatilis* (a)

338. River Don at Persley, above sewage effluent
Raeburn, 1978
Lymnaea peregra (a), *Ancylus fluviatilis* (a)

339. River Don at Grandholm Bridges
Raeburn, 1978
Lymnaea peregra (u), *Ancylus fluviatilis* (a)

340. Loch Davan, NJ4--0--
Young, 1978 (unpublished data)
Sphaerium corneum (+), *Valvata piscinalis* (+), *Potamopyrgus jenkinsi* (+), *Physa fontinalis* (+), *Lymnaea peregra* (+), *Gyraulus laevis* (+), *Gyraulus albus* (+), *Gyraulus crista* (+)

341. Pitfour Loch, Old Deer, 38/9748 (probably introduced 'about 40 years ago'), Aberdeen North (93)
Leg. M. R. Young (in Kerney, 1978)
Planorbarius corneus (+)

342. R. North Esk at St Cyrus, NOXX-YY- (according to Woodward, 1993)
Leg. Aikman, 1978 (in Cosgrove, 1997)
1 shell found
Margaritifera margaritifera (rr)

343. R. Dee at Banchory, NOX--Y--
Leg. Marren, 1978 (in Cosgrove, 1997)
Shells on bank just up/s from bri
Margaritifera margaritifera (+)

344. R. Dee at Banchory, NOX--Y--
Leg. Lowell, 1978 (in Cosgrove, 1997)
On path next to golf course
Margaritifera margaritifera (+)

345. R. Don up/s of Inverurie, NJX--Y--
Leg. Davidson, 1978 (in Cosgrove, 1997)
Dead shells
Margaritifera margaritifera (+)

346. R. Ythan at Ellon
Leg. Williams, 1978 (in Cosgrove, 1997)
2 huge mussels from M M bri to wooden foot-bri up/s
Margaritifera margaritifera (r)

347. Loch Davan
Reade, 1979
Acroloxus lacustris (c), *Lymnaea palustris* (rr), *Lymnaea peregra* (a), *Physa fontinalis* (a), *Planorbis albus* (a), *Planorbis contortus* (a), *Planorbis laevis* (r), *Potamopyrgus jenkinsi* (a), *Valvata piscinalis* (c)

348. Lake Kinord, NO4--9--
Young, 1979 (unpublished data)
Physa fontinalis (+), *Lymnaea peregra* (+), *Gyraulus albus* (+), *Acroloxus lacustris* (+)

349. Loch Davan, 38/4400, Aberdeen South (92)
Leg. M. R. Young (in Kerney, 1979)
Gyraulus laevis (+)

350. R. Dee at Banchory, NOXXXYYY
Leg. Owen, 1979 (in Cosgrove, 1997)
One mussel 2.5km d/s from Banchory bri opposite village of Mill
Margaritifera margaritifera (rr)

351. R. Ugie, NKX--Y--
Leg. Sinclair, 1979-80 (in Cosgrove, 1997)

6 mussels killed 100 yds d/s of bri & castle at Inverugie
Margaritifera margaritifera (+)

352. R. Don from Inverurie to Kemnay & on to Monymusk
Leg. Young, Purser & Williams, 1979 & 1984 (in Cosgrove, 1997)
Very few specimens left, all large heavy dark shells very difficult to find
Margaritifera margaritifera (r)

353. R. Ugie at Artlaw
Leg. Williams, 1980 (in Cosgrove, 1997)
5 mussels killed just d/s of Middleton of Rora
Margaritifera margaritifera (r)

354. Botany Gardens Aberdeen, NJ9--0--
Young, 1980 (unpublished data)
Planorbis planorbis (+)

355. R. Don, Aberdeen, 38/9309, Aberdeen South (92)
Leg. M. B. Davidson (in Kerney, 1981)
Hippeutis complanatus (+)

356. River Dee, Aberdeenshire
Leg. Young, 1982 (in Young *et al.*, 1987)
Margaritifera margaritifera (+)

357. Forfarshire, VC 90
Kerney, 1982
Valvata cristata (+), *Valvata piscinalis* (+), *Hydrobia ulvae* (+), *Potamopyrgus jenkinsi* (+), *Physa fontinalis* (+), *Lymnaea truncatula* (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Anisus leucostoma* (+), *Anisus vortex* (+), *Bathyomphalus contortus* (+), *Gyraulus laevis* (+), *Gyraulus albus* (+), *Armiger crista* (+), *Hippeutis complanatus* (+), *Ancylus fluviatilis* (+), *Acroloxus lacustris* (+), *Margaritifera margaritifera* (+), *Sphaerium corneum* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+)

358. Kincardineshire, VC 91
Kerney, 1982
Potamopyrgus jenkinsi (+), *Lymnaea truncatula* (+), *Lymnaea peregra* (+), *Bathyomphalus contortus* (+), *Gyraulus albus* (+), *Ancylus fluviatilis* (+), *Margaritifera margaritifera* (+)

359. Aberdeenshire South, VC 92
Kerney, 1982
Valvata piscinalis (+), *Hydrobia ulvae* (+), *Potamopyrgus jenkinsi* (+), *Physa fontinalis* (+), *Lymnaea truncatula* (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Bathyomphalus contortus* (+), *Gyraulus laevis* (+), *Gyraulus albus* (+), *Armiger crista* (+), *Hippeutis complanatus* (+), *Ancylus fluviatilis* (+), *Acroloxus lacustris* (+), *Margaritifera margaritifera* (+), *Sphaerium corneum* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+), *Pisidium lilljeborgii* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+), *Pisidium pulchellum* (+)

360. Aberdeenshire North, VC 93
Kerney, 1982
Potamopyrgus jenkinsi (+), *Lymnaea truncatula* (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Anisus leucostoma* (+), *Bathyomphalus contortus* (+), *Gyraulus laevis* (+), *Gyraulus albus* (+), *Armiger crista* (+), *Hippeutis complanatus* (+), *Planorbarius corneus* (+), *Ancylus fluviatilis* (+), *Acroloxus lacustris* (+), *Margaritifera margaritifera* (+), *Anodonta anatina* (+), *Sphaerium corneum* (+), *Sphaerium lacustre* (+), *Pisidium amnicum* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+), *Pisidium nitidum* (+)

361. Banffshire, VC 94
Kerney, 1982
Potamopyrgus jenkinsi (+), *Lymnaea truncatula* (+), *Lymnaea auricularia* (+), *Lymnaea peregra* (+), *Bathyomphalus contortus* (+), *Gyraulus albus* (+), *Armiger crista* (+), *Ancylus fluviatilis* (+), *Margaritifera margaritifera* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+), *Pisidium obtusale* (+), *Pisidium milium* (+), *Pisidium subtruncatum* (+), *Pisidium hibernicum* (+), *Pisidium nitidum* (+)

362. Loch of Aboyne, NO5--9--
Young, 1983 (unpublished data)
Potamopyrgus jenkinsi (+), *Physa fontinalis* (+), *Lymnaea truncatula* (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Bathyomphalus contortus* (+), *Gyraulus albus* (+)

363. River Dee, Aberdeenshire (Maryculter), NO 8--9--
Young & Williams, 1983b
Margaritifera margaritifera (u)

364. Eigie Burn, Balmedie, NJ9--1--
Young, 1984 (unpublished data)
Potamopyrgus antipodarum (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Gyraulus albus* (+), *Ancylus fluviatilis* (+)

365. Loch of Aboyne, 37/5399, Aberdeen South (92)
Leg. M. R. Young (in Kerney, 1984)
Anisus leucostoma (+)

366. River Dee, Aberdeenshire
Young & Williams, 1984
Margaritifera margaritifera (+)

367. Loch Saugh, 37/6778, Kincardine (91)
Leg. N. K. Atkinson, 1984 (in Kerney, 1986)
Valvata piscinalis (+)

368. Loch Wee, Edzell, 37/6269, Kincardine (91)
Leg. N. K. Atkinson, 1984 (in Kerney, 1986)
Pisidium subtruncatum (+), *Pisidium nitidum* (+)

369. River Dee catchment
Davidson *et al.*, 1985
Potamopyrgus jenkinsi (+), *Lymnaea peregra* (+), *Physa fontinalis* (+), *Planorbis albus* (+), *Planorbis contortus* (+), *Ancylus fluviatilis* (+), *Sphaerium* spp. (+), *Pisidium* spp. (+)

370. R. Dee Ballater to Braemar
Leg. Richard, 1985 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

371. River Ythan at Gight Castle, NJXXXYYY
Leg. Young, 1986 (in Cosgrove, 1997)
Freshly dead shell. 2 live specimens + several dead shells following floods (leg. Young & Hastie, 1996)
Margaritifera margaritifera (+)

372. River Dee at Inver
Moore, 1987
Margaritifera margaritifera (+)

373. R. Don, NJXX-YY-
Leg. McCormick, 1989 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

374. R. Ugie, NKXX-YY-
Leg. McCormick, 1989 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

375. Loch of Strathbeg
McLean, 1990
Potamopyrgus jenkinsi (a), *Anodonta anatina* (r)

376. Potterton Burn
Jones, 1991
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (u), *Ancylus fluviatilis* (r), *Sphaerium* (r)

377. Den Burn
Jones, 1991
Potamopyrgus jenkinsi (r), *Lymnaea peregra* (r), *Ancylus fluviatilis* (r)

378. Glashie How Burn
Jones, 1991
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (a), *Planorbis contortus* (r-c), *Segmentina complanata* (r)

379. Leggart Burn
Jones, 1991
Potamopyrgus jenkinsi (a), *Planorbis contortus* (r), *Ancylus fluviatilis* (r)

380. Fasque Loch, 37/6575, Kincardine (91)
Leg. J. Milne (in Kerney, 1992)
Anodonta anatina (+)

381. Loch Callater, NO180843
Morrison & Harriman, 1992
Limnaea peregra (+), *Ancylus fluviatilis* (+), *Pisidium* spp. (+)

382. Loch Muick, NO300835
Morrison & Harriman, 1992
Limnaea peregra (+)

383. Scotston Mow [=Scotstown Moor], NJ9--1--
Young, 1992 (unpublished data)
Lymnaea truncatula (+), *Lymnaea palustris* (+), *Lymnaea peregra* (+), *Bathyomphalus contortus* (+)

384. Ditch left tributary of Black Water, St. Fergus Gas Terminal
Stevenson, 1992
Hydrobiidae (a), *Lymnaea peregra* (a), Sphaeriidae (+)

385. Kessock Burn, Fraserburgh
Stevenson, 1992
Hydrobiidae (a), *Lymnaea peregra* (+), Sphaeriidae (+)

386. Kelly Burn, Haddo House, Methlick
Heyes, 1993
Potamopyrgus jenkinsi (a), *Ancylus fluviatilis* (r), *Pisidium* spp. (a), *Planorbis albus* (c), *Sphaerium corneum* (rr)

387. Haddo Lake, Haddo House, Methlick
Heyes, 1993
Planorbis albus (r), *Pisidium* spp. (c), *Potamopyrgus jenkinsi* (rr), *Segmentina complanata* (rr)

388. Kelly Lake, Haddo House, Methlick
Heyes, 1993
Planorbis albus (a), *Pisidium* spp. (a), *Lymnaea peregra* (a), *Sphaerium corneum* (a), *Valvata piscinalis* (a), *Potamopyrgus jenkinsi* (a), *Segmentina complanata* (r)

389. R. North Esk, Tarfside, NOXX-YY-
Leg. Woodward, 1993 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

390. R. Dee at Kincardine O'Neil, NOXXXYYY
Leg. Woodward & McMillan, 1994 (in Cosgrove, 1997)
12 specimens
Margaritifera margaritifera (c)

391. R. Dee at Park Ho/Drum Oak, NOXXXYYY
Leg. Woodward & McMillan, 1994 (in Cosgrove, 1997)
28 specimens
Margaritifera margaritifera (a)

392. R. Dee at Banchory Golf Course, NOXXXYYY
Leg. Woodward & McMillan, 1994 (in Cosgrove, 1997)
15 specimens
Margaritifera margaritifera (c)

393. R. Dee at Mill Village, NOXXXYYY
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

394. R. Dee, NJXX-YY-
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

395. R. Dee at Dinnet, NOXX-YY-
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

396. R. Dee, NOXX-YY-
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

397. R. Dee at Park bri/Banchory, NOXX-YY-
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

398. R. Dee at Banchory/Park Ho, NOXX-YY-
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

399. R. Dee up/s Park bri, NOXX-YY-
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

400. Ythan Estuary: Foveran Burn, OSGR [NK]003255; Waterside Bridge, OSGR [NK]002268; Bend of Tarty, OSGR [NJ]996273; Sleek of Tarty, OSGR [NJ]998278; Sheepfold, OSGR [NK]006284
Huxham *et al.*, 1995
Hydrobia ulvae (a)

401. Strathbeg, NK0--5--
Young, 1996 (unpublished data)
Anodonta anatina (+)

402. Bronie Burn
Mackay, 1996
Potamopyrgus jenkinsi (a)

403. R. Dee at Banchory, NOX--Y--
Leg. Hastie, 1996 (in Cosgrove, 1997)
Still quite common, but overfished
Margaritifera margaritifera (c)

404. R. Don at Strathdon village
Smith, 1996 > (in Cosgrove, 1997)
Trout hatchery workers report mussel shells occasionally washed down during spates
Margaritifera margaritifera (+)

405. R. Ythan at Ythan Bank bri up/s for 400 yds
Leg. Milne, 1996 (in Cosgrove, 1997)
Formerly good area for mussels. 1 live mussel washed down (leg. Young & Hastie, 1996)
Margaritifera margaritifera (rr)

406. R. Deveron at Drachlaw, NJXXXYYY
Leg. McGregor, 1996 (in Cosgrove, 1997)
One dead shell
Margaritifera margaritifera (rr)

407. R. Dee at Kincardine O'Neil, NOXXXYYY
Leg. Woodward, 1995 (in Cosgrove, 1997)
Margaritifera margaritifera (+)

408. R. Isla, NJXXXYYY, map 28/29
Cosgrove, 1997
Margaritifera margaritifera (+)

409. R. Don at Dyce, NJXX-YY-
No date (Cosgrove, 1997)
Margaritifera margaritifera (+)

410. R. Ugie at Fetterangus, NJX--Y--
Hearsay, Sinclair, no date (in Cosgrove, 1997)
Margaritifera margaritifera (+)

411. Fourdoun [sic Fordoun] B. at Fisherford on B992, NJX--Y--
Heresay [sic Hearsay], Sinclair, no date (in Cosgrove, 1997)
Headwaters of trib of Ythan which joins at Fyvie
Margaritifera margaritifera (+)

412. Ebrie B., Aughnagatt [sic Auchnagatt] to Ythan, NJX--Y--
Heresay [sic Hearsay], Sinclair, no date (in Cosgrove, 1997)
More shells near Ythan
Margaritifera margaritifera (+)

413. Ythan Estuary, OSGR NJ[sic NK]0026
Collier & Pinn, 1998
Hydrobia ulvae (a)

414. River Ythan, Logie Buchan, NJ9-2-
Young, 1998 (unpublished data)
Hydrobia ulvae (+)

415. Bend of Tarty on the Ythan Estuary at Newburgh, Aberdeenshire, OSGR NJ996273
Field & Irwin, 1999
Hydrobia ulvae (a)

416. Strichen Loch, 38/9454, Aberdeen North (93)
Leg. T. Huxley (in Kerney, 1999a)
Pisidium obtusale (+)

417. Loch of Strathbeg, Aberdeenshire
Kerney, 1999b
Anodonta anatina (+)

418. Loch of Strathbeg
Parrot, 1999
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (u), *Planorbis albus* (u), *Planorbis contortus* (r), *Planorbis laevis* (r), *Ancylus fluviatilis* (u), *Pisidium* (+), Sphaeriidae (+)

419. Two ponds in the Lochter commercial fishery, Oldmeldrum
Dunn, 2001
Hydrobia jenkinski [sic *jenkinsi]* (a), *Limnaea pereger* (+)

420. Tarfside, 37/4979, Forfar (90)
Leg. T. Huxley (in Kerney, 2001)
Pisidium obtusale (+)

421. Distillery Burn, Oldmeldrum
Stenhouse, 2002
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (c), Sphaeriidae (u)

422. Meadow Burn, Oldmeldrum
Stenhouse, 2002
Potamopyrgus jenkinsi (a), *Lymnaea peregra* (a), *Planorbis albus* (rr), *Ancylus fluviatilis* (a), Sphaeriidae (a)

423. Botany Gardens Aberdeen, NJ9--0--
Young, 2003 (unpublished data)
Planorbis planorbis (+)

424. River Dee on Invercauld Estate
Anonymous, 2005
Reintroduced specimens
Margaritifera margaritifera (+)

425. Maryculter near Aberdeen
Leg. S. P. Dance, 2010 (in Norris, 2011)
Planorbis planorbis (+)

426. Haughton Country Park, NJ577165 South Aberdeenshire (VC 92)
Leg. A. T. Sumner, 2012 (in Norris, 2013)
Musculium lacustre (+)

ROYAL EDINBURGH MUSEUM RECORDS

Dry collection

1. *Lymnaea truncatula,* Reg. No. NMSZ: 1919.11.45
Original tag: *Limnaea truncatula* common
Boggy ground. Belhelvie Golf Links. Aberdeen S. 14.6.1910
RME label: v.c. 92. 38/9417
Det. Pettinelli: *Galba truncatula,* 9 specimens

2. *Pisidium*, Reg. No. NMSZ: 1919.11.40
In pond in brickyard behind Bridge of Don. Aberdeen S. 13.8.1910
RME label: Bridge of Don 13.8.1910, v.c. 92 38/9409
Det. Pettinelli: *Pisidium subtruncatum,* 29 specimens + 8 right valves + 4 left valves
Det. Pettinelli: *Pisidium nitidum,* 23 specimens + 4 right valves + 5 left valves
Det. Pettinelli: *Pisidium casertanum,* 4 specimens
Det. Pettinelli: *Pisidium milium,* 3 specimens

3. *Lymnaea peregra,* Reg. No. NMSZ: 1919.11.41
Original tag: *Limnaea pereger.* Common but small
Pond in brickyard behind Bridge of Don. Aberdeen S. 13.8.1910
RME label: v.c. 92. 38/9409
Det. Pettinelli: *Radix balthica,* 14 specimens

4. *Armiger crista,* Reg. No. NMSZ: 1919.11.42
Original tag: *Planorbis crista*. scarce.
Pond in brickyard behind Bridge of Don. Aberdeen S. 13.8.1910
RME label: v.c. 92 38/9409
Det. Pettinelli: *Gyraulus crista,* 2 specimens

5. *M. margaritifera,* Reg. No. NMSZ: 1919.11.76
R. Ugie, v.c. 93,? 48/
Det. Pettinelli: *Margaritifera margaritifera,* 1 specimen, 2 right valves, 1 left valve

6. *Lymnaea peregra,* Reg. No. NMSZ: 1919.11.83
Original tag: *Limnaea pereger.* On *Potamogeten* [sic *Potamogeton]?*
In small pond at Sandend, South of Cruden Bay Aberdeen N. 15.8.1910
Det. Pettinelli: *Radix balthica,* 9 specimens

7. *Lymnaea truncatula,* Reg. No. NMSZ: 1919.11.87
Original tag: *Limnaea truncatula.* Not Common & very small.
On the ground in wet places between Cruden Bay & Old Slain Castle, Aberdeen N. 15.8.10
RME label: v.c. 93. 4-8103
Det. Pettinelli: *Galba truncatula,* 2 specimens

8. *Lymnaea peregra,* Reg. No. NMSZ: 1919.11.95
Original tag: *Limnaea pereger.* Common in streams. In small streams on sandhills North of R. Ugie Aberdeen N. 17.8.1910
Det. Pettinelli: *Radix balthica,* 21 specimens + 1 fragment

9. Fresh-water Pearl mussel, *Unio (Margaritana) margaritifera,* Reg. No. NMSZ: 1922.87
R. Don at Monymusk, Leg Smith
On a label present in one of the boxes is written:
'Shells opened by pearl-hunters on the River Don at Monymusk, summer 1922. Presented by Alfred Smith, 191 Union Street, Aberdeen'.
Det. Pettinelli: *Margaritifera margaritifera,* 11 specimens, 1 right valve with an aborted pearl, 2 left valve, 4 fragments of a right valve

10. *Ancylus fluviatilis,* Reg. No. NMSZ: 1959.21.634
Original tag: *Ancylus fluviatilis* Mull.
Auchenblae, 13.8.1928 v.c. 91. 37/77
Det. Pettinelli: *Ancylus fluviatilis,* 2 specimens

11. *Lymnaea peregra,* Reg. No. NMSZ: 1968.68
Original tag: *Limnaea pereger.* (9)
Loch of Skene (Aberdeen) rejectamenta a.c.s. 30.1.30 D. K. Kevan Collection, 1968.68
Det. Pettinelli: *Radix balthica,* 33 specimens

12. *Lymnaea palustris,* Reg. No. NMSZ: 1959.21.241
Original tag: *Lymnaea palustris* (Mull.)
Loch Skene, Aberdeensh. S. v.c. 92, 8.9.1934 J. E. Forrest & A. R. W. e. coll. A. R. Waterston
Det. Pettinelli: *Stagnicola palustris,* 1 specimen

13. *Lymnaea peregra,* Reg. No. NMSZ: 1959.21.363
Original tag: *Lymnaea perega* [sic *peregra]* (Mull.)
Loch Skene, Aberdeen S., v.c. 92, 8.9.1934 e. coll. A. R. Waterston
Det. Pettinelli: *Radix balthica,* 4 specimens

14. *Physa fontinalis,* Reg. No. NMSZ: 1959.21.457
Original tag: *Physa fontinalis* (L.).
Loch Skene, Aberdeen S., v.c. 92, 8.9.1934 J. E. Forrest & A. R. W. e. coll. A. R. Waterston
Det. Pettinelli: *Physa fontinalis,* 9 specimens

15. *Planorbis albus,* Reg. No. NMSZ: 1959.21.546
Original tag: *Planorbis albus* Muller, one var. albina,
Loch Skene, Aberdeensh. S., v.c. 92, 8.9.1934. 38/70 e. coll. A. R. Waterston
Det. Pettinelli: *Gyraulus albus,* 3 specimens

16. *Planorbis contortus,* Reg. No. NMSZ: 1959.21.592
Original tag: *Planorbis contortus* (L.)
Loch Skene, Aberdeensh. S., 8.9.34 J. E. Firw. coll v.c. 92, 8.9.1934 38/70 e. coll. A. R. Waterston
Det. Pettinelli: *Bathyomphalus contortus,* 5 specimens

17. *Potamopyrgus antipodarum,* Reg. No. NMSZ: 1959.21.85
Original tag: *Potamopyrgus jenkinsi* (Smith)
Saltings mouth of R. N. Esk, North side, v.c. 91 28.7.1955 e. coll. A. R. Waterston
RME label: NHR NO/5078
Det. Pettinelli: *Potamopyrgus antipodarum,* 18 specimens

18. *Lymnaea?,* Reg. No. NMSZ: 2005004.015
Original tag: Pond near to S. at Mossat, Duruft? (word unreadable in the label)
7.Aug.58 T. Huxley in vegetation (ex Huxley collection)
Det. Pettinelli: *Stagnicola* cf. *palustris,* 1 specimen

19. *Potamopyrgus antipodarum,* Reg. No. NMSZ: 2000376.002
Original tag: *Potamopyrgus jenkinsi*
Boyndie Bay, Banff August 1973 coll. H. Dott Banffshire VC 94
Det. Pettinelli: *Potamopyrgus antipodarum,* 3 specimens

20. *Potamopyrgus antipodarum,* Reg. No. NMSZ: 2000376.003
Original tag: *Potamopyrgus jenkinsi*
Water of Cruden Cruden Bay/Port Errol August 1973 Coll: H. Dott
RME label: North Aberdeenshire VC 93
Det. Pettinelli: *Potamopyrgus antipodarum,* 26 specimens

21. *M. margaritifera,* Reg. No. NMSZ: 1961.61
R. Dee, Banchory, Kincardineshire, v.c. 91, leg. Evans, e coll. A. E. Salisbury
Det. Pettinelli: *Margaritifera margaritifera,* 4 specimens

22. *Unio margaritifera* (L.), Reg. No. NMSZ: 1961.61
R. Dee Scotland, e coll. A. E. Salisbury
Det. Pettinelli: *Margaritifera margaritifera,* 1 specimen

23. *Unio margaritifer* (Linn.), Reg. No. NMSZ: 1961.61
Cannal, Aberdeen, v.c. 92, e coll. A. E. Salisbury
Det. Pettinelli: *Margaritifera margaritifera,* 1 specimen

24. *M. margaritifera* (Linn.), Reg. No. NMSZ: 1961.61
R. Don, Waterton, Aberdeensh., v.c. 92, e coll. A. E. Salisbury
Det. Pettinelli: *Margaritifera margaritifera,* 3 specimens, 1 left valve, 1 right valve

Wet collection

1. *Physa acuta* (Draparnaud), Reg. No. NMSZ: 1976.45.11
Pond Hazlehead Park, Aberdeen VC 92 38/99, D W McKay
Det. Pettinelli: *Physella acuta*

University of Aberdeen - Zoology Department Collection

1. Strathbeg North Aberdeenshire
Recording month: 01/76
Leg. M. R. Young, det. M. P. Kerney
Pisidium amnicum (rr)

2. Wells of Ythan Abdn
Recording date: 20/4/76
Leg. M. R. Young
Pisidium personatum (r)

3. Corby Loch Abdn
Recording date: 21/6/76
Leg. M. R. Young
Pisidium hibernicum (r), *Pisidium nitidum* (r)

4. Tillycorthie Pond Abdn
Recording date: 22/6/76
Leg. M. R. Young
Pisidium nitidum (u)

5. Afforsk Pond Bennachie
Recording month: 06/77
Leg. M. R. Young
Pisidium milium (r), *Pisidium nitidum* (u), *Pisidium subtruncatum* (r)

6. Aberdeen, Botany Gdns ponds
Recording date: 23/5/79
Leg. M. R. Young
Physella acuta (u)

7. Hazlehead Park
Recording date: 13/4/03
Leg. M. R. Young
Physella acuta (rr), *Pisidium nitidum* (rr)

8. Hazlehead Park
Recording date: 2/10/03
Leg. M. R. Young
Physella acuta (r)

NBN Gateway Records

100 m Grid resolution

1. Loch Park - NJ361435
Recording month: August 1967
Leg. E. Kellock, det. M. P. Kerney
Pisidium hibernicum (+)

2. Site name protected - NO7XX6YY
Recording month: July, 1978
Leg. Norman Atkinson, leg. E. Kellock, det. M. P. Kerney
Margaritifera margaritifera (rr)

3. Lochter Burn at Fingask, 3 km west of Oldmeldrum - NJ779269
Recording year: 1980
Radix balthica (+), *Ancylus fluviatilis* (+)

4. Site name protected - NO2XX9XX
Recording date: 15/5/1982
Leg. Adrian Sumner
Margaritifera margaritifera (u)

5. Old Wood of Drum - NJ792010
Recording year: 1984
Radix balthica (+)

6. Old Wood of Drum - NJ792010
Recording year: 1990
Potamopyrgus antipodarum (+), *Galba truncatula* (+), *Ancylus fluviatilis* (+), *Pisidium casertanum* (+)

7. Muir of Dinnet Lochan - NJ434012
Recording year: 1992
Radix balthica (+)

8. Sands of Forvie Coastguard Pool - NK032277
Recording year: 1993
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Galba truncatula* (+), *Gyraulus albus* (+), *Gyraulus laevis* (+), *Gyraulus crista* (+)

9. Tarfside - NO494798
Recording date: 16/11/1999
Galba truncatula (+)

10. Bruxic [=Bruxie] Hill - NO820803
Recording date: 16/12/1999
Bathyomphalus contortus (+)

11. Craigeven Bay - NO886874
Recording date: 1/10/2000
Galba truncatula (+)

12. Far Burn U/S Aberdeen Airport - NJ873124
Recording year: 2003
Potamopyrgus antipodarum (+), *Bathyomphalus contortus* (+)

13. Far Burn U/S Farburn Ind Est - NJ885122
Recording year: 2003
Potamopyrgus antipodarum (+), *Radix balthica* (+)

14. Far Burn U/S Wellheads Ind Est - NJ885123
Recording year: 2003
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Ancylus fluviatilis* (+)

15. Mains of Dyce Burn at Mains of Dyce Farm - NJ888138
Recording year: 2003
Radix balthica (+)

16. River Don at Cordyce School - NJ892138
Recording year: 2003
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Anisus vortex* (+), *Bathyomphalus contortus* (+), *Gyraulus laevis* (+), *Ancylus fluviatilis* (+)

17. Far Burn at Dyce Pumping Station - NJ896121
Recording year: 2003
Potamopyrgus antipodarum (+), *Radix balthica* (+)

18. River Don at Riverview - NJ897131
Recording year: 2003
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Gyraulus laevis* (+), *Ancylus fluviatilis* (+)

19. Burn of King Edward Bridge of Eden - NJ694579
Recording year: 2005
Radix balthica (+), *Ancylus fluviatilis* (+)

20. Burn of King Edward Stocherie - NJ727558
Recording year: 2005
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Ancylus fluviatilis* (+)

21. R. Dee Milltimber - NJ858003
Recording year: 2005
Radix balthica (+), *Ancylus fluviatilis* (+)

22. Water of Fedderate Mill of Fedderate - NJ889504
Recording year: 2005
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Ancylus fluviatilis* (+)

23. Callater Burn - NO156881
Recording year: 2005
Radix balthica (+)

24. R. Dee Ballater bridge - NO385965
Recording year: 2005
Radix balthica (+), *Ancylus fluviatilis* (+)

25. Bervie Water d/s Macphies - NO767803
Recording year: 2005
Radix balthica (+), *Ancylus fluviatilis* (+)

26. Carron Water Tewel Ford - NO828853
Recording year: 2005
Radix balthica (+), *Ancylus fluviatilis* (+)

27. Carron Water Stonehaven - NO873857
Recording year: 2005
Potamopyrgus antipodarum (+), *Ancylus fluviatilis* (+)

28. Castle Fraser Fire Pond - NJ721125
Recording year: 2006
Gyraulus laevis (+)

29. Castle Fraser Flight Pond - NJ723134
Recording year: 2006
Radix balthica (+)

30. Fyvie Castle - Loch of Fyvie - NJ765387
Recording year: 2006
Potamopyrgus antipodarum (+), *Gyraulus albus* (+), *Gyraulus laevis* (+), *Sphaerium corneum* (+)

31. Water of Tanar Bridge of Ess - NO502970
Recording year: 2006
Radix balthica (+)

32. Water of Feugh - Birsewood, 20/06/2006 - NO533905
Recording date: 20/06/2006
Ancylus fluviatilis (+)

33. Maryculter near Aberdeen - NO840983
Recording date: 26/09/2010
Planorbis planorbis (+)

1 km Grid resolution

1. North Esk, Gallery - NO6765
Recorded before 1884
Anodonta anatina (+)

2. Site name protected - NK0026
Recording year: 1972
Hydrobia ventrosa agg. (+), *Hydrobia ventrosa* seg. (+),
Potamopyrgus antipodarum (+), *Radix balthica* (+),
Bathyomphalus contortus (+), *Gyraulus albus* (+),
Gyraulus laevis (+)

3. Gight Woods - NJ8239
Recording year: 1981
Galba truncatula (+)

4. Glenkindie, River Don - NJ4313
Recorded between 1980 and 1986
Radix balthica (+), *Ancylus fluviatilis* (+)

5. Balmoral - NO2595
Recording year: 1988
Anodonta anatina (+)

6. Site name protected - NJ7901
Recording year: 1990
Ancylus fluviatilis (+)

7. Crathes Castle - NO7396
Recording year: 1990
Radix balthica (+), *Galba truncatula* (+), *Gyraulus albus* (+)

8. Site name protected - NK1038
Recording year: 1994
Potamopyrgus antipodarum (+), *Galba truncatula* (+),
Ancylus fluviatilis (+)

10 km Grid resolution

1. Lesmurdie Cottage, nr, - NJ33
Recorded between 1670 and 1854
Hippeutis complanatus (+)

2. Boyndie - NJ66
Recorded between 1670 and 1900
Det. A. W. Stelfox
Pisidium subtruncatum (+), *Pisidium hibernicum* (+)

3. Site name protected - NJ66
Recorded between 1670 and 1950
Margaritifera margaritifera (+), *Pisidium personatum* (+)

4. Aberdeen - NJ90
Recorded between 1850 and 1925
Tullie Museum Natural History Collections
Valvata piscinalis (+)

5. South Aberdeenshire - NO49
Recorded between 1870 and 1950
Bathyomphalus contortus (+), *Pisidium personatum* (+)

6. Abergeldie - NO29
Recorded before 1880
Acroloxus lacustris (+)

7. Logie - NO66
Recorded before 1884
Bathyomphalus contortus (+), *Gyraulus crista* (+)

8. Aberdeen Links - NJ90
Recording year: 1890
Pisidium subtruncatum (+), *Pisidium milium* (+)

9. Sand-end, Cruden Bay - NK03
Recording year: 1910
Leg. Booth, det. A. W. Stelfox
Pisidium subtruncatum (+)

10. Loch Davan - NJ40
Recording month: July, 1927
Leg. C. Oldham, det. A. W. Stelfox
Pisidium hibernicum (+)

11. Loch Skene - NJ70
Recording date: 19/7/1929
Leg. and det. C. Oldham
Pisidium pulchellum (+)

12. Loch Davan - NJ40
Recording date: 20/7/1929
Leg. C. Oldham, det. A. W. Stelfox
Pisidium pulchellum (+), *Pisidium nitidum* (+), *Pisidium milium* (+)

13. Loch Davan - NJ40
Recording date: 20/7/1929
Pisidium subtruncatum (+)

14. South Aberdeenshire - NO18
Recording year: 1964
Sphaerium corneum (+)

15. South Aberdeenshire - NJ20
Recorded between 1965 and 1998
Ancylus fluviatilis (+)

16. Banffshire - NJ21
Recorded between 1965 and 1998
Galba truncatula (+)

17. Banffshire - NJ33
Recorded between 1965 and 1998
Ancylus fluviatilis (+), *Pisidium casertanum* (+)

18. Banffshire - NJ34
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+), *Pisidium casertanum* (+), *Pisidium subtruncatum* (+), *Pisidium nitidum* (+), *Pisidium milium* (+), *Pisidium personatum* (+)

19. North Aberdeenshire - NJ42
Recorded between 1965 and 1998
Ancylus fluviatilis (+)

20. North Aberdeenshire - NJ43
Recorded between 1965 and 1998
Radix balthica (+), *Ancylus fluviatilis* (+)

21. North Aberdeenshire - NJ44
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+)

22. Banffshire - NJ45
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+), *Ancylus fluviatilis* (+), *Pisidium casertanum* (+), *Pisidium subtruncatum* (+), *Pisidium nitidum* (+), *Pisidium personatum* (+), *Pisidium obtusale* (+)

23. Banffshire - NJ46
Recorded between 1965 and 1998
Ancylus fluviatilis (+), *Pisidium casertanum* (+), *Pisidium personatum* (+)

24. North Aberdeenshire - NJ53
Recorded between 1965 and 1998
Ancylus fluviatilis (+)

25. North Aberdeenshire - NJ54
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+), *Ancylus fluviatilis* (+), *Margaritifera margaritifera* (+), *Pisidium personatum* (+)

26. Banffshire - NJ55
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+), *Ancylus fluviatilis* (+), *Pisidium casertanum* (+), *Pisidium subtruncatum* (+), *Pisidium personatum* (+)

27. Banffshire - NJ56
Recorded between 1965 and 1998
Galba truncatula (+), *Pisidium obtusale* (+)

28. South Aberdeenshire - NJ61
Recorded between 1965 and 1998
Galba truncatula (+), *Ancylus fluviatilis* (+), *Pisidium personatum* (+)

29. North Aberdeenshire - NJ63
Recorded between 1965 and 1998
Pisidium casertanum (+)

30. Banffshire - NJ64
Recorded between 1965 and 1998
Radix balthica (+), *Ancylus fluviatilis* (+), *Margaritifera margaritifera* (+), *Pisidium casertanum* (+), *Pisidium subtruncatum* (+), *Pisidium nitidum* (+)

31. South Aberdeenshire - NJ71
Recorded between 1965 and 1998
Potamopyrgus antipodarum (+), *Physa fontinalis* (+), *Ancylus fluviatilis* (+)

32. Banffshire - NJ73
Recorded between 1965 and 1998
Pisidium casertanum (+), *Pisidium personatum* (+)

33. North Aberdeenshire - NJ74
Recorded between 1965 and 1998
Radix balthica (+), *Gyraulus albus* (+)

34. Banffshire - NJ76
Recorded between 1965 and 1998
Radix balthica (+), *Ancylus fluviatilis* (+), *Pisidium casertanum* (+)

35. South Aberdeenshire - NJ80
Recorded between 1965 and 1998
Pisidium casertanum (+), *Pisidium milium* (+)

36. South Aberdeenshire - NJ81
Recorded between 1965 and 1998

Physa fontinalis (+), *Gyraulus albus* (+), *Gyraulus crista* (+)

37. North Aberdeenshire - NJ83
Recorded between 1965 and 1998
Bathyomphalus contortus (+), *Pisidium subtruncatum* (+)

38. North Aberdeenshire - NJ86
Recorded between 1965 and 1998
Galba truncatula (+), *Ancylus fluviatilis* (+)

39. South Aberdeenshire - NJ91
Recorded between 1965 and 1998
Pisidium casertanum (+)

40. North Aberdeenshire - NJ95
Recorded between 1965 and 1998
Potamopyrgus antipodarum (+), *Radix balthica* (+)

41. North Aberdeenshire - NJ96
Recorded between 1965 and 1998
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Anisus leucostoma* (+), *Ancylus fluviatilis* (+), *Pisidium subtruncatum* (+), *Pisidium personatum* (+)

42. North Aberdeenshire - NK04
Recorded between 1965 and 1998
Potamopyrgus antipodarum (+), *Radix balthica* (+), *Pisidium personatum* (+)

43. North Aberdeenshire - NK05
Recorded between 1965 and 1998
Pisidium milium (+)

44. North Aberdeenshire - NK06
Recorded between 1965 and 1998
Galba truncatula (+)

45. North Aberdeenshire - NK14
Recorded between 1965 and 1998
Potamopyrgus antipodarum (+)

46. South Aberdeenshire - NO08
Recorded between 1965 and 1998
Ancylus fluviatilis (+), *Pisidium casertanum* (+)

47. South Aberdeenshire - NO09
Recorded between 1965 and 1998
Pisidium casertanum (+)

48. East Perthshire - NO17
Recorded between 1965 and 1998
Pisidium casertanum (+), *Pisidium subtruncatum* (+), *Pisidium nitidum* (+), *Pisidium milium* (+), *Pisidium personatum* (+)

49. South Aberdeenshire - NO18
Recorded between 1965 and 1998
Galba truncatula (+), *Pisidium casertanum* (+), *Pisidium personatum* (+)

50. South Aberdeenshire - NO19
Recorded between 1965 and 1998
Pisidium casertanum (+), *Pisidium subtruncatum* (+), *Pisidium milium* (+), *Pisidium personatum* (+)

51. South Aberdeenshire - NO29
Recorded between 1965 and 1998
Pisidium personatum (+)

52. South Aberdeenshire - NO38
Recorded between 1965 and 1998
Ancylus fluviatilis (+)

53. South Aberdeenshire - NO39
Recorded between 1965 and 1998
Pisidium personatum (+)

54. Angus (Forfarshire) - NO48
Recorded between 1965 and 1998
Radix balthica (+)

55. South Aberdeenshire - NO49
Recorded between 1965 and 1998
Potamopyrgus antipodarum (+), *Sphaerium corneum* (+)

56. Angus (Forfarshire) - NO57
Recorded between 1965 and 1998
Ancylus fluviatilis (+)

57. South Aberdeenshire - NO59
Recorded between 1965 and 1998
Pisidium lilljeborgii (+)

58. Angus (Forfarshire) - NO66
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+), *Ancylus fluviatilis* (+), *Sphaerium corneum* (+)

59. Kincardineshire - NO76
Recorded between 1965 and 1998
Radix balthica (+), *Galba truncatula* (+), *Anisus leucostoma* (+), *Ancylus fluviatilis* (+), *Pisidium casertanum* (+), *Pisidium personatum* (+)

60. Kincardineshire - NO78
Recorded between 1965 and 1998
Galba truncatula (+)

61. Kincardineshire - NO79
Recorded between 1965 and 1998
Pisidium personatum (+)

62. Kincardineshire - NO87
Recorded between 1965 and 1998
Radix balthica (+), *Ancylus fluviatilis* (+)

63. Kincardineshire - NO88
Recorded between 1965 and 1998
Pisidium personatum (+)

64. Site name protected - NJ34
Recorded year: 1970
Margaritifera margaritifera (+)

65. Site name protected - NJ65
Recorded year: 1976
Leg. Neil McCormick
Margaritifera margaritifera (rr)

SCOTTISH NATURAL HERITAGE (SNH) RECORDS

1 m Grid resolution (encrypted data)

1. River Dee - NJXXXXXYYYYY
Leg. Cosgrove, 1/8/97; 14 adults, 0 juveniles
Margaritifera margaritifera (c)

2. River Dee - NJXXXXXYYYYY
Leg. Cosgrove, 1/8/97; 750 adults
Margaritifera margaritifera (a)

3. River Dee - NJXXXXXYYYYY
Leg. Cosgrove, 1/8/97; 86 adults
Margaritifera margaritifera (a)

4. River Dee - NJXXXXXYYYYY
Leg. Cosgrove, 1/8/97; 27 adults, 0 juveniles
Margaritifera margaritifera (a)

5. River Dee- NJXXXXXYYYYY
Leg. Cosgrove, 1/8/97; 42 adults, 0 juveniles
Margaritifera margaritifera (a)

6. River Dee - NJXXXXXYYYYY
Leg. Hastie, 4/11/01; 2 adults, 0 juveniles
Margaritifera margaritifera (r)

7. River Dee - NJXXXXXYYYYY
Leg. Hastie, 4/11/01; 3 adults, 0 juveniles
Margaritifera margaritifera (r)

8. River Dee - NJXXXXXYYYYY
Leg. Hastie, 4/11/01; 52 adults, 0 juveniles
Margaritifera margaritifera (a)

9. River Dee - NJXXXXXYYYYY
Leg. Hastie, 28/11/01; 6 adults, 0 juveniles
Margaritifera margaritifera (u)

10. River Dee - NJXXXXXYYYYY
Leg. Hastie, 28/11/01; 2 adults, 0 juveniles
Margaritifera margaritifera (r)

11. River Dee - NJXXXXXYYYYY
Leg. Hastie, 28/11/01; 1 adults, 0 juveniles
Margaritifera margaritifera (rr)

12. River Dee - NJXXXXXYYYYY
Leg. Pearson/MacKenzie, 10/12/01; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

13. River Dee - NOXXXXXYYYYY
Leg. Cooksley, 5/6/04; 33 adults, 0 juveniles
Margaritifera margaritifera (a)

14. River Dee - NOXXXXXYYYYY
Leg. Hastie, 27/9/04; 20 adults, 3 juveniles
Margaritifera margaritifera (c)

15. River Dee - NOXXXXXYYYYY
Leg. Hastie, 27/9/04; 14 adults, 1 juvenile
Margaritifera margaritifera (c)

16. River Dee - NOXXXXXYYYYY
Leg. Hastie, 9/6/06; 85 adults, 7 juveniles
Margaritifera margaritifera (a)

17. River Dee - NOXXXXXYYYYY
Leg. Hastie, 9/6/06; 22 adults, 0 juveniles
Margaritifera margaritifera (c)

18. River Dee - NOXXXXXYYYYY
Leg. Hastie, 9/6/06; 9 adults, 0 juveniles
Margaritifera margaritifera (u)

19. River Dee - NOXXXXXYYYYY
Leg. Hastie, 9/6/06; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

20. River Dee - NOXXXXXYYYYY
Leg. Hastie, 9/6/06; 5 adults, 1 juvenile
Margaritifera margaritifera (r)

21. River Dee - NOXXXXXYYYYY
Leg. Hastie/Cosgrove, 15/7/06; 46 adults
Margaritifera margaritifera (a)

22. River Dee - NOXXXXXYYYYY
Leg. Hastie/Cosgrove, 15/7/06; 1 adult
Margaritifera margaritifera (rr)

23. River Dee - NOXXXXXYYYYY
Leg. Hastie/Cosgrove, 15/7/06; 36 adults
Margaritifera margaritifera (a)

24. River Dee - NOXXXXXYYYYY
Leg. Hastie/Cosgrove, 15/7/06; 3 adults
Margaritifera margaritifera (r)

25. River Dee - NOXXXXXYYYYY
Leg. Jacobs, 1/9/06; 41 adults, 2 juveniles
Margaritifera margaritifera (a)

26. River Dee - NOXXXXXYYYYY
Leg. Jacobs, 1/9/06; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

27. River Dee - NOXXXXXYYYYY
Leg. Jacobs, 1/9/06; 26 adults, 2 juveniles
Margaritifera margaritifera (a)

28. River Dee - NOXXXXXYYYYY
Leg. Jacobs, 1/4/07; 9 adults
Margaritifera margaritifera (u)

29. River Dee - NOXXXXXYYYYY
Leg. Jacobs, 1/4/07; 15 adults
Margaritifera margaritifera (c)

10 m Grid resolution (encrypted data)

1. Water of Feugh - NOXXXXYYYY
Leg. Hastie, 29/10/01; 2 adults, 0 juveniles
Margaritifera margaritifera (r)

2. Water of Feugh - NOXXXXYYYY
Leg. Hastie, 29/10/01; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

3. Water of Feugh - NOXXXXYYYY
Leg. Hastie, 29/10/01; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

4. Water of Feugh - NOXXXXYYYY
Leg. Hastie, 29/10/01; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

5. River Dee - NOXXXXYYYY
Leg. Hastie/Hewlett, 29/6/04; 17 adults, 3 juveniles
Margaritifera margaritifera (c)

6. River Dee - NOXXXXYYYY
Leg. Hastie/Hewlett, 29/6/04; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

7. River Dee - NOXXXXYYYY
Leg. Hastie/Hewlett, 29/6/04; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

8. River Dee - NOXXXXYYYY
Leg. Hastie/Hewlett, 29/6/04; 2 adults, 0 juveniles
Margaritifera margaritifera (r)

100 m Grid resolution (encrypted data)

1. River Ythan - NJXXXYYY
Leg. Cosgrove, 1/1/97; 3 adults, 0 juveniles
Margaritifera margaritifera (r)

2. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/7/97; 14 adults, 5 juveniles
Margaritifera margaritifera (c)

3. River Dee SAC - NJXXXYYY
Leg. Sime, 28/6/01; 16 adults, 2 juveniles
Margaritifera margaritifera (c)

4. River Clunie - NOXXXYYY
Leg. Cooksley, 21/7/01; 3 adults, 0 juveniles
Margaritifera margaritifera (r)

5. River Dee - NOXXXYYY
Leg. Pearson/MacKenzie, 10/12/01; 12 adults, 4 juveniles
Margaritifera margaritifera (c)

6. River Dee - NOXXXYYY
Leg. Pearson/MacKenzie, 10/12/01; 75 adults, 1 juvenile
Margaritifera margaritifera (a)

7. River Dee - NOXXXYYY
Leg. Pearson/Gayle, 21/12/01; ? adults
Margaritifera margaritifera (+)

8. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 17/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland, grazing
Margaritifera margaritifera (rr)

9. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 17/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland, grazing, good substrate
Margaritifera margaritifera (rr)

10. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland, grassland, weak
Margaritifera margaritifera (rr)

11. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 17/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland, grassland, weak
Margaritifera margaritifera (rr)

12. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland, grassland
Margaritifera margaritifera (rr)

13. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland, grassland
Margaritifera margaritifera (rr)

14. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/8/02; 2 adults, 0 juveniles
Habitat: riparian woodland, grassland
Margaritifera margaritifera (r)

15. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 17/8/02; 4 adults, 0 juveniles
Habitat: riparian woodland, grazing, end of field
Margaritifera margaritifera (r)

16. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (rr)

17. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (rr)

18. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 1 adult, 0 juveniles
Habitat: grassland
Margaritifera margaritifera (rr)

19. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 1 adult, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (rr)

20. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 2 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (r)

21. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 4 adults, 0 juveniles
Habitat: riparian woodland, opposite upstream tip of island
Margaritifera margaritifera (rr)

22. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 6 adults, 0 juveniles
Habitat: riparian woodland, suitable substrate
Margaritifera margaritifera (r)

23. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 6 adults, 0 juveniles
Habitat: riparian woodland and grassland
Margaritifera margaritifera (u)

24. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 6 adults, 0 juveniles
Habitat: riparian woodland, depth post, steep wooded impenetrable bank side c300-400m, substrate and water look very good for mussels
Margaritifera margaritifera (u)

25. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 10 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (u)

26. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 25/8/02; 13 adults, 0 juveniles
Habitat: riparian woodland and grassland
Margaritifera margaritifera (c)

27. River Dee SAC - NJXXXYYY
Leg. Scougall, 27/8/02; 1 adult, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (rr)

28. River Dee SAC - NJXXXYYY
Leg. Scougall, 27/8/02; 1 adult, 0 juveniles
Habitat: boulders
Margaritifera margaritifera (rr)

29. River Dee SAC - NJXXXYYY
Leg. Hastie, 27/8/02; 1 adult, 0 juveniles
Habitat: start of island
Margaritifera margaritifera (rr)

30. River Dee SAC - NJXXXYYY
Leg. Hastie, 27/8/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

31. River Dee SAC - NJXXXYYY
Leg. Hastie, 27/8/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

32. River Dee SAC - NJXXXYYY
Leg. Hastie, 27/8/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

33. River Dee SAC - NJXXXYYY
Leg. Scougall, 27/8/02; 2 adults, 0 juveniles
Habitat: mussels also on opposite bank, weeds
Margaritifera margaritifera (r)

34. River Dee SAC - NJXXXYYY
Leg. Hastie, 27/8/02; 2 adults, 0 juveniles

Habitat: water very cloudy (high suspended load)
Margaritifera margaritifera (r)

35. River Dee SAC - NJXXXYYY
Leg. Hastie, 27/8/02; 5 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (r)

36. River Dee SAC - NJXXXYYY
Leg. Hastie, 30/8/02; 1 adult, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (rr)

37. River Dee SAC - NJXXXYYY
Leg. Hastie, 1/9/02; 1 adult, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (rr)

38. River Dee SAC - NJXXXYYY
Leg. Hastie, 1/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

39. River Dee SAC - NJXXXYYY
Leg. Hastie, 1/9/02; 12 adults, 0 juveniles
Habitat: above confluence with Culter Burn
Margaritifera margaritifera (c)

40. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

41. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 1 adult, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (rr)

42. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

43. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

44. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 6 adults, 0 juveniles
Habitat: below Crathes Br.
Margaritifera margaritifera (r)

45. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 3 adults, 0 juveniles
Margaritifera margaritifera (r)

46. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 3 adults, 0 juveniles
Margaritifera margaritifera (r)

47. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 5 adults, 0 juveniles
Margaritifera margaritifera (r)

48. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 9 adults, 0 juveniles
Margaritifera margaritifera (r)

49. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 10 adults, 0 juveniles
Margaritifera margaritifera (u)

50. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 18 adults, 0 juveniles
Habitat: lots of rubbish on riverbed
Margaritifera margaritifera (c)

51. River Dee SAC - NOXXXYYY
Leg. Scougall, 2/9/02; 18 adults, 0 juveniles
Margaritifera margaritifera (c)

52. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 32 adults, 0 juveniles
Habitat: lots of rubbish on riverbed
Margaritifera margaritifera (a)

53. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/9/02; 45 adults, 0 juveniles
Margaritifera margaritifera (a)

54. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 1 adult, 0 juveniles
Habitat: side channel
Margaritifera margaritifera (rr)

55. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 1 adult, 0 juveniles
Habitat: side channel
Margaritifera margaritifera (rr)

56. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 1 adult, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (rr)

57. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

58. River Dee SAC - NOXXXYYY
Leg. Scougall, 3/9/02; 1 adult, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (rr)

59. River Dee SAC - NOXXXYYY
Leg. Scougall, 3/9/02; 1 adult, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (rr)

60. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

61. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

62. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 3 adults, 0 juveniles
Habitat: side-channel
Margaritifera margaritifera (r)

63. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

64. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 5 adults, 0 juveniles
Margaritifera margaritifera (r)

65. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 7 adults, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (u)

66. River Dee SAC - NOXXXYYY
Leg. Scougall, 3/9/02; 8 adults, 0 juveniles
Margaritifera margaritifera (u)

67. River Dee SAC - NOXXXYYY
Leg. Scougall, 3/9/02; 11 adults, 0 juveniles
Habitat: *Ranunculus*
Margaritifera margaritifera (c)

68. River Dee SAC - NOXXXYYY
Leg. Scougall, 3/9/02; 13 adults, 0 juveniles
Habitat: mostly juvenile mussels [this is in contradiction with the juveniles count above], *Ranunculus*
Margaritifera margaritifera (c)

69. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 16 adults, 0 juveniles
Margaritifera margaritifera (c)

70. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 16 adults, 0 juveniles
Margaritifera margaritifera (c)

71. River Dee SAC - NOXXXYYY
Leg. Scougall, 3/9/02; 19 adults, 0 juveniles
Margaritifera margaritifera (c)

72. River Dee SAC - NOXXXYYY

Leg. Hastie, 3/9/02; 46 adults, 0 juveniles
Margaritifera margaritifera (a)

73. River Dee SAC - NOXXXYYY
Leg. Hastie, 3/9/02; 115 adults, 0 juveniles
Margaritifera margaritifera (a)

74. River Dee SAC - NOXXXYYY
Leg. Hastie, 4/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

75. River Dee SAC - NOXXXYYY
Leg. Hastie, 4/9/02; 1 adults, 0 juveniles
Habitat: side-channel, *Ranunculus*
Margaritifera margaritifera (rr)

76. River Dee SAC - NOXXXYYY
Leg. Scougall, 4/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

77. River Dee SAC - NOXXXYYY
Leg. Hastie, 4/9/02; 2 adults, 0 juveniles
Habitat: *Ranunculus,* lots of filamentous algae on stones
Margaritifera margaritifera (r)

78. River Dee SAC - NOXXXYYY
Leg. Scougall, 4/9/02; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

79. River Dee SAC - NOXXXYYY
Leg. Hastie, 4/9/02; 6 adults, 0 juveniles
Margaritifera margaritifera (u)

80. River Dee SAC - NOXXXYYY
Leg. Scougall, 4/9/02; 6 adults, 0 juveniles
Margaritifera margaritifera (u)

81. River Dee SAC - NOXXXYYY
Leg. Scougall, 4/9/02; 7 adults, 0 juveniles
Margaritifera margaritifera (u)

82. River Dee SAC - NOXXXYYY
Leg. Hastie, 6/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

83. River Dee SAC - NOXXXYYY
Leg. Hastie, 6/9/02; 1 adults, 0 juveniles
Margaritifera margaritifera (rr)

84. River Dee SAC - NOXXXYYY
Leg. Hastie, 6/9/02; 6 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (u)

85. River Dee SAC - NOXXXYYY
Leg. Hastie, 6/9/02; 8 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (u)

86. River Dee SAC - NOXXXYYY
Leg. Hastie, 6/9/02; 24 adults, 0 juveniles
Margaritifera margaritifera (c)

87. River Dee SAC - NOXXXYYY
Leg. Scougall, 6/9/02; 57 adults, 0 juveniles
Habitat: log-reinforced bank, *Ranunculus,*
mussels spread evenly (no clumps)
Margaritifera margaritifera (a)

88. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 7/9/02; 1 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (rr)

89. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 7/9/02; 2 adults, 0 juveniles
Habitat: good substrate underneath
overhanging riparian woodland
Margaritifera margaritifera (r)

90. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap),
30m below storm drain
Margaritifera margaritifera (rr)

91. River Dee SAC - NOXXXYYY
Leg. Scougall, 8/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

92. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

93. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 1 adult, 0 juveniles
Habitat: film of silt/algae on substrate
Margaritifera margaritifera (rr)

94. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

95. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 2 adults, 0 juveniles
Habitat: reinforced bank (blocks)
Margaritifera margaritifera (r)

96. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 3 adults, 0 juveniles
Margaritifera margaritifera (r)

97. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 7 adults, 0 juveniles
Habitat: reinforced bank (concrete)
Margaritifera margaritifera (u)

98. River Dee SAC - NOXXXYYY
Leg. Hastie, 8/9/02; 19 adults, 0 juveniles
Habitat: reinforced bank (concrete block)
Margaritifera margaritifera (c)

99. River Dee SAC - NOXXXYYY
Leg. Scougall, 8/9/02; 23 adults, 0 juveniles
Margaritifera margaritifera (c)

100. River Dee SAC - NOXXXYYY
Leg. Scougall, 8/9/02; 34 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap)
Margaritifera margaritifera (a)

101. River Dee SAC - NOXXXYYY
Leg. Hastie, 9/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

102. River Dee SAC - NOXXXYYY
Leg. Hastie, 9/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap)
Margaritifera margaritifera (rr)

103. River Dee SAC - NOXXXYYY
Leg. Hastie, 9/9/02; 1 adult, 0 juveniles
Habitat: silt film on substrate
Margaritifera margaritifera (rr)

104. River Dee SAC - NOXXXYYY
Leg. Hastie, 9/9/02; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

105. River Dee SAC - NOXXXYYY
Leg. Hastie, 9/9/02; 18 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (c)

106. River Dee SAC - NOXXXYYY
Leg. Hastie, 10/9/02; 1 adult, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (rr)

107. River Dee SAC - NOXXXYYY
Leg. Hastie, 10/9/02; 1 adult, 0 juveniles
Habitat: mussel bed on opposite bank (leg. D. Trembath)
Margaritifera margaritifera (rr)

108. River Dee SAC - NOXXXYYY
Leg. Hastie, 10/9/02; 1 adult, 0 juveniles
Habitat: sand deposits below confluence of burn
Margaritifera margaritifera (rr)

109. River Dee SAC - NOXXXYYY

Leg. Hastie, 10/9/02; 2 adults, 0 juveniles
Habitat: lots of algae
Margaritifera margaritifera (r)

110. River Dee SAC - NOXXXYYY
Leg. Hastie, 10/9/02; 3 adults, 0 juveniles
Habitat: lots of algae
Margaritifera margaritifera (r)

111. River Dee SAC - NOXXXYYY
Leg. Hastie, 10/9/02; 29 adults, 0 juveniles
Habitat: lots of algae, reinforced bank (concrete)
Margaritifera margaritifera (a)

112. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 1 adult, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (rr)

113. River Dee SAC - NOXXXYYY
Habitat: leg. Hastie, 11/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

114. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 1 adult, 0 juveniles
Habitat: silty in places
Margaritifera margaritifera (rr)

115. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 2 adults, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (r)

116. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 5 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (r)

117. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 7 adults, 0 juveniles
Margaritifera margaritifera (u)

118. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 13 adults, 0 juveniles
Habitat: good habitat (substrate) in places
Margaritifera margaritifera (c)

119. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/9/02; 26 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (a)

120. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap)
Margaritifera margaritifera (rr)

121. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), difficult to sample due to excessive algal growth
Margaritifera margaritifera (rr)

122. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), difficult to sample due to excessive algal growth
Margaritifera margaritifera (rr)

123. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), difficult to sample due to excessive algal growth
Margaritifera margaritifera (rr)

124. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap)
Margaritifera margaritifera (rr)

125. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: difficult to sample due to excessive algal growth
Margaritifera margaritifera (rr)

126. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 1 adult, 0 juveniles
Habitat: difficult to sample due to excessive algal growth
Margaritifera margaritifera (rr)

127. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 2 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), algae
Margaritifera margaritifera (r)

128. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 3 adults, 0 juveniles
Habitat: *Ranunculus,* lots of filamentous algae
Margaritifera margaritifera (r)

129. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 3 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), difficult to sample due to excessive algal growth
Margaritifera margaritifera (r)

130. River Dee SAC - NOXXXYYY
Leg. Hastie, 12/9/02; 5 adults, 0 juveniles
Habitat: reinforced bank (cobble-wire), lots of filamentous algae
Margaritifera margaritifera (r)

131. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 1 adult, 0 juveniles
Habitat: fine sand deposits
Margaritifera margaritifera (rr)

132. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

133. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

134. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 2 adults, 0 juveniles
Margaritifera margaritifera (r)

135. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 4 adults, 0 juveniles
Habitat: good habitat (substrate), fine sand deposits
Margaritifera margaritifera (r)

136. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 4 adults, 0 juveniles
Habitat: algal/silt film on substrate
Margaritifera margaritifera (r)

137. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 5 adults, 0 juveniles
Margaritifera margaritifera (r)

138. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 35 adults, 0 juveniles
Habitat: good habitat (substrate), fine sand deposits
Margaritifera margaritifera (a)

139. River Dee SAC - NOXXXYYY
Leg. Hastie, 13/9/02; 88 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (a)

140. River Dee SAC - NOXXXYYY
Leg. Scougall, 15/9/02; 1 adult, 0 juveniles
Habitat: algal film on substrate, shell on shingle bar
Margaritifera margaritifera (rr)

141. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 15/9/02; 1 adult, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (rr)

142. River Dee SAC - NOXXXYYY
Leg. Scougall, 15/9/02; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

143. River Dee SAC - NOXXXYYY
Leg. Hastie, 15/9/02; 14 adults, 0 juveniles
Margaritifera margaritifera (r)

144. River Dee SAC - NOXXXYYY
Leg. Scougall, 15/9/02; 5 adults, 0 juveniles
Margaritifera margaritifera (r)

145. River Dee SAC - NOXXXYYY
Leg. Scougall, 15/9/02; 20 adults, 0 juveniles
Habitat: reinforced bank (earth)
Margaritifera margaritifera (c)

146. River Dee SAC - NOXXXYYY
Leg. Scougall, 15/9/02; 45 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap)
Margaritifera margaritifera (a)

147. River Dee SAC - NOXXXYYY
Leg. Hastie, 16/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

148. River Dee SAC - NOXXXYYY
Leg. Hastie, 16/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), algal film on substrate
Margaritifera margaritifera (rr)

149. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

150. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (boulder rip-rap toe)
Margaritifera margaritifera (rr)

151. River Dee SAC - NOXXXYYY
Leg. Scougall, 17/9/02; 4 adults, 0 juveniles
Habitat: good habitat (substrate), snails and limpets
Margaritifera margaritifera (r)

152. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/9/02; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

153. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/9/02; 11 adults, 0 juveniles
Habitat: reinforced bank (wood)
Margaritifera margaritifera (c)

154. River Dee SAC - NOXXXYYY
Leg. Scougall, 17/9/02; 22 adults, 0 juveniles
Habitat: side-channel
Margaritifera margaritifera (c)

155. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/9/02; 28 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap)
Margaritifera margaritifera (a)

156. River Dee SAC - NOXXXYYY
Leg. Hastie, 17/9/02; 37 adults, 0 juveniles
Habitat: reinforced bank (wood)
Margaritifera margaritifera (a)

157. River Dee SAC - NOXXXYYY
Leg. Scougall, 17/9/02; 95 adults, 0 juveniles
Habitat: good habitat (substrate), lots of filamentous algae
Margaritifera margaritifera (a)

158. River Dee SAC - NOXXXYYY
Leg. Scougall, 17/9/02; 135 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (a)

159. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 1 adult, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (rr)

160. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 1 adult, 0 juveniles
Habitat: reinforced bank (concrete, boulder rip-rap), lots of algae
Margaritifera margaritifera (rr)

161. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

162. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 1 adult, 0 juveniles
Habitat: algal/silt film on substrate
Margaritifera margaritifera (rr)

163. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 2 adults, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (r)

164. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 2 adults, 0 juveniles
Habitat: reinforced bank (cobble/boulder rip-rap), rubble on riverbed
Margaritifera margaritifera (r)

165. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 3 adults, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (r)

166. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 8 adults, 0 juveniles
Margaritifera margaritifera (u)

167. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 15 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (c)

168. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 19 adults, 0 juveniles
Habitat: lots of weed
Margaritifera margaritifera (c)

169. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 33 adults, 0 juveniles
Habitat: side-channel, lots of algae, good habitat but encroached by shingle bar
Margaritifera margaritifera (a)

170. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 51 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (a)

171. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 54 adults, 0 juveniles
Habitat: side-channel, lots of algae, mussel bed partly covered by fresh sand deposits
Margaritifera margaritifera (a)

172. River Dee SAC - NOXXXYYY
Leg. Hastie, 22/9/02; 60 adults, 0 juveniles
Habitat: side-channel, lots of algae, shell
Margaritifera margaritifera (a)

173. River Dee SAC - NOXXXYYY
Leg. Hastie, 29/9/02; 1 adult, 0 juveniles
Habitat: algal film on substrate
Margaritifera margaritifera (rr)

174. River Dee SAC - NOXXXYYY
Leg. Hastie, 29/9/02; 1 adult, 0 juveniles
Habitat: algal mat
Margaritifera margaritifera (rr)

175. River Dee SAC - NOXXXYYY
Leg. Hastie, 29/9/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

176. River Dee SAC - NOXXXYYY
Leg. Scougall, 29/9/02; 2 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (r)

177. River Dee SAC - NOXXXYYY
Leg. Hastie, 29/9/02; 2 adults, 0 juveniles
Habitat: algal mat - difficult to sample
Margaritifera margaritifera (r)

178. River Dee SAC - NOXXXYYY

Leg. Cosgrove, 29/9/02; 3 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (r)

179. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 29/9/02; 3 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (r)

180. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 29/9/02; 4 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (r)

181. River Dee SAC - NOXXXYYY
Leg. Hastie, 29/9/02; 6 adults, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (u)

182. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 29/9/02; 6 adults, 0 juveniles
Habitat: riparian woodland, good substrate
Margaritifera margaritifera (u)

183. River Dee SAC - NOXXXYYY
Leg. Scougall, 29/9/02; 7 adults, 0 juveniles
Habitat: poached bank, slime covering on substrate
Margaritifera margaritifera (u)

184. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 29/9/02; 7 adults, 0 juveniles
Habitat: underneath Ballater road bridge
Margaritifera margaritifera (u)

185. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 29/9/02; 8 adults, 0 juveniles
Habitat: riparian woodland
Margaritifera margaritifera (u)

186. River Dee SAC - NOXXXYYY
Leg. Hastie, 29/9/02; 13 adults, 0 juveniles
Habitat: algal film on substrate
Margaritifera margaritifera (c)

187. River Dee SAC - NOXXXYYY
Leg. Scougall, 29/9/02; 15 adults, 0 juveniles
Habitat: good habitat (substrate)
Margaritifera margaritifera (c)

188. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 29/9/02; 21 adults, + juveniles
Habitat: riparian woodland and grassland, very suitable substrate, juvenile mussels visible
Margaritifera margaritifera (c)

189. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 1 adult, 0 juveniles
Habitat: side-channel, algal film on substrate
Margaritifera margaritifera (rr)

190. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 1 adult, 0 juveniles
Habitat: lots of algae - difficult to sample
Margaritifera margaritifera (rr)

191. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 1 adult, 0 juveniles
Habitat: good habitat (substrate), algal film on substrate, *Ranunculus*
Margaritifera margaritifera (rr)

192. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 1 adult, 0 juveniles
Habitat: algal/silt film on substrate, *Ranunculus*
Margaritifera margaritifera (rr)

193. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 2 adults, 0 juveniles
Habitat: algal film on substrate
Margaritifera margaritifera (r)

194. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 2 adults, 0 juveniles
Habitat: lots of algae - difficult to sample
Margaritifera margaritifera (r)

195. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 2 adults, 0 juveniles
Habitat: good habitat (substrate), algal film on substrate
Margaritifera margaritifera (r)

196. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 3 adults, 0 juveniles
Habitat: sand deposits, algal/silt film on substrate
Margaritifera margaritifera (r)

197. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 3 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), algal film, *Ranunculus*
Margaritifera margaritifera (r)

198. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 4 adults, 0 juveniles
Margaritifera margaritifera (r)

199. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 6 adults, 0 juveniles
Habitat: algal film on substrate
Margaritifera margaritifera (u)

200. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 8 adults, 0 juveniles
Habitat: algal film on substrate
Margaritifera margaritifera (u)

201. River Dee SAC - NOXXXYYY
Leg. Hastie, 2/10/02; 93 adults, 0 juveniles
Habitat: reinforced bank (concrete), lots of algae, *Ranunculus*
Margaritifera margaritifera (u)

202. River Dee SAC - NJXXXYYY
Leg. Hastie, 4/10/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

203. River Dee SAC - NOXXXYYY
Leg. Scougall, 4/10/02; 2 adults, 0 juveniles
Habitat: reinforced bank (boulder rip-rap), block boulders on riverbed
Margaritifera margaritifera (r)

204. River Dee SAC - NOXXXYYY
Leg. Scougall, 4/10/02; 2 adults, 0 juveniles
Habitat: lots of filamentous algae
Margaritifera margaritifera (r)

205. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 5/10/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

206. River Dee SAC - NOXXXYYY
Leg. Hastie, 5/10/02; 2 adults, 0 juveniles
Habitat: riparian woodland, substrate good
Margaritifera margaritifera (r)

207. River Dee SAC - NOXXXYYY
Leg. Hastie, 6/10/02; 5 adults, 0 juveniles
Habitat: riparian woodland, good substrate, 1 dead shell
Margaritifera margaritifera (r)

208. River Dee SAC - NOXXXYYY
Leg. Hastie, 11/10/02; 182 adults, 13 juveniles
Margaritifera margaritifera (a)

209. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 31/10/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

210. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 31/10/02; 2 adults, 0 juveniles
Margaritifera margaritifera (rr)

211. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 21/12/02; 1 adult, 0 juveniles
Margaritifera margaritifera (r)

212. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 21/12/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

213. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 21/12/02; 8 adults, 0 juveniles
Margaritifera margaritifera (u)

214. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 21/12/02; 12 adults, 4 juveniles
Margaritifera margaritifera (c)

215. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 22/12/02; 6 adults, 0 juveniles
Margaritifera margaritifera (u)

216. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 22/12/02; 9 adults, 3 juveniles
Margaritifera margaritifera (u)

217. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 22/12/02; 11 adults, 0 juveniles
Margaritifera margaritifera (c)

218. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 22/12/02; 17 adults, 6 juveniles
Margaritifera margaritifera (c)

219. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 22/12/02; 27 adults, 9 juveniles
Margaritifera margaritifera (a)

220. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 30/12/02; 25 adults, 3 juveniles
Margaritifera margaritifera (a)

221. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 30/12/02; 2 adults, 0 juveniles
Margaritifera margaritifera (r)

222. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 30/12/02; 7 adults, 0 juveniles
Margaritifera margaritifera (u)

223. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 31/12/02; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

224. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 31/12/02; 11 adults, 0 juveniles
Margaritifera margaritifera (c)

225. River Dee SAC - NOXXXYYY
Leg. Cosgrove, 31/12/02; 11 adults, 0 juveniles
Margaritifera margaritifera (c)

226. River Dee SAC - NJXXXYYY
Leg. Sime, 7/8/03; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

227. River Dee SAC - NJXXXYYY
Leg. Sime, 7/8/03; 15 adults, 0 juveniles
Margaritifera margaritifera (c)

228. River Dee - NOXXXYYY
Leg. Cooksley, 5/6/04; 22 adults, 1 juvenile
Margaritifera margaritifera (c)

229. River Dee - NOXXXYYY
Leg. Hastie/Hewlett, 29/6/04; 1 adult, 0 juveniles
Margaritifera margaritifera (rr)

230. River Dee - from donor (Banchory, NOXXXYYY) to re-intro site (Gairn River 1, NOXXXYYY)
Leg. Cosgrove, 25/8/05; 10 adults
Margaritifera margaritifera (u)

231. River Dee - from donor (Crathes, NOXXXYYY) to re-intro site (Gairn River 1, NOXXXYYY)
Leg. Cosgrove, 25/8/05; 40 adults
Margaritifera margaritifera (a)

232. River Dee - from donor (Drumoak, NOXXXYYY) to re-intro site (Gairn River 1, NOXXXYYY)
Leg. Cosgrove, 25/8/05; 30 adults
Margaritifera margaritifera (a)

233. River Dee - from donor (Woodend, NO6XX9YY) to re-intro site (Gairn River 1, NO2XX9YY)
Leg. Cosgrove, 25/8/05; 20 adults
Margaritifera margaritifera (c)

234. River Dee - from donor (Xxxx Mill, NOXXXYYY) to re-intro site (Gairn River 2, NOXXXYYY)
Leg. Cosgrove, 29/8/05; 80 adults
Margaritifera margaritifera (a)

235. River Dee - from donor (Drumoak, NO8XX9YY) to re-intro site (Gairn River 2, NOXXXYYY)
Leg. Cosgrove, 29/8/05; 20 adults
Margaritifera margaritifera (c)

236. River Dee - NOXXXYYY
Leg. Hastie, 9/6/06; 41 adults, 3 juveniles
Margaritifera margaritifera (a)

237. River Dee - NOXXXYYY
Leg. Hastie/Cosgrove, 15/7/06; 28 adults
Margaritifera margaritifera (a)

238. River Dee - NOXXXYYY
Leg. Hastie/Cosgrove, 15/7/06; 95 adults
Margaritifera margaritifera (a)

239. River Dee - NOXXXYYY
Leg. Hastie/Cosgrove, 15/7/06; 67 adults
Margaritifera margaritifera (a)

240. River Dee - NOXXXYYY
Leg. Hastie/Cosgrove, 15/7/06; 59 adults
Margaritifera margaritifera (a)

241. River Dee - NOXXXYYY
Leg. Jacobs, 1/9/06; 5 adults, 0 juveniles
Margaritifera margaritifera (r)

242. River Dee - NOXXXYYY
Leg. Jacobs, 1/4/07; 13 adults
Margaritifera margaritifera (c)

1000 Grid resolution (encrypted data)

1. River Dee, Xxxxxx Estate, Aberdeenshire - NJXXYY
Leg. Sime, 31/7/01; 16 adults
Margaritifera margaritifera (c)

APPENDIX II - FIELD DATA

1. Spring stream between Stonehaven and Dunnottar Castle, northern side of Strathlethan Bay, Stonehaven
Lat. 56° 57' 14.57" N, Long. -02° 12' 08.52" W, Alt. 53 m AMSL; date 14/02/2004, T 5.80°C, C 702 µS/cm, Sal 0.10%, pH 8.27, [O_2] 12.02 mg/l, Sat O_2 95.20%, V 176 mV
Sandy-gravelly stream bed, flow rate: VL
Pisidium personatum (u)

2. Spring stream between Stonehaven and Dunnottar Castle, 300 m westward from Bowdun Head, Stonehaven
Lat. 56° 57' 07.67" N, Long. -02° 12' 00.80" W, Alt. 40 m AMSL; date 20/04/2002, T 6.80°C, C 544 µS/cm, Sal. 0.00%, pH 8.90, [O_2] 13.84 mg/l, Sat O_2 112.10%, V 161 mV
Gravelly-pebbly stream bed with sandy pockets, flow rate: LM
Potamopyrgus antipodarum (a), *Radix balthica* (a), *Galba truncatula* (u), *Pisidium personatum* (a)

3. Spring stream flowing along the SW cliff of Dunnottar Castle, Stonehaven
Lat. 56° 56' 43.69" N, Long. -02° 12' 03.94" W, Alt. 5 m AMSL; date 20/04/2002, T 6.40°C, C 545 µS/cm, Sal. 0.00%, pH 9.12, [O_2] 12.93 mg/l, Sat O_2 103.60%, V 163 mV
Gravelly-pebbly stream bed with sandy pockets, flow rate: LM
Potamopyrgus antipodarum (c), *Radix balthica* (a), *Galba truncatula* (r), *Ancylus fluviatilis* (u), *Pisidium personatum* (a)

4. Spring stream between Stonehaven and Dunnottar Castle, flowing toward Castle Haven Bay, Stonehaven
Lat. 56° 57' 01.59" N, Long. -02° 11' 57.66" W, Alt. 30 m AMSL; date 20/04/2002, T 8.20°C, C 617 µS/cm, Sal. 0.00%, pH 8.50, [O_2] 10.04 mg/l, Sat O_2 84.30%, V 175 mV
Gravelly-pebbly stream bed with sandy pockets, flow rate: LM
Potamopyrgus antipodarum (c), *Radix balthica* (r), *Galba truncatula* (c), *Pisidium personatum* (c)

5. Stream flowing between Arbroath and Auchmithie, near the high tide mark in Carlingheugh Bay, Arbroath
Lat. 56° 34' 21.81" N, Long. -02° 32' 26.70" W, Alt. 5 m AMSL; date 27/04/2002
Sandy-gravelly stream bed with muddy pockets, flow rate: LM
Potamopyrgus antipodarum (r), *Galba truncatula* (r), *Pisidium personatum* (r)

6. Stream flowing between Arbroath and Auchmithie, flowing at the bottom of the southern cliff of Auchmithie, Auchmithie
Lat. 56° 35' 22.15" N, Long. -02° 31' 11.41" W, Alt. 5 m AMSL; date 27/04/2002
Sandy-gravelly stream bed, flow rate: LM
Radix balthica (a), *Galba truncatula* (a), *Pisidium personatum* (a)

7. Loch of Skene outlet, near Milton of Garlogie, Garlogie
Lat. 57° 09' 05.01" N, Long. -02° 21' 35.42" W, Alt. 83 m AMSL; date 04/05/2002, T 13.30°C, C 271 µS/cm, Sal. 0.00%, pH 6.74, [O_2] 7.34 mg/l, Sat O_2 71.20%, V 193 mV
Sandy-gravelly stream bed. Large part of the sediment is composed by thousands of *Sphaerium corneum* valves, flow rate: LM
Potamopyrgus antipodarum (r), *Radix balthica* (c), *Bathyomphalus contortus* (r), *Sphaerium corneum* (a), *Pisidium subtruncatum* (r), *Pisidium nitidum* (c)

8. Loch of Skene inlet, 500 m south-southeastward from Wantonwells, Dunecht
Lat. 57° 09' 57.50" N, Long. -02° 22' 44.21" W, Alt. 85 m AMSL; date 04/05/2002, T 15.80°C, C 279 µS/cm, Sal.0.00%, pH 8.56, [O_2] 9.70 mg/l, Sat O_2 99.30%, V 145 mV
Sandy stream bed with scattered boulders, flow rate: M
Potamopyrgus antipodarum (r), *Radix balthica* (u), *Pisidium casertanum* (r), *Pisidium personatum* (u), *Pisidium subtruncatum* (rr), *Pisidium nitidum* (r)

9. Spring stream flowing 50 m southward from the Chapel of St Mary of the storms, Stonehaven
Lat. 56° 58' 35.74" N, Long. -02° 11' 33.05" W, Alt. 20 m AMSL; date 25/05/2002
Pebbly-cobbly stream bed with sandy pockets and scattered boulders, flow rate: L
Radix balthica (a), *Pisidium personatum* (a)

10. Stream flowing at the bottom of the southern slope of Kempstone Hill, Stonehaven
Lat. 56° 59' 32.54" N, Long. -02° 10' 44.71" W, Alt. 10 m AMSL; date 25/05/2002
Sandy-gravelly stream bed with scattered boulders, flow rate: LM
Potamopyrgus antipodarum (u), *Radix balthica* (r), *Ancylus fluviatilis* (c), *Pisidium nitidum* (rr)

11. Small lochan in locality Blackhills, 2 Km south-eastward from Bridge of Muchalls, Stonehaven
Lat. 57° 00' 10.03" N, Long. -02° 10' 14.55" W, Alt. 55 m AMSL; date 25/05/2002
Silty-sandy substrate with scattered boulders, quite rich in organic matter, outlet flow rate: VL
Potamopyrgus antipodarum (a), *Pisidium casertanum* (r), *P. casertanum* f. *ponderosa* (rr), *Pisidium subtruncatum* (c)

12. Burn of Muchalls, in the vicinity of a mill, 150 m from the high tide mark, Newtonhill
Lat. 57° 00' 41.86" N, Long. -02° 10' 03.06" W, Alt. 30 m AMSL; date 25/05/2002
Sandy stream bed with scattered boulders, flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Ancylus fluviatilis* (c), *Pisidium personatum* (a), *Pisidium subtruncatum* (rr)

13. Stream flowing in the valley between Muchalls and Newtonhill, Newtonhill
Lat. 57° 01' 18.49" N, Long. -02° 09' 28.60" W, Alt. 35 m AMSL; date 25/05/2002
Sandy stream bed with scattered boulders, flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (r), *Ancylus fluviatilis* (a), *Gyraulus crista* (rr), *Pisidium personatum* (r)

14. Blanket bog situated on the north-eastern slope of Carn nan Sac, Cairnwell hills, Braemar
Lat. 56° 52' 47.08" N, Long. -03° 26' 44.41" W, Alt. 855 m AMSL; date 26/05/2002, T 15.70°C, C 36 µS/cm, Sal. 0.00%, pH 4.94, [O_2] 5.67 mg/l, Sat O_2 63.40%, V 57 mV
Silty-muddy substrate with scattered boulders, very rich in organic matter, no flow out
Barren

15. Burn of Elsick, 100 m from the high tide mark, Newtonhill
Lat. 57° 01' 58.88" N, Long. -02° 08' 35.76" W, Alt. 5 m AMSL; date 09/06/2002
Rocky stream bed with sandy-silty pockets and scattered boulders, flow rate: M
Radix balthica (r), *Ancylus fluviatilis* (a), *Pisidium personatum* (rr)

16. Stream flowing along the northern slope of Cran Hill, 350 m from the high tide mark, Newtonhill
Lat. 57° 02' 30.33" N, Long. -02° 07' 55.53" W, Alt. 40 m AMSL; date 09/06/2002
Rocky stream bed with silty-sandy pockets, flow rate: LM
Potamopyrgus antipodarum (r), *Radix balthica* (rr), *Ancylus fluviatilis* (rr), *Pisidium personatum* (c)

17. Stream of the Mill of Findon, Portlethen
Lat. 57° 03' 50.33" N, Long. -02° 07' 19.59" W, Alt. 52 m AMSL; date 09/06/2002
Rocky stream bed with scattered boulders and rare sandy pockets, flow rate: M
Potamopyrgus antipodarum (u), *Radix balthica* (a), *Galba truncatula* (r), *Physella acuta* (r), *Ancylus fluviatilis* (u), *Gyraulus crista* (r), *Pisidium personatum* (u), *Pisidium nitidum* (c)

18. Spring stream flowing toward Blowup Nose, 750 m from the high tide mark, Portlethen
Lat. 57° 04' 56.51" N, Long. -02° 05' 55.28" W, Alt. 70 m AMSL; date 09/06/2002
Muddy-sandy river bed with gravelly pockets (highly eutrophic), flow rate: L
Potamopyrgus antipodarum (c), *Pisidium personatum* (r),

19. Spring stream of Blackhills of Cairnrobin, 600 m from the high tide mark, Cove Bay
Lat. 57° 05' 03.11" N, Long. -02° 05' 48.72" W, Alt. 80 m AMSL; date 09/06/2002
Silty-sandy stream bed with scattered boulders, flow rate: LM
Radix balthica (a), *Pisidium casertanum* (c), *Pisidium personatum* (u)

20. Burn of Crawton, flowing toward Trollochy Bay, 100 m from the high tide mark, Catterline
Lat. 56° 54' 36.89" N, Long. -02° 11' 53.70" W, Alt. 30 m AMSL; date 15/06/2002, T 17.30°C, C 565 µS/cm, Sal. 0.00%, pH 8.34, [O_2] 9.85 mg/l Sat O_2 102.10%, V 6 mV
Silty-sandy stream bed with scattered boulders, flow rate: M
Potamopyrgus antipodarum (u), *Radix balthica* (a), *Ancylus fluviatilis* (a), *Pisidium casertanum* (rr), *Pisidium subtruncatum* (r), *Pisidium nitidum* (r)

21. Spring stream between Crawton and Catterline, flowing at the northern edge of 'The Garran' cliff, Catterline
Lat. 56° 54' 09.88" N, Long. -02° 12' 19.35" W, Alt. 30 m AMSL; date 15/06/2002
Silty-sandy stream bed with muddy pockets and scattered boulders, flow rate: VL
Pisidium personatum (c)

22. Spring stream between Dunnottar Castle and Crawton, flowing toward Wine Cove fjord, Stonehaven
Lat. 56° 55' 38.98" N, Long. -02° 12' 00.35" W, Alt. 45 m AMSL; date 15/06/2002
Silty-sandy stream bed with gravelly pockets and scattered boulders, flow rate: VL
Potamopyrgus antipodarum (a), *Radix balthica* (a), *Pisidium personatum* (a)

23. Spring stream flowing toward the coast between Dunnottar Castle and Crawton, southward from Tremuda Bay, Stonehaven
Lat. 56° 56' 08.44" N, Long. -02°11' 55.55" W, Alt. 55 m AMSL; date 15/06/2002
Muddy-silty stream bed with sandy-gravelly pockets, flow rate: VL
Radix balthica (u), *Potamopyrgus antipodarum* (r), *Galba truncatula* (r), *Pisidium personatum* (r), *Pisidium nitidum* (rr)

24. Stream flowing toward the northern sector of the Bridge of Don beach, in proximity of the Technology Park, Aberdeen
Lat. 57° 11' 21.88" N, Long. -02° 04' 21.52" W, Alt. 1 m AMSL; date 16/06/2002, T 8.50°C, C 527 µS/cm, Sal. 0.00%, pH 9.40, [O_2] 10.32 mg/l, Sat O_2 85.80%, V 84 mV
Sandy-gravelly stream bed with scattered cobbles, flow rate: L
Barren

25. Stream flowing toward the northern sector of the Bridge of Don beach, northward from Findlay Fm, Aberdeen
Lat. 57° 11' 48.58" N, Long. -02° 04' 09.77" W, Alt. 1 m AMSL; date 16/06/2002, T 6.80°C, C 2570 µS/cm, Sal. 0.10%, pH 9.62, [O_2] 17.33 mg/l, Sat O_2 139.80%, V 86 mV
Sandy stream bed, flow rate: M
Potamopyrgus antipodarum (rr), *Radix balthica* (r), *Musculium lacustre* (rr)

26. Stream flowing toward the northern sector of the Bridge of Don beach, southeastward from Tarbothill Fm, Aberdeen
Lat. 57° 12' 22.75" N, Long. -02° 03' 54.53" W, Alt. 1 m AMSL; date 16/06/2002, T 6.70°C, C 2880 µS/cm, Sal. 1.30%, pH 9.63, [O_2] 15.91 mg/l, Sat O_2 127.80%, V 77 mV
Sandy stream bed, flow rate: M
Barren

27. Blackdog Burn, near the high tide mark, north of Bridge of Don beach, Aberdeen
Lat. 57° 13' 00.41" N, Long. -02° 03' 35.67" W, Alt. 1 m AMSL; date 16/06/2002, T 6.30°C, C 411 µS/cm, Sal. 0.00%, pH 7.35, [O_2] 7.16 mg/l, Sat O_2 58.30%, V 244 mV
Sandy stream bed, flow rate: MH
Potamopyrgus antipodarum (c)

28. Catterline Burn, 30 m from the high tide mark, Catterline
Lat. 56° 53' 22.17" N, Long. -02° 12' 58.78" W, Alt. 2 m AMSL; date 06/07/2002
Rocky stream bed covered by small scattered sandy pockets, flow rate: M
Potamopyrgus antipodarum (rr), *Radix balthica* (c), *Galba truncatula* (rr), *Ancylus fluviatilis* (c), *Pisidium personatum* (r), *Pisidium nitidum* (rr)

29. Stream flowing along the northern side of Millhill toward Braidon Bay, 30 m from the high tide mark, Catterline
Lat. 56° 53' 17.21" N, Long. -02° 13' 05.39" W, Alt. 1 m AMSL; date 06/07/2002
Gravelly-pebbly stream bed, flow rate: LM
Radix balthica (u), *Potamopyrgus antipodarum* (c), *Galba truncatula* (r), *Ancylus fluviatilis* (u), *Pisidium personatum* (a), *Pisidium nitidum* (rr)

30. Spring stream of Millhill, Braidon Bay, Catterline
Lat. 56° 53' 14.35" N, Long. -02° 13' 11.51" W, Alt. 10 m AMSL; date 06/07/2002
Rocky stream bed, flow rate: VL
Radix balthica (a), *Galba truncatula* (rr)

31. Spring brook flowing along the south side of Millhill toward Braidon Bay, 30 m from the high tide mark, Catterline
Lat. 56° 53' 09.00" N, Long. -02° 13' 10.03" W, Alt. 1 m AMSL; date 06/07/2002
Gravelly-pebbly stream bed, flow rate: LM
Potamopyrgus antipodarum (rr), *Radix balthica* (rr), *Galba truncatula* (rr), *Ancylus fluviatilis* (a), *Pisidium personatum* (a)

32. Spring stream flowing toward Cullen Bay, 100 m from the high tide mark, Cullen
Lat. 57° 41' 51.06" N, Long. -02° 50' 48.70" W, Alt. 1 m AMSL; date 04/08/2002
Gravelly stream bed with sandy pockets, flow rate: LM
Pisidium personatum (rr)

33. Spring stream flowing toward Cullen Bay, at the base of the Portknockie cliff, Portknockie
Lat. 57° 41' 58.44" N, Long. -02° 50' 56.57" W, Alt. 1 m AMSL; date 04/08/2002
Gravelly stream bed with sandy pockets, flow rate: L
Potamopyrgus antipodarum (a), *Pisidium subtruncatum* (r)

34. Spring stream flowing toward Rouen Bay, between Catterline and Inverbervie, Catterline
Lat. 56° 52' 22.67" N, Long. -02° 13' 32.94" W, Alt. 40 m AMSL; date 18/08/2002
Gravelly stream bed with sandy pockets, flow rate: VL
Barren

35. Spring stream flowing toward a small inlet southward from Rouen Bay, between Catterline and Inverbervie, Catterline
Lat. 56° 52' 19.11" N, Long. -02° 13' 36.87" W, Alt. 42 m AMSL; date 18/08/2002
Gravelly stream bed with sandy pockets, flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (r), *Galba truncatula* (u), *Pisidium personatum* (a)

36. Spring stream flowing toward Little John's Haven, between Catterline and Inverbervie, Inverbervie
Lat. 56° 51' 38.71" N, Long. -02° 14' 33.74" W, Alt. 30 m AMSL; date 18/08/2002
Gravelly stream bed with sandy pockets, flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (c), *Ancylus fluviatilis* (c), *Pisidium personatum* (a)

37. Spring stream flowing toward Darn Bay, between Catterline and Inverbervie, Inverbervie
Lat. 56° 51' 19.47" N, Long. -02° 14' 57.13" W, Alt. 50 m AMSL; date 18/08/2002
Gravelly stream bed with sandy pockets, flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (a), *Galba truncatula* (a), *Ancylus fluviatilis* (c), *Pisidium personatum* (a)

38. Upper section of Allt a' Choire Odhair, between Coire Odhar and 'The Devil's Point', Cairngorms, Braemar
Lat. 57° 02' 19.80" N, Long. -03° 42' 00.49" W, Alt. 930 m AMSL; date 01/09/2002
Gravelly stream bed only composed by granitic fragments, flow rate: M
Barren

39. River Dee in proximity of the bridge leading to Corrour bothy, Cairngorms, Braemar
Lat. 57° 02' 11" N, Long. 03° 40' 41" W, Alt. 550 m AMSL; date 01/09/2002
Gravelly river bed with coarse sandy pockets only composed by granitic fragments, flow rate: H
Barren

40. Glen Luibeg, 400 m downward from Luibeg Bridge, Cairngorms, Braemar
Lat. 57° 01' 32.67" N, Long. -03° 37' 25.49" W, Alt. 480 m AMSL; date 01/09/2002
Gravelly river bed with coarse sandy pockets only composed by granitic fragments and scattered boulders, flow rate: H
Barren

41. Spring stream crossing the costal pathway between Collieston and Slains Castle ruins, Collieston
Lat. 57° 21' 17.45" N, Long. -01° 55' 29.78" W, Alt. 20 m AMSL; date 14/09/2002, T 8.20°C, C 770 µS/cm, Sal. 0.10%, pH 7.52, $[O_2]$ 10.98 mg/l, Sat O_2 91.90%, V 185 mV
Gravelly river bed, flow rate: LM
Potamopyrgus antipodarum (c), *Galba truncatula* (rr), *Ancylus fluviatilis* (rr)

42. Spring stream flowing toward Broad Haven Bay, Collieston
Lat. 57° 21' 49.37" N, Long. -01° 54' 55.51" W, Alt. 20 m AMSL; date 14/09/2002, T 12.50°C, C 797 µS/cm, Sal. 0.10%, pH 7.57, $[O_2]$ 3.49 mg/l, Sat O_2 32.20%, V -58 mV
Silty-muddy river bed, flow rate: L
Galba truncatula (r), *Pisidium personatum* (u)

43. Spring stream rising from a small valley between Broad Haven and Radel Haven, Collieston
Lat. 57° 21' 58.72" N, Long. -01° 54' 34.30" W, Alt. 10 m AMSL; date 14/09/2002, T 8.50°C, C 795 µS/cm, Sal. 0.10%, pH 7.44, $[O_2]$ 11.64 mg/l, Sat O_2 97.80%, V 228 mV
Gravelly stream bed with sandy pockets, flow rate: LM
Potamopyrgus antipodarum (rr), *Galba truncatula* (u)

44. Stream flowing along a valley between Radel Haven and Bruce's Haven, Collieston
Lat. 57° 22' 16.28" N, Long. -01° 53' 58.03" W, Alt. 25 m AMSL; date 14/09/2002, T 13.50°C, C 433 µS/cm, Sal. 0.00%, pH 8.22, $[O_2]$ 10.44 mg/l, Sat O_2 98.70%, V 130 mV
Rocky stream bed with gravelly-sandy pockets, flow rate: M
Potamopyrgus antipodarum (r), *Radix balthica* (a), *Ancylus fluviatilis* (a), *Pisidium personatum* (rr), *Pisidium nitidum* (r)

45. Spring stream flowing toward Bruce's Haven, Collieston
Lat. 57° 22' 26.50" N, Long. -01° 53' 39.08" W, Alt. 22 m AMSL; date 14/09/2002, T 10.80°C, C 674 µS/cm, Sal. 0.10%, pH 7.84, $[O_2]$ 9.74 mg/l, Sat O_2 86.70%, V 137 mV
Gravelly-sandy river bed with scattered boulders, flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (u), *Pisidium personatum* (a)

46. Spring stream flowing toward Green Craig bay, Collieston
Lat. 57° 22' 35.61" N, Long. -01° 53' 10.51" W, Alt. 30 m AMSL; date 14/09/2002, T 12.40°C, C 629 µS/cm, Sal. 0.00%, pH 7.49, $[O_2]$ 6.86 mg/l, Sat O_2 63.30%, V 177 mV
Rocky stream bed with scattered boulders and muddy pockets, flow rate: LM
Potamopyrgus antipodarum (c), *Galba truncatula* (c), *Pisidium personatum* (u)

47. Spring stream flowing toward bay of Cave Arthur, Collieston
Lat. 57° 22' 58.63" N, Long. -01° 52' 29.95" W, Alt. 12 m AMSL; date 14/09/2002, T 11.90°C, C 624 µS/cm, Sal. 0.00%, pH 7.85, $[O_2]$ 8.46 mg/l, Sat O_2 77.30%, V 184 mV
Muddy stream bed with scattered boulders, flow rate: LM
Potamopyrgus antipodarum (u), *Radix balthica* (a), *Galba truncatula* (rr), *Pisidium personatum* (r)

48. Spring stream flowing from West Sandend to Cave Arthur, Collieston
Lat. 57° 22' 58.02" N, Long. -01° 52' 30.32" W, Alt. 11 m AMSL; date 14/09/2002, T 12.50°C, C 375 µS/cm, Sal. 0.00%, pH 7.52, $[O_2]$ 9.14 mg/l, Sat O_2 84.70%, V 165 mV
Gravelly-sandy river bed with scattered boulders, flow rate: M
Radix balthica (a), *Potamopyrgus antipodarum* (a), *Pisidium personatum* (a)

49. Allt Coire Fionn, at the base of the ski lift situated on the northern slope of Glas Maol, Braemar
Lat. 56° 53' 14.31" N, Long. -03° 22' 47.81" W, Alt. 708 m AMSL; date 15/09/2002, T 10.40°C, C 35 µS/cm, Sal. 0.00%, pH 7.95, $[O_2]$ 9.26 mg/l, Sat O_2 88.70%, V 188 mV
Coarse gravelly stream bed with scattered boulders, flow rate: MH
Barren

50. Spring stream flowing between Tom Buidhe and Tolmount, Braemar
Lat. 56° 53' 48.53" N, Long. -03° 18' 02.44" W, Alt. 863 m AMSL; date 15/09/2002, T 12.50°C, C 49 µS/cm, Sal. 0.00%, pH 7.16, $[O_2]$ 8.98 mg/l, Sat O_2 92.10%, V 180 mV
Sandy-gravelly stream bed with muddy (rich in organic matter) pockets, flow rate: LM
Barren

51. Spring stream flowing at the base of the western slope of Knock Saul, Alford
Lat. 57° 17' 51.40" N, Long. -02° 42' 40.47" W, Alt. 344 m AMSL; date 29/09/2002, T 9.20°C, C 79 µS/cm, Sal. 0.00%, pH 6.91, $[O_2]$ 9.57 mg/l, Sat O_2 85.90%, V 83 mV
Muddy-silty stream bed, flow rate: VL
Pisidium casertanum (u), *Pisidium personatum* (c)

52. Stream flowing in the proximity of Knockespock cottage, Insch
Lat. 57° 18' 20.92" N, Long. -02° 45' 17.85" W, Alt. 262 m AMSL; date 29/09/2002, T 11.20°C, C 71 µS/cm, Sal. 0.00%, pH 7.69, $[O_2]$ 9.61 mg/l, Sat O_2 90.00%, V 209 mV
Gravelly stream bed with sandy-silty pockets and scattered boulders, flow rate: M
Radix balthica (c), *Ancylus fluviatilis* (c), *Pisidium personatum* (c), *Pisidium subtruncatum* (rr), *Pisidium nitidum* (a)

53. Glen Lee in proximity of the confluence with a left tributary near Stables of Lee, Invermark
Lat. 56° 55' 8.20" N, Long. -03° 01' 45.57" W, Alt. 450 m AMSL; date 06/10/2002, T 9.80°C, C 90 µS/cm, Sal. 0.00%, pH 7.88, $[O_2]$ 10.74 mg/l, Sat O_2 99.10%, V 252 mV
Rocky river bed covered by coarse gravelly bars, flow rate: M
Barren

54. Glen Lee at the confluence with a left tributary flowing from Muckle Cairn, Invermark
Lat. 56° 55' 13.15" N, Long. -03° 03' 30.42" W, Alt. 573 m AMSL; date 06/10/2002, T 8.50°C, C 37 µS/cm, Sal. 0.00%, pH 7.49, $[O_2]$ 10.21 mg/l, Sat O_2 92.70%, V 221 mV
Rocky river bed covered by coarse gravelly bars, flow rate: M
Barren

55. Upper sector of Glen Lee, downward from the col between knowe of Lee and Easter Balloch, Invermark
Lat. 56° 54' 27.62" N, Long. -03° 04' 50.35" W, Alt. 780 m AMSL; date 06/10/2002, T 6.40°C, C 37 µS/cm, Sal. 0.00%, pH 6.51, $[O_2]$ 9.87 mg/l, Sat O_2 87.40%, V 232 mV
Sandy-silty river bed with a rich content of organic matter, flow rate: VL
Pisidium casertanum (u), *Pisidium personatum* (u)

56. Glen Lee in proximity of the confluence with Burn of Camlet, Invermark
Lat. 56° 55' 00.36" N, Long. -02° 59' 33.31" W, Alt. 343 m AMSL; date 06/10/2002, T 8.90°C, C 47 µS/cm, Sal. 0.00%, pH 7.01, $[O_2]$ 10.88 mg/l, Sat O_2 97.10%, V 275 mV
Gravelly river bed with scattered boulders, flow rate: MH
Barren

57. Burn of Balmedie, Balmedie
Lat. 57° 15' 09.71" N, Long. -02° 02' 11.22" W, Alt. 1 m AMSL; date 09/11/2002, T 6.00°C, C 417 µS/cm, Sal. 0.00%, pH 7.23, $[O_2]$ 7.63 mg/l, Sat O_2 61.70%, V 102 mV
Sandy-silty stream bed, flow rate: MH
Potamopyrgus antipodarum (r)

58. Potterton Burn in locality Eigie Links, Balmedie

Lat. 57° 14' 36.25" N, Long. -02° 02' 35.82" W, Alt. 1 m AMSL; date 09/11/2002, T 6.00°C, C 490 µS/cm, Sal. 0.00%, pH 7.72, [O_2] 8.59 mg/l, Sat O_2 69.50%, V 215 mV
Sandy-silty stream bed, flow rate: MH
Barren

59. Upper sector of Water of Feugh, on the col between Mudlee Bracks and Tampie, Ballochan
Lat. 56° 57' 48.75" N, Long. -02° 48' 57.16" W, Alt. 590 m AMSL; date 17/11/2002, T 3.00°C, C 28 µS/cm, Sal. 0.00%, pH 4.80, [O_2] 7.69 mg/l, Sat O_2 61.90%, V 350 mV
Gravelly river bed with scattered coarse sandy pockets, flow rate: LM
Barren

60. Blanket bog on the col between Tampie and Gannoch, upper sector of Water of Feugh, Ballochan
Lat. 56° 58' 23.39" N, Long. -02° 50' 01.04" W, Alt. 692 m AMSL; date 17/11/2002, T 1.00°C, C 24 µS/cm, Sal. 0.00%, pH 4.93, [O_2] 10.98 mg/l, Sat O_2 84.40%, V 323 mV
Coarse sandy substrate with muddy pockets very rich in organic matter, inlet flow rate: VL
Barren

61. Burn of Auldmad, north-eastern slope of Hill of St Colm, Ballochan
Lat. 56° 59' 51.85" N, Long. -02° 48' 40.72" W, Alt. 380 m AMSL; date 17/11/2002, T 3.50°C, C 25 µS/cm, Sal. 0.00%, pH 5.95, [O_2] 11.78 mg/l, Sat O_2 93.10%, V 201 mV
Gravelly stream bed with scattered boulders, flow rate: MH
Barren

62. Water of Feugh downstream from the confluences with the Burn of Auldmad and the Burn of Allanstank, Ballochan
Lat. 57° 00' 04.61" N, Long. -02° 47' 15.70" W, Alt. 245 m AMSL; date 17/11/2002, T 4.90°C, C 31 µS/cm, Sal. 0.00%, pH 6.84, [O_2] 9.41 mg/l, Sat O_2 76.00%, V 254 mV
Gravelly river bed with scattered boulders, flow rate: H
Barren

63. Cowie Water, 300 m ca. from the high tide mark in Stonehaven Bay, Stonehaven
Lat. 56° 58' 06.72" N, Long. -02° 12' 38.36" W, Alt. 1 m AMSL; date 07/12/2002, T 6.40°C, C 122 µS/cm, Sal. 0.00%, pH 7.05, [O_2] 11.84 mg/l, Sat O_2 94.10%, V 335 mV
Sandy-gravelly stream bed, flow rate: H
Barren

64. Carron Water, 100 m ca. from the high tide mark in Stonehaven Bay, Stonehaven
Lat. 56° 57' 45.99" N, Long. -02° 12' 31.04" W, Alt. 1 m AMSL; date 07/12/2002, T 6.90°C, C 218 µS/cm, Sal. 0.00%, pH 7.39, [O_2] 12.16 mg/l, Sat O_2 97.80%, V 288 mV
Gravelly river bed with coarse sandy pockets, flow rate: MH
Barren

65. Cowie Water, 1200 m ca. south-westward from Tillybreak, Fetteresso Forest, Stonehaven
Lat. 56° 58' 55.83" N, Long. -02° 22' 18.21" W, Alt. 143 m AMSL; date 15/12/2002, T 5.10°C, C 86 µS/cm, Sal. 0.00%, pH 6.77, [O_2] 13.16 mg/l, Sat O_2 108.40%, V 275 mV
River bed characterized by scattered boulders with gravelly-coarse sandy pockets, flow rate: MH
Ancylus fluviatilis (rr), *Pisidium personatum* (rr)

66. Wolf Burn, uppermost section of Cowie Water, Fetteresso Forest, Stonehaven
Lat. 56° 57' 45.99" N, Long. -02° 27' 00.25" W, Alt. 308 m AMSL; date 15/12/2002, T 5.80°C, C 63 µS/cm, Sal. 0.00%, pH 6.13, [O_2] 12.85 mg/l, Sat O_2 106.40%, V 365 mV
Stream bed characterized by scattered boulders with coarse gravelly-sandy pockets, flow rate: L
Barren

67. Water of Tanar, downstream from the confluence with the Burn of Glendui, Aboyne
Lat. 57° 01' 31.58" N, Long. -02° 55' 39.35" W, Alt. 272 m AMSL; date 25/01/2003, T 3.90°C, C 33 µS/cm, Sal. 0.00%, pH 6.53, [O_2] 13.89 mg/l, Sat O_2 109.20%, V 230 mV
Gravelly stream bed with scattered boulders and coarse sandy pockets, flow rate: MH
Barren

68. Water of Tanar, in proximity of Cowie Burn confluence, Aboyne
Lat. 56° 59' 38.49" N, Long. -02° 58' 36.32" W, Alt. 376 m AMSL; date 25/01/2003, T 3.30°C, C 35 µS/cm, Sal. 0.00%, pH 6.75, [O_2] 12.11 mg/l, Sat O_2 94.90%, V 222 mV
Sandy-gravelly river bed with scattered boulders, flow rate: M
Barren

69. Small brook located on the left side of Coinlach Burn, Bridgefoot, Dinnet
Lat. 57° 07' 15.17" N, Long. -02° 58' 46.52" W, Alt. 250 m AMSL; date 22/02/2003, T 1.90°C, C 48 µS/cm, Sal. 0.00%, pH 7.10, [O_2] 12.77 mg/l, Sat O_2 93.80%, V 119 mV
Gravelly-sandy stream bed rich in iron hydroxides, flow rate: L
Pisidium casertanum (a), *Pisidium personatum* (a)

70. Southern shore of Loch Kinord, in the vicinity of Meikle Kinord, Dinnet
Lat. 57° 04' 41.39" N, Long. -02° 55' 27.49" W, Alt. 176 m AMSL; date 22/02/2003, T 0.40°C, C 93 µS/cm, Sal. 0.00%, pH 6.95, [O_2] 16.09 mg/l, Sat O_2 112.10%, V 318 mV
Sandy substrate with spare cobbles and pebbles
Gyraulus albus (rr), *Sphaerium corneum* (u)

71. Beginning of Monandavan Burn (Loch Davan outlet), Dinnet
Lat. 57° 05' 33.19" N, Long. -02° 54' 53.93" W, Alt. 176 m AMSL; date 22/02/2003, T 1.70°C, C 152 µS/cm, Sal. 0.00%, pH 6.76, [O_2] 11.84 mg/l, Sat O_2 85.60%, V 252 mV
Muddy-silty stream bed with sandy bars, flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (r), *Gyraulus albus* (c), *Sphaerium corneum* (r), *Pisidium casertanum* (a), *Pisidium subtruncatum* (u), *Pisidium nitidum* (a), *Pisidium lilljeborgii* (a)

72. Coinlach Burn near a small bridge in locality Homehead, Dinnet
Lat. 57° 07' 34.63" N, Long. -02° 56' 08.53" W, Alt. 185 m AMSL; date 22/02/2003, T 3.10°C, C 127 µS/cm, Sal. 0.00%, pH 6.79, [O_2] 14.21 mg/l, Sat O_2 107.10%, V 210 mV
Sandy-gravelly stream bed with muddy-silty pockets, flow rate: M
Ancylus fluviatilis (u), *Pisidium casertanum* (c), *Pisidium personatum* (u)

73. Upper sector of Coinlach Burn at the intersection with the pathway coming from Balhennie, Dinnet
Lat. 57° 06' 57.10" N, Long. -03° 00' 08.17" W, Alt. 509 m AMSL; date 22/02/2003, T 2.20°C, C 50 µS/cm, Sal. 0.00%, pH 6.11, [O_2] 18.10 mg/l, Sat O_2 138.80%, V 112 mV
Gravelly-cobbly stream bed, flow rate: M
Barren

74. Outlet of an artificial lochan at the bottom of the southern slope of Crannach Hill, Ballater
Lat. 57° 04' 20.01" N, Long. -03° 00' 02.83" W, Alt. 242 m AMSL; date 02/03/2003, T 5.50°C, C 43 µS/cm, Sal. 0.00%, pH 6.88, [O_2] 14.01 mg/l, Sat O_2 115.30%, V 261 mV
Gravelly-sandy stream bed with scattered pebbles, flow rate: LM
Pisidium personatum (u)

75. Intersection between Little Burn and Rashy Burn (beginning of Tullich Burn), southern slope of Morven, Ballater
Lat. 57° 06' 03.74" N, Long. -03° 01' 48.00" W, Alt. 400 m AMSL; date 02/03/2003, T 2.70°C, C 47 µS/cm, Sal. 0.00%, pH 5.44, [O_2] 13.87 mg/l, Sat O_2 107.70%, V 227 mV
Gravelly-pebbly stream bed with sparse cobbles, flow rate: M
Pisidium personatum (rr)

76. Upper sector of Little Burn, west-southwestern slope of Morven, Ballater
Lat. 57° 06' 54.90" N, Long. -03° 03' 20.61" W, Alt. 580 m AMSL; date 02/03/2003, T 2.00°C, C 53 µS/cm, Sal. 0.00%, pH 4.14, [O_2] 12.86 mg/l, Sat O_2 99.90%, V 192 mV
Pebbly-cobbly stream bed with scattered boulders, flow rate: LM
Barren

77. Upper sector of Glenfenzie Burn, southern slope of Cairnagour Hill, Ballater

Lat. 57° 07' 25.22" N, Long. -03° 06' 58.69" W, Alt. 460 m AMSL; date 22/03/2003, T 5.80°C, C 49 µS/cm, Sal. 0.00%, pH 7.38, [O_2] 12.39 mg/l, Sat O_2 104.10%, V 284 mV
Gravelly-pebbly stream bed with sparse sandy pockets, flow rate: LM
Barren

78. Confluence between Morven Burn and Allt Coire nan Imireachan, upper sector of Lary Burn, Ballater
Lat. 57° 06' 38.59" N, Long. -03° 05' 10.81" W, Alt. 393 m AMSL; date 22/03/2003, T 6.00°C, C 73 µS/cm, Sal. 0.00%, pH 7.40, [O_2] 14.37 mg/l, Sat O_2 120.50%, V 186 mV
Pebbly-cobbly stream bed with gravelly pockets, flow rate: M
Barren

79. Very small spring brook flowing along the eastern slope of Lary Hill, Ballater
Lat. 57° 05' 45.97" N, Long. -03° 05' 03.01" W, Alt. 382 m AMSL; date 22/03/2003, T 5.10°C, C 58 µS/cm, Sal. 0.00%, pH 5.14, [O_2] 12.68 mg/l, Sat O_2 103.60%, V 277 mV
Sandy-gravelly stream bed with scattered pebbles, flow rate: L
Pisidium casertanum (r)

80. Feardar Burn, 700 m south-westward from Auchtavan, Inver
Lat. 57° 02' 30.15" N, Long. -03° 19' 33.74" W, Alt. 379 m AMSL; date 22/03/2003, T 6.70°C, C 65 µS/cm, Sal. 0.00%, pH 7.69, [O_2] 9.73 mg/l, Sat O_2 82.60%, V 239 mV
Gravelly-pebbly stream bed with sandy-gravelly pockets, flow rate: M
Barren

81. Very small spring brook flowing along the northern slope of Meall Gorm, Inver
Lat. 57° 02' 30.57" N, Long. -03° 20' 44.23" W, Alt. 400 m AMSL; date 23/03/2003, T 6.70°C, C 108 µS/cm, Sal. 0.00%, pH 7.41, [O_2] 8.52 mg/l, Sat O_2 72.50%, V 159 mV
Stream bed mainly composed of a rich muddy-sandy fraction, flow rate: VL
Radix balthica (a), *Pisidium personatum* (c), *Pisidium milium* (c), *Pisidium nitidum* (r)

82. Right side tributary of the Feardar Burn in between Middleton of Aberarder and Balnoe, Inver
Lat. 57° 01' 40.60" N, Long. -03° 17' 55.91" W, Alt. 322 m AMSL; date 23/03/2003, T 8.70°C, C 125 µS/cm, Sal. 0.00%, pH 7.71, [O_2] 10.96 mg/l, Sat O_2 97.30%, V 253 mV
Gravelly-pebbly stream bed, flow rate: LM
Radix balthica (r), *Ancylus fluviatilis* (a), *Pisidium casertanum* (r), *Pisidium personatum* (rr), *Pisidium milium* (r)

83. Allt an t-Slugain at the base of the southern slope of Meall an t-Slugain, Braemar
Lat. 57° 02' 15.23" N, Long. -03° 26' 48.45" W, Alt. 510 m AMSL; date 30/03/2003, T 3.30°C, C 23 µS/cm, Sal. 0.00%, pH 6.76, [O_2] 13.65 mg/l, Sat O_2 107.90%, V 320 mV
Gravelly-pebbly stream bed with sandy-muddy pockets, flow rate: LM
Radix balthica (r), *Pisidium casertanum* (c), *Pisidium personatum* (c)

84. Allt an t-Slugain pool in proximity of the ruins of a fortified house, Braemar
Lat. 57° 02' 26.90" N, Long. -03° 27' 13.54" W, Alt. 585 m AMSL; date 30/03/2003, T 4.60°C, C 23 µS/cm, Sal. 0.00%, pH 7.39, [O_2] 12.51 mg/l, Sat O_2 103.60%, V 180 mV
Muddy-sandy stream bed, flow rate: VL
Pisidium casertanum (a), *Pisidium personatum* (u)

85. Confluence of Allt Dearg with Glass Allt Mòr, south-eastern slope of Ben Avon, Braemar
Lat. 57° 04' 22.98" N, Long. -03° 27' 57.49" W, Alt. 685 m AMSL; date 30/03/2003, T 2.90°C, C 20 µS/cm, Sal. 0.00%, pH 3.56, [O_2] 13.54 mg/l, Sat O_2 108.40%, V 294 mV
Pebbly-cobbly stream bed with scattered boulders, flow rate: MH
Barren

86. Loch Muick, 500 m north-eastward from Glas-allt-Shiel, Ballater
Lat. 56° 55' 48.94" N, Long. -03° 11' 05.94" W, Alt. 398 m AMSL; date 03/05/2003, T 9.10°C, C 22 µS/cm, Sal. 0.00%, pH 7.02, [O_2] 11.34 mg/l, Sat O_2 103.80%, V 150 mV
Sandy-gravelly substrate with scattered pebbles
Barren

87. Loch Muick in proximity of the northern inlet Allt and Dubh-loch, Ballater
Lat. 56° 55' 28.37" N, Long. -03° 11' 57.08" W, Alt. 398 m AMSL; date 03/05/2003, T 8.10°C, C 21 µS/cm, Sal. 0.00%, pH 7.16, [O_2] 12.33 mg/l, Sat O_2 110.10%, V 203 mV
Sandy-gravelly substrate with scattered pebbles
Barren

88. Dubh-Loch in proximity of the inlet Allt an Dubh-loch, Ballater
Lat. 56° 55' 49.55" N, Long. -03° 15' 32.65" W, Alt. 638 m AMSL; date 03/05/2003, T 8.80°C, C 21 µS/cm, Sal. 0.00%, pH 4.97, [O_2] 12.47 mg/l, Sat O_2 166.60%, V 296 mV
Coarse whitish sandy substrate derived from granitic rocks weathering
Barren

89. Leuchar Burn in between Inverord and North Linn farms, Peterculter
Lat. 57° 07' 18.80" N, Long. -02° 17' 43.45" W, Alt. 71 m AMSL; date 04/05/2003, T 10.80°C, C 273 µS/cm, Sal. 0.00%, pH 4.23, [O_2] 10.62 mg/l, Sat O_2 98.10%, V 91 mV
Muddy stream bed, flow rate: M
Radix balthica (u), *Physa fontinalis* (rr), *Sphaerium corneum* (u), *Pisidium casertanum* (u), *Pisidium personatum* (r), *Pisidium subtruncatum* (a), *Pisidium nitidum* (u)

90. Leuchar Burn below the old bridge of Mill of Garlogie, Peterculter
Lat. 57° 08' 20.06" N, Long. -02° 21' 40.78" W, Alt. 78 m AMSL; date 04/05/2003, T 10.30°C, C 254 µS/cm, Sal. 0.00%, pH 4.18, [O_2] 8.43 mg/l, Sat O_2 77.00%, V 140 mV
Cobbly stream bed with scattered sandy pockets, flow rate: H
Potamopyrgus antipodarum (c), *Radix balthica* (r), *Bathyomphalus contortus* (rr), *Sphaerium corneum* (c), *Pisidium casertanum* (c), *Pisidium personatum* (u)

91. Upper sector of a left tributary of Gormack Burn, in proximity of the farm Culfosie, Dunecht
Lat. 57° 9'21.62" N, Long. -02° 26' 23.19" W, Alt. 125 m AMSL; date 04/05/2003, T 9.50°C, C 209 µS/cm, Sal. 0.00%, pH 4.24, [O_2] 12.08 mg/l, Sat O_2 109.20%, V 187 mV
Sandy-gravelly stream bed with scattered pebbles and some muddy pockets, flow rate: L
Ancylus fluviatilis (a), *Pisidium casertanum* (r)

92. Gormack Burn in proximity of Quiddies Mill, below a bridge, Peterculter
Lat. 57° 06' 36.66" N, Long. -02° 23' 15.28" W, Alt. 62 m AMSL; date 04/05/2003, T 9.70°C, C 173 µS/cm, Sal. 0.00%, pH 3.97, [O_2] 11.75 mg/l, Sat O_2 105.90%, V 119 mV
Sandy-gravelly stream bed with scattered cobbles and spare boulders, flow rate: MH
Ancylus fluviatilis (u), *Pisidium casertanum* (r), *Pisidium personatum* (r)

93. Lui Water at the intersection with Derry Burn, Derry Lodge, Braemar
Lat. 57° 01' 14.21" N, Long. -03° 34' 56.15" W, Alt. 419 m AMSL; date 07/06/2003, T 12.50°C, C 29 µS/cm, Sal. 0.00%, pH 6.32, [O_2] 6.31 mg/l, Sat O_2 62.50%, V 354 mV
Gravelly-pebbly river bed, flow rate: MH
Barren

94. Blanket bog localised on the upper sector of Allt Carn a' Mhaim, southern slope of Ben Macdui, Braemar
Lat. 57° 03' 11.13" N, Long. -03° 40' 15.45" W, Alt. 818 m AMSL; date 07/06/2003, T 14.70°C, C 17 µS/cm, Sal. 0.00%, pH 4.79, [O_2] 8.40 mg/l, Sat O_2 91.70%, V 233 mV
Muddy-sandy substrate with scattered boulders, no flow out
Barren

95. Blanket bog localised on the upper sector of Luibeg Burn, northern slope of Derry Cairngorm, Braemar

Lat. 57° 04' 35.56" N, Long. -03° 38' 07.98" W, Alt. 1055 m AMSL; date 07/06/2003, T 12.30°C, C 12 µS/cm, Sal. 0.00%, pH 5.06, [O_2] 8.64 mg/l, Sat O_2 92.00%, V 152 mV
Muddy-sandy substrate, no flow out
Barren

96. River Dee at the intersection with Geldie Burn, White Bridge, Braemar
Lat. 56° 58' 36.89" N, Long. -03° 36' 40.39" W, Alt. 404 m AMSL; date 08/06/2003, T 12.00°C, C 19 µS/cm, Sal. 0.00%, pH 3.69, [O_2] 13.85 mg/l, Sat O_2 136.10%, V 119 mV
Gravelly-pebbly river bed with scattered boulders and scattered sandy-gravelly pockets, flow rate: H
Barren

97. River Dee at the intersection with Geusachan Burn, southern slope of the Devil's Point, Braemar
Lat. 57° 00' 28.85" N, Long. -03° 40' 08.64" W, Alt. 498 m AMSL; date 08/06/2003, T 11.50°C, C 17 µS/cm, Sal. 0.00%, pH 5.02, [O_2] 15.25 mg/l, Sat O_2 149.50%, V 204 mV
Sandy-gravelly river bed with scattered boulders and sandy-muddy pockets, flow rate: H
Barren

98. Eastern shore of Loch nan Stuirteag, northern slope of Monadh Mòr, Braemar
Lat. 57° 02' 26.17" N, Long. -03° 44' 39.23" W, Alt. 815 m AMSL; date 08/06/2003, T 13.60°C, C 32 µS/cm, Sal. 0.00%, pH 3.70, [O_2] 8.40 mg/l, Sat O_2 90.30%, V 175 mV
Pebbly-cobbly substrate, outlet flow rate: LM
Barren

99. Southern shore of Loch of Aboyne, Aboyne
Lat. 57° 05' 05.27" N, Long. -02° 46' 02.08" W, Alt. 137 m AMSL; date 12/06/2003, T 18.00°C, C 204 µS/cm, Sal. 0.00%, pH 8.07, [O_2] 9.55 mg/l, Sat O_2 102.40%, V 101 mV
Muddy-sandy substrate, very rich in organic matter and covered by a thick layer of vegetal fragments
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Bathyomphalus contortus* (rr), *Gyraulus albus* (u), *Pisidium lilljeborgii* (a), *Pisidium hibernicum* (a)

100. Loch of Aboyne outlet, Aboyne
Lat. 57° 05' 18.98" N, Long. -02° 46' 06.00" W, Alt. 137 m AMSL; date 12/06/2003, T 17.70°C, C 158 µS/cm, Sal. 0.00%, pH 4.65, [O_2] 9.79 mg/l, Sat O_2 104.20%, V 71 mV
Sandy-gravelly stream bed with scattered pebbly-cobbly pockets, outlet flow rate: VL
Potamopyrgus antipodarum (u), *Gyraulus albus* (a), *Pisidium hibernicum* (r)

101. North-eastern shore of Loch of Aboyne, Aboyne
Lat. 57° 05' 20.73" N, Long. -02° 45' 54.48" W, Alt. 137 m AMSL; date 12/06/2003, T 17.60°C, C 154 µS/cm, Sal. 0.00%, pH 4.52, [O_2] 7.84 mg/l, Sat O_2 83.50%, V 158 mV
Sandy-gravelly substrate with scattered pebbles and cobbles
Potamopyrgus antipodarum (u), *Gyraulus albus* (r), *Pisidium hibernicum* (r)

102. Gelder Burn at the confluence with Féith and Laoigh, northern slope of Lochnagar, Braemar
Lat. 57° 00' 11.42" N, Long. -03° 14' 07.57" W, Alt. 389 m AMSL; date 14/06/2003, T 12.60°C, C 31 µS/cm, Sal. 0.00%, pH 6.55, [O_2] 11.64 mg/l, Sat O_2 113.70%, V 160 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: M
Barren

103. Gelder Burn at the confluence with Allt a' Ghlas-choire, northern slope of Lochnagar, Braemar
Lat. 56° 59' 22.40" N, Long. -03° 13' 03.36" W, Alt. 463 m AMSL; date 14/06/2003, T 12.90°C, C 27 µS/cm, Sal. 0.00%, pH 7.36, [O_2] 12.08 mg/l, Sat O_2 119.70%, V 201 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: LM
Barren

104. Lochnagar at Lochnagar Burn beginning, northern slope of Lochnagar, Braemar
Lat. 56° 57' 41.03" N, Long. -03° 13' 48.26" W, Alt. 788 m AMSL; date 14/06/2003, T 13.00°C, C 20 µS/cm, Sal. 0.00%, pH 5.82, [O_2] 11.62 mg/l, Sat O_2 120.30%, V 279 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: L
Barren

105. Burn of Fordyce nearby the high tide mark in Sandend Bay, Portsoy
Lat. 57° 40' 54.48" N, Long. -02° 44' 25.01" W, Alt. 1 m AMSL; date 15/06/2003, T 16.60°C, C 456 µS/cm, Sal. 0.00%, pH 8.87, [O_2] 15.98 mg/l, Sat O_2 162.90%, V 119 mV
Sandy (mainly marine shells fragments) stream bed with scattered cobbly pockets, flow rate: LM
Radix balthica (rr), *Potamopyrgus antipodarum* (r)

106. Small stream flowing along the western side of Sandend Bay in proximity of the high tide mark, Portsoy
Lat. 57° 40' 57.92" N, Long. -02° 44' 50.83" W, Alt. 1 m AMSL; date 15/06/2003, T 17.50°C, C 528 µS/cm, Sal. 0.00%, pH 8.95, [O_2] 19.06 mg/l, Sat O_2 197.70%, V 116 mV
Sandy (mainly marine shells and foraminifers fragments) stream bed with scattered cobbly pockets, flow rate: LM
Potamopyrgus antipodarum (a), *Radix balthica* (a), *Galba truncatula* (rr), *Pisidium personatum* (u)

107. Burn of Den in proximity of Rubislaw Park, Aberdeen
Lat. 57° 08' 36.67" N, Long. -02° 08' 17.37" W, Alt. 74 m AMSL; date 17/06/2003, T 13.60°C, C 372 µS/cm, Sal. 0.00%, pH 6.38, [O_2] 8.91 mg/l, Sat O_2 86.60%, V 112 mV
Sandy-gravelly river bed with scattered cobbly-muddy pockets and boulders, flow rate: LM
Potamopyrgus antipodarum (u), *Radix balthica* (rr), *Ancylus fluviatilis* (rr), *Pisidium personatum* (r)

108. Burn of Mill of Blairton, 150 m before the high tide mark, Balmedie
Lat. 57° 15' 55.16" N, Long. -02° 01' 36.94" W, Alt. 1 m AMSL; date 28/06/2003, T 18.70°C, C 424 µS/cm, Sal. 0.00%, pH 9.21, [O_2] 19.24 mg/l, Sat O_2 206.00%, V 53 mV
Sandy stream bed with patchy Cyanophyta colonies on the bottom and on the surface, flow rate: LM
Potamopyrgus antipodarum (r)

109. Burn of Mill of Menie, 150 m before the high tide mark, Balmedie
Lat. 57° 16' 09.20" N, Long. -02° 01' 27.97" W, Alt. 1 m AMSL; date 28/06/2003, T 18.00°C, C 388 µS/cm, Sal. 0.00%, pH 6.97, [O_2] 5.80 mg/l, Sat O_2 61.20%, V 19 mV
Sandy stream bed with patchy Cyanophyta colonies on the bottom and on the surface, flow rate: M
Radix balthica (rr), *Pisidium personatum* (rr)

110. Sandend Burn, 100 m before the high tide mark, Balmedie
Lat. 57° 17' 20.49" N, Long. -02° 00' 27.59" W, Alt. 1 m AMSL; date 28/06/2003, T 15.30°C, C 433 µS/cm, Sal. 0.00%, pH 4.45, [O_2] 9.35 mg/l, Sat O_2 93.30%, V 92 mV
Sandy stream bed, flow rate: M
Galba truncatula (rr), *Pisidium casertanum* (r), *Pisidium personatum* (u)

111. Burn of Drums, 50 m before the high tide mark, Newburgh
Lat. 57° 17' 33.53" N, Long. -02° 00' 13.14" W, Alt. 1 m AMSL; date 28/06/2003, T 12.60°C, C 480 µS/cm, Sal. 0.00%, pH 3.50, [O_2] 7.67 mg/l, Sat O_2 72.20%, V 103 mV
Sandy stream bed characterised by well sorted sands, flow rate: M
Radix balthica (rr), *Galba truncatula* (rr), *Pisidium casertanum* (r), *Pisidium personatum* (c)

112. Quarry lochan located 1500 m north-eastward from Bullers of Buchan, Cruden Bay
Lat. 57° 26' 21.54" N, Long. -01° 48' 40.12" W, Alt. 40 m AMSL; date 29/06/2003, T 16.90°C, C 3310 µS/cm, Sal. 1.60%, pH 6.76, [O_2] 7.68 mg/l, Sat O_2 79.70%, V 86 mV
Sandy-gravelly substrate with muddy pockets and scattered boulders, no flow out
Potamopyrgus antipodarum (a)

113. Quarry lochan situated 100 m westward from bay Yoags' Haven, Boddam
Lat. 57° 26' 50.34" N, Long. -01° 48' 15.03" W, Alt. 63 m AMSL; date 29/06/2003, T 15.90°C, C 764 µS/cm, Sal. 0.10%, pH 3.82, [O_2] 8.16 mg/l, Sat O_2 83.10%, V 81 mV

Very deep lochan bounded by steep granite walls. Few patches of sandy-gravelly sediment pockets resting on the rock asperities, no flow out
Potamopyrgus antipodarum (a), *Ancylus fluviatilis* (r), *Pisidium casertanum* (r)

114. Southern shore of Loch Muick, in proximity of Black Burn inlet, Ballater
Lat. 56° 55' 38.76" N, Long. -03° 10' 22.12" W, Alt. 398 m AMSL; date 06/09/2003, T 14.10°C, C 23 µS/cm, Sal. 0.00%, pH 7.24, [O_2] 8.50 mg/l, Sat O_2 86.80%, V 304 mV
Gravelly-cobbly substrate with scattered boulders and sandy pockets, inlet flow rate: M
Pisidium casertanum (r)

115. Blanket bog situated on the north-eastern plateau of Sandy Hillock, Ballater
Lat. 56° 55' 00.49" N, Long. -03° 11' 20.45" W, Alt. 648 m AMSL; date 06/09/2003, T 17.70°C, C 36 µS/cm, Sal. 0.00%, pH 4.24, [O_2] 9.14 mg/l, Sat O_2 104.00%, V 390 mV
Gravelly-cobbly substrate with scattered boulders covered by thick vegetal debris, no flow out
Barren

116. Upper sector of Black Burn, eastern slope of Sandy Hillock, Ballater
Lat. 56° 54' 48.42" N, Long. -03° 11' 21.34" W, Alt. 643 m AMSL; date 06/09/2003, T 15.60°C, C 38 µS/cm, Sal. 0.00%, pH 7.17, [O_2] 9.59 mg/l, Sat O_2 104.40%, V 193 mV
Gravelly-cobbly stream bed with scattered boulders, flow rate: L
Pisidium casertanum (r)

117. Small blanket bog located on the north-northwestern slope of Sandy Hillock, Ballater
Lat. 56° 54' 43.54" N, Long. -03° 12' 52.42" W, Alt. 724 m AMSL; date 06/09/2003, T 18.40°C, C 45 µS/cm, Sal. 0.00%, pH 4.17, [O_2] 8.51 mg/l, Sat O_2 99.30%, V 310 mV
Gravelly-cobbly substrate with scattered boulders covered by thick vegetal debris, no flow out
Barren

118. Upper sector of Allt an Dubh-loch, south-eastern slope of Carn an t-Sagairt Mòr, Ballater
Lat. 56° 56' 25.63" N, Long. -03° 16' 56.54" W, Alt. 859 m AMSL; date 06/09/2003, T 12.50°C, C 20 µS/cm, Sal. 0.00%, pH 6.78, [O_2] 7.71 mg/l, Sat O_2 80.60%, V 278 mV
Gravelly-cobbly stream bed with scattered boulders, flow rate: LM
Barren

119. Artificial channel of Bucket Mill, in proximity of the confluence with Water of Feugh, Banchory
Lat. 57° 00' 36.33" N, Long. -02° 41' 50.93" W, Alt. 151 m AMSL; date 07/09/2003, T 13.10°C, C 55 µS/cm, Sal. 0.00%, pH 7.30, [O_2] 11.04 mg/l, Sat O_2 107.40%, V 238 mV
Gravelly-cobbly stream bed with scattered boulders and sandy pockets, flow rate: L
Radix balthica (u), *Ancylus fluviatilis* (a)

120. Water of Feugh, below the bridge located eastward from Whitestone, Banchory
Lat. 57° 01' 15.08" N, Long. -02° 35' 32.33" W, Alt. 89 m AMSL; date 07/09/2003, T 13.80°C, C 63 µS/cm, Sal. 0.00%, pH 7.55, [O_2] 10.23 mg/l, Sat O_2 100.30%, V 223 mV
Gravelly-cobbly river bed with scattered boulders and sandy pockets, flow rate: MH
Ancylus fluviatilis (a)

121. Water of Feugh, below the bridge of Strachan, Banchory
Lat. 57° 01' 10.40" N, Long. -02° 32' 10.93" W, Alt. 75 m AMSL; date 07/09/2003, T 13.40°C, C 68 µS/cm, Sal. 0.00%, pH 4.42, [O_2] 11.06 mg/l, Sat O_2 99.00%, V 204 mV
Gravelly-cobbly river bed with scattered boulders and sandy pockets, flow rate: MH
Ancylus fluviatilis (a)

122. Water of Feugh between Invery House and Tilquhillie Cottage, Banchory
Lat. 57° 02' 31.94" N, Long. -02° 29' 40.33" W, Alt. 68 m AMSL; date 07/09/2003, T 13.60°C, C 81 µS/cm, Sal. 0.00%, pH 7.41, [O_2] 9.10 mg/l, Sat O_2 88.60%, V 226 mV
Rocky river bed with scattered boulders and sandy pockets, flow rate: MH
Radix balthica (rr), *Ancylus fluviatilis* (a), *Pisidium personatum* (rr)
Pisidium subtruncatum (rr)

123. Spring stream flowing across Nigg Bay, Torry, Aberdeen
Lat. 57° 07' 59.59" N, Long. -02° 03' 34.39" W, Alt. 1 m AMSL; date 23/09/2003, T 9.50°C, C 875 µS/cm, Sal. 0.20%, pH 7.33, [O_2] 4.40 mg/l, Sat O_2 78.20%, V 179 mV
Sandy-muddy river bed with scattered boulders, flow rate: M
Radix balthica (a), *Physella acuta* (a)

124. Upper sector of a stream flowing across a flooding depression of Glas Allt Mòr, southern slope of Beinn a' Chaorainn, Braemar
Lat. 57° 05' 04.81" N, Long. -03° 33' 46.32" W, Alt. 872 m AMSL; date 28/09/2003, T 9.90°C, C 35 µS/cm, Sal. 0.00%, pH 6.24, [O_2] 9.16 mg/l, Sat O_2 90.30%, V 203 mV
Sandy stream bed with scattered boulders, flow rate: L
Pisidium casertanum (rr)

125. Small blanket bog situated on the col between Beinn a' Chaorainn and Beinn a' Chaorainn Bheag, Braemar
Lat. 57° 05' 45.11" N, Long. -03° 33' 45.02" W, Alt. 949 m AMSL; date 28/09/2003, T 7.70°C, C 17 µS/cm, Sal. 0.00%, pH 6.04, [O_2] 8.09 mg/l, Sat O_2 86.30%, V 336 mV
Sandy substrate with scattered boulders covered by thick vegetal debris, no flow out
Barren

126. Derry Burn at the confluence with Glas Allt Mòr, eastern slope of Derry Cairngorm, Braemar
Lat. 57° 04' 07.16" N, Long. -03° 35' 34.15" W, Alt. 561 m AMSL; date 28/09/2003, T 7.70°C, C 21 µS/cm, Sal. 0.00%, pH 6.33, [O_2] 10.71 mg/l, Sat O_2 96.40%, V 223 mV
Cobbly-pebbly stream bed with scattered boulders and sandy pockets, flow rate: MH
Barren

127. Lochan situated on the right side of Derry Burn, eastern slope of Carn Crom, Braemar
Lat. 57° 02' 27.51" N, Long. -03° 35' 15.76" W, Alt. 498 m AMSL; date 28/09/2003, T 8.10°C, C 40 µS/cm, Sal. 0.00%, pH 5.18, [O_2] 3.84 mg/l, Sat O_2 34.70%, V -270 mV
Muddy substrate covered by a thick vegetal debris and Cyanophyta, outlet flow rate: L
Barren

128. Water of Aven at the beginning of the gorge between Tomanarrach and Peter Hill, Banchory
Lat. 56° 58' 27.59" N, Long. -02° 42' 11.12" W, Alt. 373 m AMSL; date 01/11/2003, T 4.50°C, C 45 µS/cm, Sal. 0.00%, pH 7.33, [O_2] 11.70 mg/l, Sat O_2 96.40%, V 222 mV
Pebbly-cobbly river bed with gravelly pockets and scattered boulders, flow rate: MH
Barren

129. Water of Aven, northern slope of Mount Battock, Banchory
Lat. 56° 58' 23.60" N, Long. -02° 44' 19.18" W, Alt. 440 m AMSL; date 01/11/2003, T 4.80°C, C 48 µS/cm, Sal. 0.00%, pH 6.95, [O_2] 12.26 mg/l, Sat O_2 103.00%, V 130 mV
Pebbly-cobbly river bed with gravelly pockets and scattered boulders, flow rate: M
Barren

130. Blanket bog situated on the col between Baudnacauner and Peter Hill, northern ridge of Water of Aven, Banchory
Lat. 56° 58' 58.11" N, Long. -02° 43' 11.28" W, Alt. 511 m AMSL; date 01/11/2003, T 4.40°C, C 93 µS/cm, Sal. 0.00%, pH 4.13, [O_2] 9.44 mg/l, Sat O_2 79.30%, V 320 mV
Muddy substrate covered by a thick layer of vegetal debris, no flow out
Barren

131. Gadie Burn, 500 m south-eastward from Auchleven, Auchleven
Lat. 57° 18' 24.38" N, Long. -02° 37' 07.52" W, Alt. 145 m AMSL; date 02/11/2003, T 7.80°C, C 283 µS/cm, Sal. 0.00%, pH 7.95, [O_2] 10.57 mg/l, Sat O_2 93.70%, V 198 mV

Gravelly-pebbly stream bed with sandy pockets and scattered boulders, flow rate: M
Potamopyrgus antipodarum (rr), *Radix balthica* (r), *Ancylus fluviatilis* (c), *Pisidium casertanum* (r), *Pisidium personatum* (u), *Pisidium subtruncatum* (rr)

132. River Urie at the confluence with Gadie Burn, Garioch
Lat. 57° 19' 18.61" N, Long. -02° 29' 56.98" W, Alt. 78 m AMSL; date 02/11/2003, T 7.40°C, C 253 µS/cm, Sal. 0.00%, pH 7.68, [O_2] 11.70 mg/l, Sat O_2 102.60%, V 180 mV
Sandy-gravelly river bed entirely armoured with boulders, flow rate: H
Radix balthica (u), *Potamopyrgus antipodarum* (r), *Ancylus fluviatilis* (c), *Pisidium casertanum* (r), *Pisidium personatum* (u), *Pisidium subtruncatum* (rr)

133. Water of Tanar at the confluence with Water Allachy, Aboyne
Lat. 57° 02' 10.23" N, Long. -02° 52' 43.46" W, Alt. 188 m AMSL; date 09/11/2003, T 6.10°C, C 51 µS/cm, Sal. 0.00%, pH 6.36, [O_2] 14.83 mg/l, Sat O_2 121.80%, V 179 mV
Pebbly-cobbly river bed with sandy-gravelly pockets and scattered boulders, flow rate: H
Barren

134. Lochan located to the left side of Water of Tanar, 500 m south-eastward from Glen Tanar House, Aboyne
Lat. 57° 02' 43.64" N, Long. -02° 51' 46.72" W, Alt. 169 m AMSL; date 09/11/2003, T 7.20°C, C 49 µS/cm, Sal. 0.00%, pH 7.30, [O_2] 8.62 mg/l, Sat O_2 72.70%, V 163 mV
Muddy substrate with scattered boulders covered by a thick layer of vegetal debris, outlet flow rate: L
Radix balthica (u), *Pisidium hibernicum* (a)

135. Outlet of a small lochan situated northward from the station no.134, Glen Tanar House, Aboyne
Lat. 57° 02' 46.79" N, Long. -02° 51' 48.30" W, Alt. 166 m AMSL; date 09/11/2003, T 7.00°C, C 48 µS/cm, Sal. 0.00%, pH 6.64, [O_2] 18.08 mg/l, Sat O_2 151.80%, V 223 mV
Sandy-gravelly stream bed with muddy pockets and scattered boulders, flow rate: L
Radix balthica (u), *Ancylus fluviatilis* (a), *Pisidium hibernicum* (c)

136. Small lochan located at the base of the northern slope of Birsemore Hill, Aboyne
Lat. 57° 03' 54.44" N, Long. -02° 46' 59.19" W, Alt. 138 m AMSL; date 09/11/2003, T 7.20°C, C 82 µS/cm, Sal. 0.00%, pH 7.28, [O_2] 24.60 mg/l, Sat O_2 207.00%, V 247 mV
Muddy substrate covered by a thick layer of vegetal debris, no flow out
Pisidium casertanum (u), *Pisidium nitidum* (rr)

137. Burn of Blackburn, below a bridge located between Scotsmill and Begsley, Blackburn
Lat. 57° 12' 46.76" N, Long. -02° 16' 54.26" W, Alt. 71 m AMSL; date 15/11/2003, T 7.20°C, C 401 µS/cm, Sal. 0.00%, pH 6.92, [O_2] 8.76 mg/l, Sat O_2 73.90%, V 111 mV
Gravelly-pebbly stream bed with pebbly patches and scattered boulders, flow rate: M
Radix balthica (a), *Ancylus fluviatilis* (a), *Pisidium casertanum* (r), *Pisidium subtruncatum* (r), *Pisidium nitidum* (r)

138. River Don below the bridge of Boat of Hatton, Hatton of Fintray
Lat. 57° 14' 00.84" N, Long. -02° 16' 15.99" W, Alt. 43 m AMSL; date 15/11/2003, T 6.50°C, C 225 µS/cm, Sal. 0.00%, pH 7.59, [O_2] 11.43 mg/l, Sat O_2 94.40%, V 94 mV
Sandy-gravelly river bed with muddy banks, flow rate: VH
Potamopyrgus antipodarum (a), *Radix balthica* (c), *Ancylus fluviatilis* (r), *Pisidium casertanum* (r), *Pisidium subtruncatum* (a), *Pisidium milium* (rr), *Pisidium nitidum* (a), *Pisidium hibernicum* (r)

139. Blackhole bog, base of the north-eastern slope of Peter Hill, Banchory
Lat. 57° 00' 31.99" N, Long. -02° 39' 01.28" W, Alt. 119 m AMSL; date 16/11/2003, T 5.90°C, C 101 µS/cm, Sal. 0.00%, pH 5.90, [O_2] 7.49 mg/l, Sat O_2 60.80%, V 50 mV
Sandy gravelly substrate, flow rate: LM
Pisidium casertanum (r)

140. Water of Aven downstream from the confluence with the Burn of Clashmad, Banchory
Lat. 56° 59' 49.20" N, Long. -02° 38' 30.69" W, Alt. 178 m AMSL; date 16/11/2003, T 5.30°C, C 59 µS/cm, Sal. 0.00%, pH 6.00, [O_2] 11.76 mg/l, Sat O_2 94.80%, V 339 mV
Gravelly-pebbly river bed with scattered boulders, flow rate: M
Barren

141. Artificial shallow lochan located to the left side of Water of Feugh, near Waulkmill, Banchory
Lat. 57° 01' 07.88" N, Long. -02° 35' 10.68" W, Alt. 88 m AMSL; date 16/11/2003, T 5.80°C, C 69 µS/cm, Sal. 0.00%, pH 6.49, [O_2] 30.40 mg/l, Sat O_2 245.00%, V 139 mV
Sandy-gravelly substrate with scattered boulders, outlet flow rate: LM
Barren

142. Pollagach Burn at the confluence with a left tributary of Coire of Corn Arn, Ballater
Lat. 57° 02' 38.64" N, Long. -02° 58' 31.10" W, Alt. 296 m AMSL; date 23/11/2003, T 1.50°C, C 84 µS/cm, Sal. 0.00%, pH 7.34, [O_2] 13.21 mg/l, Sat O_2 98.20%, V 138 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: M
Barren

143. Upper sector of Pollagach Burn, south-eastern slope of Craig Vallich, Ballater
Lat. 57° 01' 06.10" N, Long. -03° 00' 50.68" W, Alt. 529 m AMSL; date 23/11/2003, T 2.60°C, C 74 µS/cm, Sal. 0.00%, pH 6.73, [O_2] 11.57 mg/l, Sat O_2 91.60%, V 180 mV
Sandy-gravelly stream bed with muddy pockets, flow rate: LM
Pisidium casertanum (r)

144. Blanket bog situated on the col between Cairn Leuchan and Craig Vallich, Ballater
Lat. 57° 00' 53.16" N, Long. -03° 01' 26.67" W, Alt. 576 m AMSL; date 23/11/2003, T 1.80°C, C 118 µS/cm, Sal. 0.00%, pH 3.81, [O_2] 4.75 mg/l, Sat O_2 37.00%, V 204 mV
Muddy-Silty substrate with a thick layer of vegetal debris, no flow out
Barren

145. Blanket bog situated on the col between Craig Vallich and Pannanich Hill, Ballater
Lat. 57° 01' 41.93" N, Long. -03° 00' 22.20" W, Alt. 554 m AMSL; date 23/11/2003, T 2.70°C, C 145 µS/cm, Sal. 0.00%, pH 7.25, [O_2] 28.10 mg/l, Sat O_2 223.00%, V 188 mV
Sandy-gravelly substrate with muddy pockets covered by a thick layer of vegetal debris, no flow out
Barren

146. Blanket bog situated on the col between the two peaks of Pannanich Hill, Ballater
Lat. 57° 02' 13.73" N, Long. -03° 00' 07.45" W, Alt. 585 m AMSL; date 23/11/2003, T 3.20°C, C 138 µS/cm, Sal. 0.00%, pH 4.04, [O_2] 7.13 mg/l, Sat O_2 57.80%, V 180 mV
Muddy-silty substrate covered by a thick layer of vegetal debris and Cyanophyta colonies, no flow out
Barren

147. Deskry Water at the confluence with a left tributary in locality Badnagoach, Migvie
Lat. 57° 10' 03.47" N, Long. -03° 00' 31.29" W, Alt. 336 m AMSL; date 13/12/2003, T 3.80°C, C 76 µS/cm, Sal. 0.00%, pH 7.27, [O_2] 10.32 mg/l, Sat O_2 82.30%, V 139 mV
Gravelly-pebbly river bed with sandy pockets and scattered boulders, flow rate: M
Ancylus fluviatilis (c), *Pisidium casertanum* (rr)

148. Deskry Water at the confluence with a right tributary, north-eastward from Corbies' Nest, Migvie
Lat. 57° 08' 40.21" N, Long. -03° 01' 37.70" W, Alt. 380 m AMSL; date 13/12/2003, T 4.00°C, C 58 µS/cm, Sal. 0.00%, pH 7.04, [O_2] 12.84 mg/l, Sat O_2 105.10%, V 128 mV
Gravelly-pebbly river bed with scattered boulders, flow rate: LM
Barren

149. Burn of Cattie, 250 m south-westward from Glencat farm, Ballogie

Lat. 57° 01' 36.09" N, Long. -02° 45' 44.35" W, Alt. 230 m AMSL; date 10/01/2004, T 5.00°C, C 50 µS/cm, Sal. 0.00%, pH 6.30, [O_2] 8.03 mg/l, Sat O_2 65.30%, V 126 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: M
Pisidium casertanum (u), *Pisidium personatum* (rr)

150. Bog situated on the left side of Burn of Cattie, 400 m south-southwestward from Auchaballa cottage, Ballogie
Lat. 57° 02' 02.13" N, Long. -02° 43' 34.39" W, Alt. 180 m AMSL; date 10/01/2004, T 3.60°C, C 105 µS/cm, Sal. 0.00%, pH 5.40, [O_2] 9.46 mg/l, Sat O_2 74.60%, V 118 mV
Sandy-gravelly substrate with a high component of vegetal debris, outlet flow rate: VL
Barren

151. Girnock Burn at the confluence with Megen Burn, northern slope of Craig Megen, Ballater
Lat. 57° 00' 32.15" N, Long. -03° 08' 16.72" W, Alt. 319 m AMSL; date 25/01/2004, T 1.80°C, C 47 µS/cm, Sal. 0.00%, pH 6.42, [O_2] 11.92 mg/l, Sat O_2 89.40%, V 143 mV
Pebbly-cobbly stream bed with scattered boulders, flow rate: MH
Barren

152. Upper sector of Girnock Burn, north-eastern slope of Caisteal na Caillich, Ballater
Lat. 56° 59' 10.63" N, Long. -03° 10' 03.50" W, Alt. 418 m AMSL; date 25/01/2004, T 2.60°C, C 38 µS/cm, Sal. 0.00%, pH 6.18, [O_2] 10.67 mg/l, Sat O_2 82.70%, V 42 mV
Sandy-gravelly stream bed with scattered boulders rich in iron hydroxides, flow rate: L
Pisidium personatum (r)

153. Upper sector of Megen Burn, north-eastern slope of Meall Gorm, Ballater
Lat. 56° 59' 33.58" N, Long. -03° 08' 45.88" W, Alt. 390 m AMSL; date 25/01/2004, T 1.50°C, C 51 µS/cm, Sal. 0.00%, pH 6.93, [O_2] 11.15 mg/l, Sat O_2 83.70%, V 148 mV
Gravelly-pebbly stream bed almost completely armoured with large boulders, flow rate: L
Barren

154. Glen Dye at the intersection with Water of Charr, Banchory
Lat. 56° 56' 10.77" N, Long. -02° 37' 57.53" W, Alt. 249 m AMSL; date 15/02/2004, T 4.70°C, C 54 µS/cm, Sal. 0.00%, pH 9.11, [O_2] 11.76 mg/l, Sat O_2 92.60%, V 139 mV
Gravelly-pebbly river bed with scattered boulders, flow rate: MH
Pisidium casertanum (rr)

155. Artificial channel mill derived from Glen Dye, Glendye Lodge, Banchory
Lat. 56° 57' 53.11" N, Long. -02° 34' 52.75" W, Alt. 158 m AMSL; date 15/02/2004, T 5.00°C, C 54 µS/cm, Sal. 0.00%, pH 9.45, [O_2] 15.05 mg/l, Sat O_2 118.20%, V 93 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: LM
Pisidium casertanum (r), *Pisidium personatum* (rr)

156. Burn of Forvie Church, Forvie national nature reserve, Newburgh
Lat. 57° 19' 40.82" N, Long. -01° 58' 03.52" W, Alt. 1 m AMSL; date 28/02/2004, T 3.40°C, C 242 µS/cm, Sal. 0.00%, pH 7.16, [O_2] 17.54 mg/l, Sat O_2 132.00%, V 122 mV
Sandy stream bed characterised by granules cementation due to iron hydroxides. Vegetal debris and sand granules cemented in aggregates, flow rate: LM
Pisidium casertanum (a), *Pisidium personatum* (a)

157. Stream flowing toward Hackley Bay, Forvie national nature reserve, Newburgh
Lat. 57° 20' 03.60" N, Long. -01° 57' 24.32" W, Alt. 20 m AMSL; date 28/02/2004, T 2.50°C, C 312 µS/cm, Sal. 0.00%, pH 7.17, [O_2] 16.91 mg/l, Sat O_2 124.60%, V 132 mV
Silty-sandy stream bed with soft sandy aggregates, flow rate: LM
Pisidium personatum (r)

158. Burn of Forvie Church, 450 m north-westward from the Forvie Church, Forvie national nature reserve, Newburgh
Lat. 57° 19' 54.45" N, Long. -01° 58' 24.71" W, Alt. 25 m AMSL; date 28/02/2004, T 3.00°C, C 306 µS/cm, Sal. 0.00%, pH 7.06, [O_2] 16.10 mg/l, Sat O_2 120.10%, V 130 mV
Sandy stream bed, flow rate: L
Barren

159. Sandy Loch, northern slope of Carn a' Choire Bhoidheach, Inver
Lat. 56° 57' 45.13" N, Long. -03° 16' 22.19" W, Alt. 794 m AMSL; date 07/03/2004, T 1.90°C, C 26 µS/cm, Sal. 0.00%, pH 5.90, [O_2] 17.90 mg/l, Sat O_2 141.40%, V 69 mV
Sandy-gravelly substrate with scattered boulders, outlet flow rate: LM
Barren

160. Outlet of a small bog located to the north-eastern slope of Scolty Hill, Banchory
Lat. 57° 02' 30.93" N, Long. -02° 30' 58.39" W, Alt. 109 m AMSL; date 27/03/2004, T 9.40°C, C 87 µS/cm, Sal. 0.00%, pH 6.50, [O_2] 10.33 mg/l, Sat O_2 91.30%, V 55 mV
Sandy-gravelly stream bed covered by a muddy layer mainly composed of vegetal debris and organic matter, flow rate: LM
Radix balthica (r), *Pisidium personatum* (u), *Pisidium milium* (u)

161. Western shore of Loch of Strathbeg, in proximity of a RSPB spotting house, Crimond
Lat. 57° 37' 07.90" N, Long. -01° 53' 53.03" W, Alt. 1 m AMSL; date 28/03/2004, T 10.90°C, C 611 µS/cm, Sal. 0.00%, pH 8.58, [O_2] 10.33 mg/l, Sat O_2 94.20%, V 78 mV
Sandy substrate
Potamopyrgus antipodarum (c), *Radix balthica* (rr), *Gyraulus laevis* (rr), *Hippeutis complanatus* (r), *Anodonta anatina* (c), *Pisidium casertanum* (a), *Pisidium subtruncatum* (a), *Pisidium nitidum* (a)

162. Northern shore of Loch of Strathbeg at the outlet beginning, St Combs
Lat. 57° 37' 39.82" N, Long. -01° 53' 34.00" W, Alt. 1 m AMSL; date 28/03/2004, T 11.30°C, C 521 µS/cm, Sal. 0.00%, pH 8.03, [O_2] 10.05 mg/l, Sat O_2 92.20%, V 62 mV
Sandy substrate with scattered gravels, flow rate: MH
Potamopyrgus antipodarum (a), *Radix balthica* (r), *Bathyomphalus contortus* (u), *Gyraulus laevis* (u), *Hippeutis complanatus* (rr), *Pisidium casertanum* (r), *Pisidium subtruncatum* (rr), *Pisidium milium* (rr), *Pisidium nitidum* (u)

163. Glen Ey at the intersection with Allt Connie, Inverey
Lat. 56° 58' 38.77" N, Long. -03° 30' 19.12" W, Alt. 365 m AMSL; date 04/04/2004, T 3.20°C, C 34 µS/cm, Sal. 0.00%, pH 6.86, [O_2] 10.79 mg/l, Sat O_2 85.10%, V 40 mV
Rocky river bed with pebbly-cobbly pockets and scattered boulders, flow rate: H
Barren

164. Allt Connie at the confluence with Allt Cristie Mòr, Inverey
Lat. 56° 57' 53.78" N, Long. -03° 31' 28.88" W, Alt. 417 m AMSL; date 04/04/2004, T 3.90°C, C 46 µS/cm, Sal. 0.00%, pH 7.29, [O_2] 10.68 mg/l, Sat O_2 86.50%, V 45 mV
Rocky stream bed with pebbly-cobbly pockets and scattered boulders, flow rate: M
Barren

165. Upper sector of Allt Carn Bhathaich, eastern slope of Carn Bhac, Inverey
Lat. 56° 55' 49.22" N, Long. -03° 32' 36.02" W, Alt. 748 m AMSL; date 04/04/2004, T 3.60°C, C 32 µS/cm, Sal. 0.00%, pH 7.27, [O_2] 12.89 mg/l, Sat O_2 108.00%, V 44 mV
Gravelly-pebbly stream bed with sandy pockets; the channel cuts a thick layer of peat, flow rate: L
Pisidium casertanum (r), *Pisidium personatum* (r)

166. Upper sector of Allt nan Clach Geala, southern slope of Carn Bhac, Inverey
Lat. 56° 55' 09.32" N, Long. -03° 33' 50.11" W, Alt. 763 m AMSL; date 04/04/2004, T 4.20°C, C 50 µS/cm, Sal. 0.00%, pH 7.06, [O_2] 14.74 mg/l, Sat O_2 127.40%, V 43 mV
Pebbly-cobbly stream bed with scattered boulders and gravelly pockets, flow rate: L
Pisidium personatum (r)

167. Glen Ey at the intersection with Allt an t-Sionnaich, Inverey
Lat. 56° 57' 29.36" N, Long. -03° 29' 59.81" W, Alt. 424 m AMSL; date 04/04/2004, T 6.40°C, C 36 µS/cm, Sal. 0.00%, pH 6.96, [O_2] 20.70 mg/l, Sat O_2 179.80%, V 36 mV

Pebbly-cobbly river bed with gravelly pockets and scattered boulders, flow rate: H
Barren

168. Bog situated at the base of the southern slope of Creag Choinnich, Braemar
Lat. 57° 00' 21.35" N, Long. -03° 22' 54.08" W, Alt. 368 m AMSL; date 18/04/2004, T 8.90°C, C 125 µS/cm, Sal. 0.00%, pH 6.81, [O_2] 10.32 mg/l, Sat O_2 82.30%, V 32 mV
Muddy substrate with scattered boulders, flow rate: LM
Radix balthica (a), *Pisidium nitidum* (a)

169. Loch Phàdruig at the outlet beginning, Braemar
Lat. 56° 57' 31.05" N, Long. -03° 21' 28.81" W, Alt. 685 m AMSL; date 25/04/2004, T 8.80°C, C 25 µS/cm, Sal. 0.00%, pH 6.04, [O_2] 8.75 mg/l, Sat O_2 80.80%, V 30 mV
Gravelly-cobbly substrate with scattered boulders, outlet flow rate: L
Pisidium casertanum (rr)

170. Blanket bog situated 300 m north-westward from Creag an Loch top, Braemar
Lat. 56° 56' 57.75" N, Long. -03° 19' 50.91" W, Alt. 812 m AMSL; date 25/04/2004, T 12.70°C, C 28 µS/cm, Sal. 0.00%, pH 4.26, [O_2] 8.95 mg/l, Sat O_2 92.00%, V 60 mV
Sandy-gravelly substrate with scattered boulders, no flow out
Barren

171. Blanket bog situated on the col between Creag an Loch and Carn an t-Sagairt Mòr, Braemar
Lat. 56° 56' 44.72" N, Long. -03° 19' 27.57" W, Alt. 727 m AMSL; date 25/04/2004, T 18.00°C, C 32 µS/cm, Sal. 0.00%, pH 6.43, [O_2] 7.20 mg/l, Sat O_2 81.90%, V 27 mV
Sandy-gravelly substrate covered by a thin layer of vegetal debris, no flow out
Pisidium casertanum (r)

172. Western shore of Loch nan Eun, northern slope of Carn a' Choire Bhoidheach, Braemar
Lat. 56° 57' 10.89" N, Long. -03° 16' 12.44" W, Alt. 898 m AMSL; date 25/04/2004, T 4.30°C, C 20 µS/cm, Sal. 0.00%, pH 6.23, [O_2] 9.91 mg/l, Sat O_2 83.90%, V 62 mV
Rocky substrate with scattered boulders, flow rate: M
Barren

173. Cirque loch situated at the base of the north-eastern cliffs of Carn an t-Sagairt Beag, Braemar
Lat. 56° 57' 14.71" N, Long. -03° 16' 17.52" W, Alt. 846 m AMSL; date 25/04/2004, T 11.70°C, C 16 µS/cm, Sal. 0.00%, pH 5.92, [O_2] 10.22 mg/l, Sat O_2 103.20%, V 68 mV
Sandy-gravelly substrate with scattered boulders, flow rate: LM
Pisidium casertanum (rr)

174. Bog situated on the right side of Baddoch Burn, 500 m south-westward from Baddoch cottage, Braemar
Lat. 56° 55' 30.84" N, Long. -03° 25' 48.87" W, Alt. 435 m AMSL; date 09/08/2004, T 10.90°C, C 105 µS/cm, Sal. 0.00%, pH 8.00, [O_2] 7.32 mg/l, Sat O_2 70.10%, V 75 mV
Muddy-sandy substrate, inlet flow rate: L
Radix balthica (a), *Pisidium casertanum* (a), *Pisidium personatum* (a), *Pisidium subtruncatum* (a), *Pisidium milium* (u)

175. Upper sector of Baddoch Burn, north-eastern slope of Carn Bhinnein, Braemar
Lat. 56° 53' 18.71" N, Long. -03° 29' 04.24" W, Alt. 632 m AMSL; date 09/08/2004, T 9.10°C, C 29 µS/cm, Sal. 0.00%, pH 6.84, [O_2] 9.86 mg/l, Sat O_2 92.50%, V 88 mV
Sandy-gravelly stream bed with a thick layer of vegetal debris on the inner side of the meander pool; the channel cuts a thick layer of peat, flow rate: M
Pisidium casertanum (u)

176. Blanket bog situated on the col between Carn nan Sac and Carn Aosda, Braemar
Lat. 56° 52' 52.75" N, Long. -03° 26' 38.11" W, Alt. 852 m AMSL; date 09/08/2004, T 11.30°C, C 18 µS/cm, Sal. 0.00%, pH 5.80, [O_2] 8.11 mg/l, Sat O_2 82.30%, V 74 mV
Gravelly-pebbly substrate with scattered boulders, outlet flow rate: L
Barren

177. Loch Vrotachan, south-western slope of Carn Aosda, Braemar
Lat. 56° 53' 21.41" N, Long. -03° 26' 44.93" W, Alt. 750 m AMSL; date 09/08/2004, T 11.90°C, C 64 µS/cm, Sal. 0.00%, pH 8.35, [O_2] 9.04 mg/l, Sat O_2 92.00%, V 77 mV
Pebbly-cobbly substrate with scattered boulders, flow rate: M
Radix balthica (c), *Pisidium casertanum* (c), *Pisidium personatum* (r), *Pisidium subtruncatum* (r), *Pisidium milium* (u), *Pisidium nitidum* (c), *Pisidium lilljeborgii* (u), *Pisidium hibernicum* (a)

178. South Blackwater, flowing along the southern margin of the St Fergus gas terminal, St Fergus
Lat. 57° 34' 09.69" N, Long. -01° 49' 28.04" W, Alt. 1 m AMSL; date 16/05/2004, T 20.30°C, C 1717 µS/cm, Sal. 0.70%, pH 8.69, [O_2] 35.00 mg/l, Sat O_2 382.00%, V 62 mV
Sandy-gravelly stream bed, flow rate: M
Barren

179. Cuttie Burn flowing 850 m ca. south-westward from Kirkton Head, Peterhead
Lat. 57° 32' 16.65" N, Long. -01° 48' 27.17" W, Alt. 1 m AMSL; date 16/05/2004, T 21.10°C, C 646 µS/cm, Sal. 0.10%, pH 8.89, [O_2] 13.37 mg/l, Sat O_2 148.30%, V 66 mV
Sandy stream bed, flow rate: M
Barren

180. Spring stream flowing toward a bay between Whyntie Head and Stake Ness, Banff
Lat. 57° 40' 48.43" N, Long. -02° 37' 19.06" W, Alt. 2 m AMSL; date 26/06/2004, T 11.80°C, C 819 µS/cm, Sal. 0.20%, pH 7.47, [O_2] 6.32 mg/l, Sat O_2 58.90%, V 145 mV
Sandy stream bed, flow rate: L
Pisidium personatum (r)

181. Burn of Boyne below the B9139 road bridge, Portsoy
Lat. 57° 40' 37.70" N, Long. -02° 39' 18.51" W, Alt. 20 m AMSL; date 26/06/2004, T 13.20°C, C 294 µS/cm, Sal. 0.00%, pH 7.98, [O_2] 8.51 mg/l, Sat O_2 82.10%, V 162 mV
Rocky stream bed with sandy-gravelly pockets, flow rate: M
Potamopyrgus antipodarum (u), *Radix balthica* (u), *Galba truncatula* (rr), *Ancylus fluviatilis* (a), *Pisidium personatum* (rr), *Pisidium subtruncatum* (r)

182. Ey Burn, 750 m north-westward from Creag an Fhuathais, Inverey
Lat. 56° 56' 20.20" N, Long. -03° 29' 09.90" W, Alt. 467 m AMSL; date 26/06/2004, T 10.80°C, C 77 µS/cm, Sal. 0.00%, pH 7.38, [O_2] 9.33 mg/l, Sat O_2 89.30%, V 185 mV
Sandy-gravelly stream bed, flow rate: MH
Pisidium casertanum (r), *Pisidium subtruncatum* (r)

183. Eastern shore of Loch of Skene, Westhill
Lat. 57° 09' 13.97" N, Long. -02° 20' 52.68" W, Alt. 84 m AMSL; date 27/06/2004, T 18.40°C, C 310 µS/cm, Sal. 0.00%, pH 8.21, [O_2] 9.27 mg/l, Sat O_2 100.10%, V 81 mV
Sandy-gravelly substrate
Valvata piscinalis (r), *Potamopyrgus antipodarum* (a), *Radix balthica* (u), *Physa fontinalis* (u), *Bathyomphalus contortus* (c), *Sphaerium corneum* (a), *Pisidium casertanum* (u), *Pisidium personatum* (rr), *Pisidium subtruncatum* (u), *Pisidium milium* (rr), *Pisidium nitidum* (a), *Pisidium lilljeborgii* (u)

184. Small right tributary of the Ord Burn in locality Brodiach, Westhill
Lat. 57° 09' 15.88" N, Long. -02° 15' 32.92" W, Alt. 120 m AMSL; date 27/06/2004, T 10.70°C, C 270 µS/cm, Sal. 0.00%, pH 6.76, [O_2] 8.45 mg/l, Sat O_2 77.60%, V 101 mV
Gravelly-pebby stream bed with scattered boulders, flow rate: LM
Radix balthica (r), *Ancylus fluviatilis* (a), *Pisidium casertanum* (rr), *Pisidium personatum* (r)

185. Bervie water at the confluence with Burn of Luchray, Auchenblae
Lat. 56° 56' 38.45" N, Long. -02° 29' 40.05" W, Alt. 178 m AMSL; date 04/07/2004, T 9.90°C, C 66 µS/cm, Sal. 0.00%, pH 6.75, [O_2] 10.91 mg/l, Sat O_2 98.80%, V 107 mV
Gravelly-pebbly river bed with scattered boulders, flow rate: M
Ancylus fluviatilis (r)

186. Upper sector of East Burn of Builg, in locality Bawd Bog, Auchenblae
Lat. 56° 57' 45.24" N, Long. -02° 29' 16.81" W, Alt. 265 m AMSL; date 04/07/2004, T 8.70°C, C 48 μS/cm, Sal. 0.00%, pH 5.24, [O_2] 11.15 mg/l, Sat O_2 99.30%, V 108 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: LM
Barren

187. Upper sector of Burn of Duglenny on the col between Tipperweir and Hill of Gothie, Auchenblae
Lat. 56° 57' 17.81" N, Long. -02° 31' 15.71" W, Alt. 369 m AMSL; date 04/07/2004, T 12.00°C, C 54 μS/cm, Sal. 0.00%, pH 3.99, [O_2] 8.15 mg/l, Sat O_2 19.30%, V 114 mV
Muddy stream bed with a high organic matter content; the channel cuts a thick layer of peat, flow rate: LM
Barren

188. River Ythan, 500 m to the south of the A975 road bridge, Newburgh
Lat. 57° 19' 37.96" N, Long. -01° 59' 45.24" W, Alt. 1 m AMSL; date 24/07/2004, T 15.00°C, C 15840 μS/cm, Sal. 9.20%, pH 8.67, [O_2] 11.03 mg/l, Sat O_2 115.80%, V 84 mV
Muddy-sandy river bed with scattered boulders, flow rate: H
Ecrobia ventrosa (r), *Peringia ulvae* (a), *Stagnicola palustris* (r)

189. Left tributary of River Ythan at its confluence, Newburgh
Lat. 57° 21' 04.63" N, Long. -01° 59' 50.80" W, Alt. 2 m AMSL; date 24/07/2004, T 14.50°C, C 1346 μS/cm, Sal. 0.50%, pH 8.53, [O_2] 14.06 mg/l, Sat O_2 138.10%, V 94 mV
Muddy-pebbly river bed with scattered boulders, flow rate: M
Ecrobia ventrosa (rr), *Peringia ulvae* (a), *Potamopyrgus antipodarum* (r), *Stagnicola palustris* (c), *Radix balthica* (rr), *Ancylus fluviatilis* (rr), *Pisidium personatum* (rr)

190. River Ythan, below the bridge of the road connecting Denhead with Kirkton of Logie Buchan, Newburgh
Lat. 57° 21' 35.44" N, Long. -02° 00' 59.83" W, Alt. 2 m AMSL; date 24/07/2004, T 17.60°C, C 418 μS/cm, Sal. 0.00%, pH 7.92, [O_2] 14.53 mg/l, Sat O_2 152.30%, V 94 mV
Muddy river bed with scattered boulders, flow rate: MH
Ecrobia ventrosa (rr), *Peringia ulvae* (c), *Potamopyrgus antipodarum* (u), *Stagnicola palustris* (rr), *Radix balthica* (u), *Galba truncatula* (r), *Pisidium nitidum* (rr)

191. River Gairn at the confluence with Duchrie Burn, Ballater
Lat. 57° 05' 38.33" N, Long. -03° 14' 14.23" W, Alt. 388 m AMSL; date 25/07/2004, T 15.40°C, C 87 μS/cm, Sal. 0.00%, pH 7.50, [O_2] 9.92 mg/l, Sat O_2 104.00%, V 99 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: M
Radix balthica (r)

192. Lochan Feurach in locality Lochbuilg Lodge, left side of River Gairn, Ballater
Lat. 57° 06' 30.03" N, Long. -03° 20' 21.63" W, Alt. 483 m AMSL; date 25/07/2004, T 6.80°C, C 87 μS/cm, Sal. 0.00%, pH 6.33, [O_2] 7.12 mg/l, Sat O_2 61.80%, V 115 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: LM
Pisidium casertanum (r)

193. River Gairn, 450 m eastward from the confluence with Allt an Eas Mhòir, Ballater
Lat. 57° 04' 37.95" N, Long. -03° 23' 21.22" W, Alt. 537 m AMSL; date 25/07/2004, T 15.00°C, C 23 μS/cm, Sal. 0.00%, pH 6.11, [O_2] 9.63 mg/l, Sat O_2 101.70%, V 87 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: M
Barren

194. Northern shore of Pronie Loch, situated at the base of the western slope of Baderonoch Hill, Dinnet
Lat. 57° 09' 50.47" N, Long. -02° 57' 42.37" W, Alt. 363 m AMSL; date 31/07/2004, T 18.00°C, C 125 μS/cm, Sal. 0.00%, pH 8.67, [O_2] 7.55 mg/l, Sat O_2 82.50%, V 56 mV
Gravelly-pebbly substrate with sandy pockets and scattered boulders, outlet flow rate: L
Potamopyrgus antipodarum (rr), *Radix balthica* (rr), *Gyraulus albus* (r), *Sphaerium corneum* (a), *Pisidium subtruncatum* (a), *Pisidium milium* (r), *Pisidium nitidum* (a), *Pisidium hibernicum* (c)

195. Artificial lochan near Logie Coldstone, Dinnet
Lat. 57° 07' 22.54" N, Long. -02° 55' 59.30" W, Alt. 179 m AMSL; date 31/07/2004, T 17.50°C, C 177 μS/cm, Sal. 0.00%, pH 9.03, [O_2] 9.95 mg/l, Sat O_2 105.20%, V 68 mV
Pebbly-cobbly substrate with scattered boulders covered by a thick layer of vegetal debris, inlet flow rate: L
Potamopyrgus antipodarum (r), *Radix balthica* (u), *Ancylus fluviatilis* (r), *Pisidium subtruncatum* (a), *Pisidium milium* (r), *Pisidium nitidum* (a), *Pisidium hibernicum* (r)

196. Northern shore of Loch Davan, 200 m south-eastward from Glendavan House, Dinnet
Lat. 57° 05' 52.50" N, Long. -02° 55'28.08" W, Alt. 176 m AMSL; date 31/07/2004, T 18.00°C, C 160 μS/cm, Sal. 0.00%, pH 8.34, [O_2] 1.40 mg/l, Sat O_2 14.90%, V 66 mV
Muddy-sandy substrate with scattered boulders
Valvata piscinalis (a), *Potamopyrgus antipodarum* (r), *Radix balthica* (a), *Gyraulus albus* (a), *Gyraulus laevis* (rr), *Sphaerium corneum* (a), *Pisidium casertanum* (u), *Pisidium obtusale* (a), *Pisidium subtruncatum* (a), *Pisidium milium* (a), *Pisidium nitidum* (a), *Pisidium lilljeborgii* (a), *Pisidium hibernicum* (a)

197. Northern shore of Loch Kinord in front of the islet, Dinnet
Lat. 57° 05' 06.28" N, Long. -02° 55' 31.47" W, Alt. 176 m AMSL; date 31/07/2004, T 19.30°C, C 92 μS/cm, Sal. 0.00%, pH 8.43, [O_2] 10.23 mg/l, Sat O_2 112.00%, V 64 mV
Gravelly-cobbly substrate with scattered boulders
Potamopyrgus antipodarum (rr), *Gyraulus albus* (r), *Sphaerium corneum* (c), *Pisidium hibernicum* (r)

198. Northern shore of Bishops' Loch, Dyce
Lat. 57° 13' 08.43" N, Long. -02° 08' 58.23" W, Alt. 88 m AMSL; date 01/08/2004, T 20.00°C, C 105 μS/cm, Sal. 0.00%, pH 9.06, [O_2] 8.86 mg/l, Sat O_2 97.70%, V 40 mV
Gravelly-pebbly substrate with scattered boulders
Potamopyrgus antipodarum (u), *Radix balthica* (rr), *Gyraulus albus* (c), *Gyraulus crista* (r), *Hippeutis complanatus* (rr), *Sphaerium corneum* (a), *Pisidium subtruncatum* (a), *Pisidium milium* (u), *Pisidium nitidum* (a), *Pisidium hibernicum* (a)

199. Northern shore of Corby Loch, Dyce
Lat. 57° 13' 20.55" N, Long. -02° 07' 42.27" W, Alt. 78 m AMSL; date 01/08/2004, T 19.80°C, C 274 μS/cm, Sal. 0.00%, pH 8.86, [O_2] 10.91 mg/l, Sat O_2 119.40%, V 5 mV
Gravelly-pebbly substrate armoured with boulders
Valvata piscinalis (rr), *Potamopyrgus antipodarum* (a), *Radix balthica* (u), *Physa fontinalis* (u), *Bathyomphalus contortus* (c), *Gyraulus albus* (a), *Gyraulus crista* (rr), *Hippeutis complanatus* (a), *Sphaerium corneum* (c), *Pisidium subtruncatum* (u), *Pisidium milium* (c), *Pisidium nitidum* (a)

200. South-eastern shore of Lily Loch, Dyce
Lat. 57° 13' 15.22" N, Long. -02° 07' 56.54" W, Alt. 78 m AMSL; date 01/08/2004, T 19.30°C, C 228 μS/cm, Sal. 0.00%, pH 8.64, [O_2] 4.71 mg/l, Sat O_2 51.00%, V 1 mV
Muddy substrate covered by a thick layer of vegetal debris
Potamopyrgus antipodarum (c), *Gyraulus albus* (u), *Sphaerium corneum* (rr), *Pisidium subtruncatum* (a), *Pisidium milium* (rr), *Pisidium nitidum* (c), *Pisidium hibernicum* (u)

201. River Dee below the B9077 (Great Southern Road) bridge, Aberdeen
Lat. 57° 07' 42.90" N, Long. -02° 06' 25.66" W, Alt. 2 m AMSL; date 11/08/2004, T 17.60°C, C 47 μS/cm, Sal. 0.00%, pH 8.02, [O_2] 8.47 mg/l, Sat O_2 88.4%, V 39 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: VH
Potamopyrgus antipodarum (u), *Radix balthica* (a), *Physella acuta* (r), *Ancylus fluviatilis* (a), *Pisidium personatum* (rr)

202. Spring stream rising in a wood, 700 m south-west of Craigiebuckler, Hazlehead Park, Aberdeen
Lat. 57° 08' 07.95" N, Long. -02° 10' 22.53" W, Alt. 89 m AMSL; date 14/08/2004, T 12.30°C, C 250 μS/cm, Sal. 0.00%, pH 7.10, [O_2] 9.33 mg/l, Sat O_2 87.70%, V 93 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: LM
Potamopyrgus antipodarum (a), *Ancylus fluviatilis* (a), *Pisidium casertanum* (a), *Pisidium personatum* (c)

203. Inchgarth Reservoir located to the River Dee left bank near Cults, Aberdeen

Lat. 57° 06' 53.68" N, Long. -02° 10' 01.08" W, Alt. 8 m AMSL; date 16/08/2004, T 19.40°C, C 57 µS/cm, Sal. 0.00%, pH 7.00, [O_2] 8.44 mg/l, Sat O_2 91.80%, V 26 mV
Sandy-gravelly substrate with muddy pockets and scattered boulders, outlet flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (a), *Physa fontinalis* (rr), *Bathyomphalus contortus* (c), *Gyraulus albus* (c), *Gyraulus crista* (r), *Sphaerium corneum* (r), *Pisidium subtruncatum* (c), *Pisidium milium* (rr), *Pisidium hibernicum* (rr)

204. Stream flowing to Kirk Lakes bay, north of St Combs, Fraserburgh
Lat. 57° 39' 37.98" N, Long. -01° 54' 38.35" W, Alt. 1 m AMSL; date 03/10/2004, T 8.90°C, C 520 µS/cm, Sal. 0.00%, pH 7.50, [O_2] 9.66 mg/l, Sat O_2 83.90%, V 69 mV
Sandy stream bed, flow rate: LM
Pisidium subtruncatum (rr), *Pisidium hibernicum* (rr)

205. Stream flowing to Whitelinks Bay, south of Inverallochy, Fraserburgh
Lat. 57° 40' 05.45" N, Long. -01° 55' 08.65" W, Alt. 1 m AMSL; date 03/10/2004, T 10.70°C, C 762 µS/cm, Sal. 0.10%, pH 7.85, [O_2] 14.39 mg/l, Sat O_2 130.60%, V 77 mV
Sandy stream bed, flow rate: M
Radix balthica (rr)

206. Water of Philorth, 500 m from the high tide mark, Fraserburgh
Lat. 57° 40' 27.55" N, Long. -01° 57' 26.80" W, Alt. 1 m AMSL; date 03/10/2004, T 12.20°C, C 810000 µS/cm, Sal. 2.20%, pH 7.85, [O_2] 14.39 mg/l, Sat O_2 67.60%, V -143 mV
Sandy river bed, flow rate: MH
Barren

207. Intersection between Clashnarae Burn and Long Burn, south-eastern slope of the hill 'The Buck', Kildrummy
Lat. 57° 15' 51.09" N, Long. -02° 56' 34.96" W, Alt. 325 m AMSL; date 09/10/2004, T 7.30°C, C 47 µS/cm, Sal. 0.00%, pH 7.10, [O_2] 11.73 mg/l, Sat O_2 99.80%, V 120 mV
Gravelly-pebbly river bed with scattered boulders, flow rate: M
Ancylus fluviatilis (c)

208. Upper sector of Burn of Cookies-shiel, downstream from 'Cookies-shiel Work', north-eastern slope of Mount Meddin, Kildrummy
Lat. 57° 16' 44.77" N, Long. -02° 59' 04.28" W, Alt. 560 m AMSL; date 09/10/2004, T 6.40°C, C 62 µS/cm, Sal. 0.00%, pH 5.16, [O_2] 7.71 mg/l, Sat O_2 80.60%, V 121 mV
Muddy-sandy stream bed covered by a thick layer of vegetal debris, flow rate: L
Barren

209. River Dee 200 m downstream from the bridge of the A956 road, Aberdeen
Lat. 57° 08' 15.96" N, Long. -02° 05' 36.28" W, Alt. 1 m AMSL; date 12/10/2004, T 8.70°C, C 5900 µS/cm, Sal. 3.10%, pH 7.90, [O_2] 10.73 mg/l, Sat O_2 92.30%, V 131 mV
Gravelly-pebbly river bed with cobbly pockets and scattered boulders, flow rate: VH
Peringia ulvae (r)

210. Upper sector of Bethlin Burn, 500 m south-eastward from Tillybirloch, Midmar
Lat. 57° 09' 07.45" N, Long. -02° 31' 35.90" W, Alt. 169 m AMSL; date 17/10/2004, T 9.60°C, C 192 µS/cm, Sal. 0.00%, pH 6.76, [O_2] 9.03 mg/l, Sat O_2 81.60%, V 150 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: L
Radix balthica (c), *Ancylus fluviatilis* (a), *Pisidium casertanum* (c), *Pisidium personatum* (r), *Pisidium subtruncatum* (c)

211. Auchorie Burn, below the bridge of the B9119 road, northern slope of Hill of Fare, Midmar
Lat. 57° 08' 36.54" N, Long. -02° 32' 55.69" W, Alt. 190 m AMSL; date 17/10/2004, T 9.10°C, C 88 µS/cm, Sal. 0.00%, pH 8.66, [O_2] 10.16 mg/l, Sat O_2 91.00%, V 148 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: MH
Radix balthica (u), *Ancylus fluviatilis* (c), *Pisidium casertanum* (rr)

212. Drumlasie Burn, flowing 500 m north-westward from Bogenchapel, Torphins
Lat. 57° 07' 47.87" N, Long. -02° 38' 39.99" W, Alt. 170 m AMSL; date 17/10/2004, T 9.60°C, C 141 µS/cm, Sal. 0.00%, pH 8.52, [O_2] 15.27 mg/l, Sat O_2 138.10%, V 139 mV
Gravelly-cobbly stream bed with large pebbly-bouldery patches and sandy pockets, flow rate: M
Radix balthica (r), *Ancylus fluviatilis* (a), *Pisidium casertanum* (c), *Pisidium personatum* (c)

213. Bo Burn, below the bridge of the A980 road, Banchory
Lat. 57° 04' 51.03" N, Long. -02° 30' 22.34" W, Alt. 80 m AMSL; date 17/10/2004, T 10.00°C, C 202 µS/cm, Sal. 0.00%, pH 8.37, [O_2] 19.54 mg/l, Sat O_2 176.70%, V 123 mV
Gravelly-cobbly stream bed with scattered boulders, flow rate: M
Radix balthica (r), *Ancylus fluviatilis* (a)

214. Artificial lochan situated between Loch Kinord and Dinnet, Dinnet
Lat. 57° 04' 38.99" N, Long. -02° 53' 57.48" W, Alt. 164 m AMSL; date 31/10/2004, T 7.20°C, C 67 µS/cm, Sal. 0.00%, pH 8.68, [O_2] 6.47 mg/l, Sat O_2 54.40%, V 125 mV
Sandy-gravelly substrate with cobbly pockets and scattered boulders, no flow out
Pisidium casertanum (r), *Pisidium personatum* (c), *Pisidium obtusale* (r)

215. Bog situated 400 m to the west of the north-western corner of Loch Davan, Dinnet
Lat. 57° 05' 53.87" N, Long. -02° 56' 09.91" W, Alt. 176 m AMSL; date 31/10/2004, T 7.80°C, C 47 µS/cm, Sal. 0.00%, pH 8.51, [O_2] 7.27 mg/l, Sat O_2 61.90%, V 114 mV
Muddy substrate covered by a thick layer of vegetal debris and scattered boulders (mainly occurring nearby the western inlet), inlet and outlet flow rate: L
Pisidium casertanum (c)

216. Temporary pool situated in a large depression at the base of the southern slope of Culblean Hill, Dinnet
Lat. 57° 04' 23.11" N, Long. -02° 58' 56.69" W, Alt. 208 m AMSL; date 31/10/2004, T 7.50°C, C 55 µS/cm, Sal. 0.00%, pH 8.50, [O_2] 7.25 mg/l, Sat O_2 62.00%, V 112 mV
Firm muddy substrate covered by aquatic vegetation and scattered boulders, outlet flow rate: M
Radix balthica (rr), *Pisidium casertanum* (c), *Pisidium personatum* (r), *Pisidium obtusale* (r)

217. Lochan situated 400 m downstream from the station no. 216, Dinnet
Lat. 57° 04' 16.50" N, Long. -02° 59' 20.07" W, Alt. 199 m AMSL; date 31/10/2004, T 7.80°C, C 50 µS/cm, Sal. 0.00%, pH 8.55, [O_2] 7.55 mg/l, Sat O_2 64.70%, V 116 mV
Firm muddy substrate with scattered boulders, inlet flow rate: M
Pisidium casertanum (rr)

218. Upper sector of Blacklatch Burn, Correen Hills, Alford
Lat. 57° 17' 26.31" N, Long. -02° 48' 20.36" W, Alt. 406 m AMSL; date 07/11/2004, T 7.00°C, C 50 µS/cm, Sal. 0.00%, pH 5.61, [O_2] 7.41 mg/l, Sat O_2 63.80%, V 113 mV
Muddy-gravelly stream bed covered by a layer of vegetal debris, flow rate: L
Pisidium casertanum (r), *Pisidium personatum* (c)

219. Blanket bog situated on the southern crest of Mire of Midgates, Correen Hills, Alford
Lat. 57° 17' 10.20" N, Long. -02° 47' 44.62" W, Alt. 421 m AMSL; date 07/11/2004, T 9.00°C, C 31 µS/cm, Sal. 0.00%, pH 6.56, [O_2] 6.66 mg/l, Sat O_2 60.30%, V 107 mV
Muddy substrate covered by a thick layer of vegetal debris, no flow out
Barren

220. Upper sector of Back Burn, eastern slope of Hill of the Three Stones, Rhynie
Lat. 57° 17' 36.92" N, Long. -03° 03' 02.54" W, Alt. 447 m AMSL; date 14/11/2004, T 5.90°C, C 50 µS/cm, Sal. 0.00%, pH 5.86, [O_2] 8.91 mg/l, Sat O_2 75.00%, V 115 mV
Gravelly-cobbly stream bed with scattered boulders and detrital peat pockets, flow rate: L
Barren

221. Gauch Burn at the confluence with Keirn Burn, eastern slope of Rounumuck Hill, Rhynie
Lat. 57° 18' 33.08" N, Long. -03° 03' 24.48" W, Alt. 354 m AMSL; date 14/11/2004, T 5.60°C, C 75 µS/cm, Sal. 0.00%, pH 6.72, [O_2] 6.58 mg/l, Sat O_2 54.20%, V 100 mV
Pebbly-cobbly stream bed with gravelly pockets and scattered boulders, flow rate: M
Barren

222. Stream flowing at the northern margin of the Peterhead golf course, Peterhead
Lat. 57° 31' 55.31" N, Long. -01° 48' 28.13" W, Alt. 1 m AMSL; date 20/11/2004, T 5.60°C, C 794 µS/cm, Sal. 0.10%, pH 9.11, [O_2] 18.94 mg/l, Sat O_2 194.60%, V 95 mV
Sandy stream bed, flow rate: M
Barren

223. River Ugie, 250 m upstream from the Peterhead Bridge, Peterhead
Lat. 57° 30' 59.81" N, Long. -01° 48' 17.47" W, Alt. 1 m AMSL; date 20/11/2004, T 2.60°C, C 2480 µS/cm, Sal. 1.10%, pH 7.80, [O_2] 35.60 mg/l, Sat O_2 261.00%, V 65 mV
Sandy river bed with a muddy embayment on the left side, flow rate: H
Hydrobia cf. acuta neglecta (rr), *Peringia ulvae* (rr), *Radix balthica* (r)

224. Lowest loch of the Lazy Wells Lochs, north-eastern slope of Baderonoch Hill, Towie
Lat. 57° 10' 22.62" N, Long. -02° 55' 39.85" W, Alt. 349 m AMSL; date 28/11/2004, T 3.40°C, C 74 µS/cm, Sal. 0.00%, pH 7.45, [O_2] 10.49 mg/l, Sat O_2 81.60%, V 111 mV
Gravelly-pebbly substrate with scattered boulders, eastern outlet flow rate: L
Pisidium nitidum (r)

225. Humphrey's Well, north-western slope of Cairn Pressendye, Towie
Lat. 57° 10' 24.56" N, Long. -02° 51' 51.92" W, Alt. 505 m AMSL; date 28/11/2004, T 6.60°C, C 52 µS/cm, Sal. 0.00%, pH 9.17, [O_2] 13.05 mg/l, Sat O_2 111.90%, V 106 mV
Gravelly-pebbly stream bed, flow rate: VL
Barren

226. North-western corner of Loch of Park, Drumoak
Lat. 57° 04' 49.29" N, Long. -02° 23' 08.37" W, Alt. 68 m AMSL; date 04/12/2004, T 1.30°C, C 137 µS/cm, Sal. 0.00%, pH 6.50, [O_2] 3.91 mg/l, Sat O_2 27.80%, V 130 mV
Substrate characterised by a very thick layer of aquatic plants and vegetal debris
Galba truncatula (r), *Pisidium casertanum* (a), *Pisidium personatum* (a), *Pisidium obtusale* (c)

227. North-eastern corner of Loch of Leys, Banchory
Lat. 57° 04' 18.03" N, Long. -02° 28' 55.69" W, Alt. 78 m AMSL; date 04/12/2004, T 2.20°C, C 179 µS/cm, Sal. 0.00%, pH 8.24, [O_2] 1.06 mg/l, Sat O_2 7.70%, V 64 mV
Substrate characterised by a very thick layer of aquatic plants and vegetal debris, outlet flow rate: L
Stagnicola palustris (r)

228. Eastern shore of Crathes Castle mill pool, Banchory
Lat. 57° 03' 29.93" N, Long. -02° 25' 36.40" W, Alt. 50 m AMSL; date 04/12/2004, T 4.20°C, C 189 µS/cm, Sal. 0.00%, pH 8.43, [O_2] 1.89 mg/l, Sat O_2 14.60%, V 118 mV
Gravelly-pebbly substrate with scattered boulders, outlet flow rate: MH
Valvata piscinalis (r), *Potamopyrgus antipodarum* (u), *Radix balthica* (u), *Bathyomphalus contortus* (r), *Gyraulus albus* (u), *Pisidium milium* (r)

229. Old mill pool created along Bo Burn, 1 km before River Dee confluence, Drumoak
Lat. 57° 03' 48.51" N, Long. -02° 23' 52.77" W, Alt. 52 m AMSL; date 04/12/2004, T 6.90°C, C 263 µS/cm, Sal. 0.00%, pH 8.64, [O_2] 8.84 mg/l, Sat O_2 72.80%, V 111 mV
Stream bed characterised by a very thick layer of vegetal debris and Cyanophyta colonies, flow rate: L
Potamopyrgus antipodarum (c), *Radix balthica* (rr), *Pisidium subtruncatum* (c), *Pisidium milium* (c), *Pisidium nitidum* (u), *Pisidium hibernicum* (c)

230. Stream flowing along the eastern side of The Links of Nether Dallachy, Portgordon
Lat. 57° 39' 57.21" N, Long. -03° 02' 44.39" W, Alt. 1 m AMSL; date 05/12/2004, T 6.90°C, C 392 µS/cm, Sal. 0.00%, pH 6.97, [O_2] 7.80 mg/l, Sat O_2 63.60%, V 126 mV
Muddy-sandy stream bed with scattered boulders, flow rate: M
Potamopyrgus antipodarum (r), *Radix balthica* (r)

231. Burn of Tynet, 50 m from the high tide mark, Portgordon
Lat. 57° 39' 52.22" N, Long. -03° 02' 12.22" W, Alt. 1 m AMSL; date 05/12/2004, T 6.30°C, C 340 µS/cm, Sal. 0.00%, pH 8.23, [O_2] 9.51 mg/l, Sat O_2 76.30%, V 112 mV
Sandy-gravelly stream bed with pebbly bars and muddy pockets, flow rate: MH
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Galba truncatula* (rr)

232. Southern loch of the St Jame's Lochs, Laurencekirk
Lat. 56° 49' 46.85" N, Long. -02° 25' 20.40" W, Alt. 235 m AMSL; date 12/12/2004, T 5.30°C, C 104 µS/cm, Sal. 0.00%, pH 6.67, [O_2] 2.28 mg/l, Sat O_2 18.20%, V 77 mV
Muddy substrate covered by a thick layer of vegetal debris and scattered boulders, outlet flow rate: VL
Radix balthica (r), *Pisidium personatum* (u)

233. Northern Loch of the St Jame's Lochs, Laurencekirk
Lat. 56° 49' 50.94" N, Long. -02° 25' 18.34" W, Alt. 235 m AMSL; date 12/12/2004, T 4.40°C, C 160 µS/cm, Sal. 0.00%, pH 8.74, [O_2] 4.11 mg/l, Sat O_2 32.20%, V 95 mV
Muddy substrate covered by a thick layer of vegetal debris and scattered boulders, outlet flow rate: VL
Radix balthica (a)

234. Blanket bog situated on the north-western side of Cairn, Laurencekirk
Lat. 56° 50' 15.36" N, Long. -02° 25' 03.35" W, Alt. 243 m AMSL; date 12/12/2004, T 5.10°C, C 150 µS/cm, Sal. 0.00%, pH 8.93, [O_2] 7.54 mg/l, Sat O_2 60.20%, V 104 mV
Muddy substrate with scattered boulders covered by a thick layer of vegetal debris, outlet flow rate: VL
Radix balthica (r), *Gyraulus laevis* (u), *Pisidium subtruncatum* (rr), *Pisidium milium* (rr)

235. Whitewater Moss, Nether Tulloch, Laurencekirk
Lat. 56° 49' 33.76" N, Long. -02° 22' 48.52" W, Alt. 136 m AMSL; date 12/12/2004, T 6.20°C, C 321 µS/cm, Sal. 0.00%, pH 9.03, [O_2] 15.06 mg/l, Sat O_2 122.30%, V 96 mV
Muddy substrate covered by a thick layer of vegetal debris, inlet flow rate: L
Stagnicola palustris (r), *Radix balthica* (a), *Galba truncatula* (rr)

236. Artificial lochan situated 500 m westward from Seafield, Aberdeen
Lat. 57° 08' 03.00" N, Long. -02° 09' 20.88" W, Alt. 69 m AMSL; date 19/12/2004, T 2.30°C, C 424 µS/cm, Sal. 0.00%, pH 8.50, [O_2] 6.59 mg/l, Sat O_2 48.30%, V 132 mV
Sandy-gravelly substrate with scattered boulders covered by a thick layer of vegetal debris, inlet flow rate: L
Potamopyrgus antipodarum (u), *Radix balthica* (rr), *Gyraulus laevis* (a), *Pisidium casertanum* (r), *Pisidium personatum* (c)

237. Pool situated along Burn of Den in the Maidencraig natural reserve, Aberdeen
Lat. 57° 08' 53.05" N, Long. -02° 10' 55.15" W, Alt. 99 m AMSL; date 08/01/2005, T 3.10°C, C 334 µS/cm, Sal. 0.00%, pH 6.76, [O_2] 7.73 mg/l, Sat O_2 59.40%, V 232 mV
Gravelly-cobbly stream bed with large patches of vegetal debris, outlet flow rate: LM
Radix balthica (a), *Gyraulus albus* (u), *Sphaerium corneum* (u), *Musculium lacustre* (c), *Pisidium milium* (a)

238. Quarry lochan situated on the col separating Berry Top from Stranog Hill in locality Eastside, Netherley
Lat. 57° 03' 30.04" N, Long. -02° 13' 20.10" W, Alt. 146 m AMSL; date 09/01/2005, T 2.60°C, C 123 µS/cm, Sal. 0.00%, pH 7.67, [O_2] 9.92 mg/l, Sat O_2 75.00%, V 155 mV

Gravelly-cobbly substrate with scattered boulders and some muddy pockets, no flow out
Radix balthica (rr), *Sphaerium corneum* (a), *Pisidium casertanum* (r), *Pisidium subtruncatum* (a), *Pisidium nitidum* (a)

239. Braeroddach Loch, near the inlet, Aboyne
Lat. 57° 05' 25.73" N, Long. -02° 51' 22.52" W, Alt. 199 m AMSL; date 16/01/2005, T 4.80°C, C 161 µS/cm, Sal. 0.00%, pH 7.05, [O_2] 5.59 mg/l, Sat O_2 44.90%, V 134 mV
Gravelly-pebbly substrate with scattered boulders covered by a thick layer of vegetal debris, inlet flow rate: M
Radix balthica (u), *Physa fontinalis* (r), *Gyraulus albus* (rr), *Pisidium subtruncatum* (r), *Pisidium nitidum* (r)

240. Temporary pool situated on the south-eastern slope of Craig Dhu, 100 m from Long Cairn, Aboyne
Lat. 57° 05' 44.99" N, Long. -02° 50' 37.32" W, Alt. 244 m AMSL; date 16/01/2005, T 6.40°C, C 28 µS/cm, Sal. 0.00%, pH 8.78, [O_2] 7.14 mg/l, Sat O_2 60.20%, V 158 mV
Muddy substrate with scattered boulders, no flow out
Barren

241. Bog Loch located on the north-eastern slope of Sluie Hill, Banchory
Lat. 57° 04' 18.56" N, Long. -02° 36' 10.24" W, Alt. 107 m AMSL; date 16/01/2005, T 3.80°C, C 176 µS/cm, Sal. 0.00%, pH 9.12, [O_2] 7.01 mg/l, Sat O_2 54.30%, V 162 mV
Muddy substrate covered by a thick layer of vegetal debris
Valvata piscinalis (c), *Bathyomphalus contortus* (r), *Gyraulus albus* (r), *Hippeutis complanatus* (c), *Acroloxus lacustris* (rr), *Sphaerium corneum* (c), *Pisidium casertanum* (rr), *Pisidium personatum* (r), *Pisidium subtruncatum* (c), *Pisidium milium* (a), *Pisidium nitidum* (rr)

242. Stream flowing toward the southern end of Bay of Cruden, Cruden Bay
Lat. 57° 23' 39.63" N, Long. -01° 51' 51.60" W, Alt. 1 m AMSL; date 23/01/2005, T 4.00°C, C 506 µS/cm, Sal. 0.00%, pH 7.90, [O_2] 11.96 mg/l, Sat O_2 89.70%, V 158 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (r),

243. Stream flowing toward Bay of Cruden, southeastward from Hay Farm, Cruden Bay
Lat. 57° 24' 00.75" N, Long. -01° 51' 53.97" W, Alt. 1 m AMSL; date 23/01/2005, T 2.30°C, C 466 µS/cm, Sal. 0.00%, pH 7.96, [O_2] 10.34 mg/l, Sat O_2 74.00%, V 160 mV
Sandy-gravelly stream bed with scattered boulders, flow rate: LM
Potamopyrgus antipodarum (a), *Radix balthica* (u), *Pisidium personatum* (r)

244. Small stream flowing to Bay of Cruden, south-east of Aulton of Ardendraught, Cruden Bay
Lat. 57° 24' 21.84" N, Long. -01° 51' 45.89" W, Alt. 1 m AMSL; date 23/01/2005, T 3.30°C, C 407 µS/cm, Sal. 0.00%, pH 7.84, [O_2] 11.31 mg/l, Sat O_2 83.30%, V 143 mV
Sandy stream bed, flow rate: VL
Barren

245. Stream flowing to Bay of Cruden, 1 km south-westward from Cruden Bay, Cruden Bay
Lat. 57° 24' 33.73" N, Long. -01° 51' 31.41" W, Alt. 1 m AMSL; date 23/01/2005, T 3.20°C, C 788 µS/cm, Sal. 0.10%, pH 8.38, [O_2] 10.55 mg/l, Sat O_2 77.50%, V 91 mV
Sandy stream bed, flow rate: LM
Pisidium personatum (rr)

246. Water of Cruden before entering into the harbour of Cruden Bay, Cruden Bay
Lat. 57° 24' 54.19" N, Long. -01° 50' 51.65" W, Alt. 1 m AMSL; date 23/01/2005, T 2.80°C, C 1115 µS/cm, Sal. 0.30%, pH 7.25, [O_2] 10.66 mg/l, Sat O_2 77.50%, V 102 mV
Sandy-gravelly river bed with scattered boulders, flow rate: MH
Peringia ulvae (c), *Potamopyrgus antipodarum* (a), *Radix balthica* (u), *Ancylus fluviatilis* (r), *Pisidium personatum* (r), *Pisidium subtruncatum* (r)

247. Pool located along Brackley Burn, flowing along the northern slope of Craig Vallich, 800 m eastward from House of Glenmuick, Ballater
Lat. 57° 02' 13.40" N, Long. -03° 01' 38.45" W, Alt. 322 m AMSL; date 30/01/2005, T 3.20°C, C 51 µS/cm, Sal. 0.00%, pH 7.30, [O_2] 9.66 mg/l, Sat O_2 73.80%, V 120 mV
Gravelly-pebbly stream bed with scattered boulders and sparse muddy pockets, flow rate: LM
Radix balthica (r), *Pisidium casertanum* (r)

248. Blanket bog situated 300 m north-westward from the col between Craig Vallich and Pannanich Hill, Ballater
Lat. 57° 01' 48.25" N, Long. -03° 00' 34.78" W, Alt. 546 m AMSL; date 30/01/2005, T 4.10°C, C 46 µS/cm, Sal. 0.00%, pH 6.28, [O_2] 9.94 mg/l, Sat O_2 80.10%, V 182 mV
Muddy substrate mainly composed of peat and vegetal debris, flow rate: VL
Pisidium casertanum (a), *Pisidium personatum* (c), *Pisidium obtusale* (r)

249. Blanket bog situated downhill from the col between Craig Vallich and Pannanich Hill, 300 m from the station no. 248, Ballater
Lat. 57° 01' 55.89" N, Long. -03° 00' 42.24" W, Alt. 536 m AMSL; date 30/01/2005, T 2.80°C, C 39 µS/cm, Sal. 0.00%, pH 7.59, [O_2] 8.94 mg/l, Sat O_2 69.60%, V 178 mV
Soft muddy substrate composed of vegetal debris, no flow out
Pisidium casertanum (u), *Pisidium personatum* (rr)

250. Upper sector of Burn of Glendui, 100 m north-westward from Black Moss bog, Ballater
Lat. 57° 01' 52.55" N, Long. -02° 57' 50.92" W, Alt. 463 m AMSL; date 30/01/2005, T 4.10°C, C 45 µS/cm, Sal. 0.00%, pH 6.30, [O_2] 7.94 mg/l, Sat O_2 63.40%, V 177 mV
Muddy stream bed with sandy-gravelly pockets, flow rate: VL
Barren

251. Black Moss bog, north-eastern slope of Knockie Branar, Ballater
Lat. 57° 01' 50.33" N, Long. -02° 57' 56.62" W, Alt. 465 m AMSL; date 30/01/2005, T 2.70°C, C 34 µS/cm, Sal. 0.00%, pH 5.82, [O_2] 11.30 mg/l, Sat O_2 87.00%, V 190 mV
Gravelly-pebbly substrate with scattered boulders covered by a thin muddy layer, inlet flow rate: VL, outlet flow rate: no flow
Barren

252. Pollagach Burn at the base of the north-western slope of Knockie Branar, Ballater
Lat. 57° 01' 42.53" N, Long. -02° 59' 41.39" W, Alt. 499 m AMSL; date 30/01/2005, T 3.20°C, C 63 µS/cm, Sal. 0.00%, pH 4.28, [O_2] 11.49 mg/l, Sat O_2 90.00%, V 180 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: M
Barren

253. Upper sector of Crichie Burn, on the col between Brunt Hill and Garrol Hill, Fettercairn
Lat. 56° 53' 03.04" N, Long. -02° 36' 06.14" W, Alt. 285 m AMSL; date 06/01/2005, T 4.50°C, C 67 µS/cm, Sal. 0.00%, pH 7.11, [O_2] 10.28 mg/l, Sat O_2 81.60%, V 82 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: L
Pisidium casertanum (u), *Pisidium personatum* (u)

254. Slack Pool situated on a col located 1800 m to the south-west of Hound Hillock, Fettercairn
Lat. 56° 53' 30.91" N, Long. -02° 38' 32.13" W, Alt. 490 m AMSL; date 06/01/2005, T 3.00°C, C 48 µS/cm, Sal. 0.00%, pH 4.62, [O_2] 4.34 mg/l, Sat O_2 34.00%, V 109 mV
Silty-sandy substrate covered by a layer of vegetal debris, mainly composed of detrital peat, no flow in and out
Barren

255. Well of Cardowan, south-eastern slope of Hound Hillock, Fettercairn
Lat. 56° 53' 49.80" N, Long. -02° 36' 40.76" W, Alt. 368 m AMSL; date 06/01/2005, T 7.10°C, C 113 µS/cm, Sal. 0.00%, pH 5.29, [O_2] 7.73 mg/l, Sat O_2 66.30%, V 85 mV
Gravelly-pebbly stream bed with scattered boulders, flow rate: L
Pisidium casertanum (r), *Pisidium personatum* (r)

256. Loch of Muchrae located on the col between Hound Hillock and Arnbarrow Hill, Fettercairn

Lat. 56° 53' 40.23" N, Long. -02° 35' 17.42" W, Alt. 280 m AMSL; date 06/01/2005, T 3.00°C, C 35 µS/cm, Sal. 0.00%, pH 4.27, [O_2] 10.57 mg/l, Sat O_2 80.40%, V 99 mV
Gravelly-pebbly substrate with scattered boulders, no flow out
Barren

257. Western shore of Cotehill Loch, Collieston
Lat. 57° 21' 17.77" N, Long. -01° 57' 32.46" W, Alt. 37 m AMSL; date 20/02/2005, T 0.40°C, C 709 µS/cm, Sal. 0.10%, pH 7.12, [O_2] 4.85 mg/l, Sat O_2 33.40%, V 103 mV
Muddy substrate covered by a thick layer of vegetal debris, flow rate: L
Radix balthica (r), *Gyraulus albus* (u), *Pisidium casertanum* (rr), *Pisidium subtruncatum* (r), *Pisidium nitidum* (r)

258. Eastern shore of Sand Loch, nearby the outlet beginning, Collieston
Lat. 57° 20' 47.97" N, Long. -01° 56' 33.81" W, Alt. 18 m AMSL; date 20/02/2005, T 1.50°C, C 199 µS/cm, Sal. 0.00%, pH 6.52, [O_2] 9.73 mg/l, Sat O_2 69.10%, V 98 mV
Sandy substrate covered by a thick layer of vegetal debris, outlet flow rate: M
Barren

259. South-eastern shore of Meikle Loch, Collieston
Lat. 57° 21' 56.47" N, Long. -01° 56' 53.60" W, Alt. 49 m AMSL; date 20/02/2005, T 2.90°C, C 351 µS/cm, Sal. 0.00%, pH 6.69, [O_2] 12.58 mg/l, Sat O_2 92.00%, V 102 mV
Gravelly-pebbly substrate with scattered boulders
Potamopyrgus antipodarum (u), *Radix balthica* (rr), *Gyraulus albus* (u), *Pisidium nitidum* (r)

260. Northern shore of Little Loch, Collieston
Lat. 57° 22' 12.66" N, Long. -01° 57' 40.18" W, Alt. 48 m AMSL; date 20/02/2005, T 2.60°C, C 201 µS/cm, Sal. 0.00%, pH 5.98, [O_2] 11.03 mg/l, Sat O_2 80.50%, V 106 mV
Gravelly-pebbly substrate covered by a thick layer of vegetal debris
Potamopyrgus antipodarum (rr), *Radix balthica* (r), *Gyraulus albus* (a), *Pisidium milium* (c)

261. Artificial lochan situated on the left side of Water of Cruden, 2 km westward from Cruden Bay, Cruden Bay
Lat. 57° 25' 11.84" N, Long. -01° 52' 54.39" W, Alt. 16 m AMSL; date 20/02/2005, T 4.00°C, C 880 µS/cm, Sal. 0.20%, pH 4.96, [O_2] 9.76 mg/l, Sat O_2 74.00%, V 85 mV
Muddy-sandy substrate covered by a thick layer of vegetal debris, inlet flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (u), *Physella acuta* (c), *Ancylus fluviatilis* (a), *Gyraulus laevis* (c), *Gyraulus crista* (r), *Pisidium casertanum* (a), *Pisidium personatum* (r), *Pisidium subtruncatum* (a), *Pisidium milium* (c), *Pisidium nitidum* (a)

262. Lochan situated 100 m from the A975 road, 500 m southward from Blackhill farm, Collieston
Lat. 57° 22' 15.37" N, Long. -01° 56' 03.01" W, Alt. 42 m AMSL; date 20/02/2005, T 1.70°C, C 479 µS/cm, Sal. 0.00%, pH 5.13, [O_2] 12.09 mg/l, Sat O_2 86.50%, V 105 mV
Muddy substrate covered by a thick layer of vegetal debris, no flow out
Radix balthica (rr)

263. Artificial lochan located 250 m north-westward from Pitfour Lake, Mintlaw
Lat. 57° 31' 51.36" N, Long. -02° 02' 50.74" W, Alt. 59 m AMSL; date 27/02/2005, T 5.00°C, C 258 µS/cm, Sal. 0.00%, pH 7.30, [O_2] 10.50 mg/l, Sat O_2 81.20%, V 84 mV
Gravelly-pebbly substrate with scattered boulders covered by a layer of vegetal debris, inlet flow rate: VL
Galba truncatula (r)

264. Northern shore of Pitfour Lake, Mintlaw
Lat. 57° 31' 46.89" N, Long. -02° 02' 16.29" W, Alt. 55 m AMSL; date 27/02/2005, T 4.30°C, C 238 µS/cm, Sal. 0.00%, pH 6.96, [O_2] 8.06 mg/l, Sat O_2 61.20%, V 97 mV
Muddy substrate covered by a layer of vegetal debris, inlet flow rate: M
Potamopyrgus antipodarum (a), *Radix balthica* (c), *Planorbarius corneus* (u), *Bathyomphalus contortus* (r), *Gyraulus albus* (r), *Gyraulus laevis* (rr), *Gyraulus crista* (rr), *Hippeutis complanatus* (u), *Pisidium casertanum* (rr), *Pisidium personatum* (rr), *Pisidium subtruncatum* (r), *Pisidium milium* (r), *Pisidium nitidum* (r), *Pisidium hibernicum* (r)

265. Western shore of Strichen Lochan, Strichen
Lat. 57° 35' 03.76" N, Long. -02° 05' 39.98" W, Alt. 58 m AMSL; date 27/02/2005, T 4.10°C, C 227 µS/cm, Sal. 0.00%, pH 6.35, [O_2] 10.43 mg/l, Sat O_2 78.80%, V 95 mV
Gravelly-pebbly substrate with scattered boulders, inlet flow rate: LM
Potamopyrgus antipodarum (a), *Pisidium subtruncatum* (r)

266. Artificial lochan situated on the left bank of North Ugie Water, 100 m to the south of Strichen, Strichen
Lat. 57° 35' 01.85" N, Long. -02° 05' 20.13" W, Alt. 49 m AMSL; date 27/02/2005, T 4.50°C, C 261 µS/cm, Sal. 0.00%, pH 6.45, [O_2] 10.13 mg/l, Sat O_2 77.30%, V 94 mV
Muddy-sandy substrate, colonized by an introduced aquatic flora, outlet flow rate: VL
Potamopyrgus antipodarum (a), *Lymnaea stagnalis* (c), *Radix balthica* (a), *Galba truncatula* (rr), *Gyraulus albus* (r), *Pisidium personatum* (rr), *Pisidium obtusale* (rr), *Pisidium subtruncatum* (rr), *Pisidium nitidum* (rr)

267. Artificial lochan situated on the left bank of a right tributary of the North Ugie Water, 1250 m south-eastward from Strichen, Strichen
Lat. 57° 34' 33.01" N, Long. -02° 05' 03.59" W, Alt. 50 m AMSL; date 27/02/2005, T 4.40°C, C 260 µS/cm, Sal. 0.00%, pH 6.35, [O_2] 10.21 mg/l, Sat O_2 77.30%, V 97 mV
Gravelly-pebbly substrate with scattered boulders, no flow out
Radix balthica (a)

268. River North Esk below the A92 road bridge, St Cyrus
Lat. 56° 45' 02.42" N, Long. -02° 27' 07.01" W, Alt. 2 m AMSL; date 26/03/2005, T 8.40°C, C 143 µS/cm, Sal. 0.00%, pH 7.03, [O_2] 9.89 mg/l, Sat O_2 85.60%, V 62 mV
Gravelly-pebbly river bed with scattered boulders and sandy pockets, flow rate: VH
Potamopyrgus antipodarum (r), *Radix balthica* (rr), *Ancylus fluviatilis* (a), *Pisidium casertanum* (r), *Pisidium subtruncatum* (r), *Pisidium nitidum* (rr)

269. Mill of Criggie lochan, northern slope of Hill of Morphie, St Cyrus
Lat. 56° 47' 06.42" N, Long. -02° 27' 05.59" W, Alt. 105 m AMSL; date 26/03/2005, T 9.40°C, C 415 µS/cm, Sal. 0.00%, pH 7.24, [O_2] 9.90 mg/l, Sat O_2 87.60%, V 71 mV
Muddy-sandy substrate with scattered boulders and gravelly-pebbly pockets, outlet flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Ancylus fluviatilis* (c), *Gyraulus albus* (a), *Gyraulus laevis* (rr), *Musculium lacustre* (c), *Pisidium casertanum* (u), *Pisidium subtruncatum* (a), *Pisidium milium* (rr), *Pisidium nitidum* (a), *Pisidium hibernicum* (r)

270. Lochan situated 500 m to the north-east of Mill of Criggie, St Cyrus
Lat. 56° 47' 13.34" N, Long. -02° 26' 48.36" W, Alt. 115 m AMSL; date 26/03/2005, T 7.80°C, C 310 µS/cm, Sal. 0.00%, pH 7.62, [O_2] 11.44 mg/l, Sat O_2 97.70%, V 62 mV
Muddy substrate with scattered boulders; heavily eutrophic, inlet flow rate: VL
Potamopyrgus antipodarum (c), *Gyraulus laevis* (a), *Pisidium personatum* (rr), *Pisidium subtruncatum* (a), *Pisidium milium* (a), *Pisidium nitidum* (a), *Pisidium hibernicum* (r)

271. Lochan situated 750 m to the east of Mill of Criggie, St Cyrus
Lat. 56° 47' 06.21" N, Long. -02° 26' 22.66" W, Alt. 126 m AMSL; date 26/03/2005, T 8.00°C, C 348 µS/cm, Sal. 0.00%, pH 7.18, [O_2] 6.83 mg/l, Sat O_2 58.60%, V 84 mV
Gravelly-pebbly substrate covered by a layer of vegetal debris
Potamopyrgus antipodarum (rr), *Gyraulus albus* (c), *Gyraulus crista* (r), *Hippeutis complanatus* (c), *Pisidium milium* (a), *Pisidium nitidum* (a)

272. Tore Burn flowing toward Cullykhan Bay, 50 m before the high tide mark, Pennan
Lat. 57° 40' 53.68" N, Long. -02° 16' 19.58" W, Alt. 1 m AMSL; date 04/04/2005, T 9.20°C, C 287 µS/cm, Sal. 0.00%, pH 7.07, [O_2] 11.23 mg/l, Sat O_2 97.60%, V 119 mV

Gravelly-pebbly stream bed with scattered boulders and sandy pockets, flow rate: LM
Potamopyrgus antipodarum (a), *Radix balthica* (a), *Ancylus fluviatilis* (a)

273. Spring stream flowing toward the southern end of an unnamed bay near a Pictish fort, Pennan
Lat. 57° 40' 59.47" N, Long. -02° 16' 33.43" W, Alt. 8 m AMSL; date 04/04/2005, T 9.50°C, C 633 µS/cm, Sal. 0.00%, pH 7.22, $[O_2]$ 3.35 mg/l, Sat O_2 29.50%, V 90 mV
Muddy stream bed mainly composed of organic matter rich in iron hydroxides, flow rate: VL
Potamopyrgus antipodarum (a), *Galba truncatula* (u), *Pisidium personatum* (a)

274. Artificial by-pass channel leading to an unnamed bay derived from a stream flowing to the south of Lion's Head, Pennan
Lat. 57° 41' 05.11" N, Long. -02° 16' 29.41" W, Alt. 6 m AMSL; date 04/04/2005, T 9.20°C, C 409 µS/cm, Sal. 0.00%, pH 7.03, $[O_2]$ 12.37 mg/l, Sat O_2 107.40%, V 118 mV
Muddy-sandy substrate with scattered boulders, flow rate: L
Potamopyrgus antipodarum (c), *Radix balthica* (r), *Ancylus fluviatilis* (a), *Pisidium casertanum* (r), *Pisidium personatum* (a), *Pisidium nitidum* (r)

275. Stream flowing to the south of Lion's Head, Pennan
Lat. 57° 41' 05.24" N, Long. -02° 16' 36.07" W, Alt. 4 m AMSL; date 04/04/2005, T 9.10°C, C 405 µS/cm, Sal. 0.00%, pH 7.02, $[O_2]$ 12.77 mg/l, Sat O_2 106.70%, V 123 mV
Gravelly-pebbly stream bed with scattered boulders and sandy pockets, flow rate: LM
Potamopyrgus antipodarum (a), *Ancylus fluviatilis* (a), *Pisidium personatum* (a), *Pisidium nitidum* (r)

276. Spring brook flowing into a tectonic cave invaded by the sea, Pennan
Lat. 57° 41' 09.23" N, Long. -02° 16' 32.69" W, Alt. 4 m AMSL; date 04/04/2005, T 10.90°C, C 1045 µS/cm, Sal. 0.30%, pH 7.04, $[O_2]$ 11.76 mg/l, Sat O_2 106.90%, V 117 mV
Muddy-sandy stream bed, flow rate: VL
Potamopyrgus antipodarum (a), *Galba truncatula* (rr), *Pisidium casertanum* (c), *Pisidium personatum* (c)

277. Stream flowing toward Downie Bay, Pennan
Lat. 57° 41' 18.67" N, Long. -02° 17' 48.13" W, Alt. 16 m AMSL; date 04/04/2005, T 9.40°C, C 460 µS/cm, Sal. 0.00%, pH 7.08, $[O_2]$ 11.98 mg/l, Sat O_2 105.80%, V 90 mV
Muddy stream bed mainly composed of organic matter, flow rate: L
Galba truncatula (rr), *Pisidium casertanum* (r)

278. Craigiebuckler pond, Aberdeen
Lat. 57° 08' 20.81" N, Long. -02° 09' 29.41" W, Alt. 74 m AMSL; date 05/04/2005, T 10.90°C, C 325 µS/cm, Sal. 0.00%, pH 7.06, $[O_2]$ 9.29 mg/l, Sat O_2 84.70%, V 130 mV
Muddy substrate covered by a thick layer of vegetal debris, inlet flow rate: L
Potamopyrgus antipodarum (rr), *Radix balthica* (c), *Physella acuta* (r), *Ancylus fluviatilis* (c), *Gyraulus albus* (c), *Gyraulus crista* (c), *Pisidium personatum* (r), *Pisidium obtusale* (r), *Pisidium milium* (u), *Pisidium nitidum* (u)

279. Pond of Johnston Park, Aberdeen
Lat. 57° 08' 10.45" N, Long. -02° 08' 54.63" W, Alt. 57 m AMSL; date 05/04/2005, T 8.50°C, C 720 µS/cm, Sal. 0.10%, pH 7.04, $[O_2]$ 10.74 mg/l, Sat O_2 92.60%, V 126 mV
Gravelly-pebbly substrate with scattered boulders; the basin is bounded by concrete walls, outlet flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Gyraulus albus* (rr), *Musculium lacustre* (c), *Pisidium casertanum* (a), *Pisidium nitidum* (r)

280. Small stream flowing downstream from an artificial lochan located in locality Banchory-Devenick, Aberdeen
Lat. 57° 06' 46.92" N, Long. -02° 09' 03.47" W, Alt. 18 m AMSL; date 13/04/2005, T 6.90°C, C 301 µS/cm, Sal. 0.00%, pH 7.20, $[O_2]$ 11.35 mg/l, Sat O_2 94.40%, V 117 mV
Gravelly-pebbly stream bed with scattered boulders and muddy pockets, flow rate: LM
Potamopyrgus antipodarum (a), *Galba truncatula* (rr), *Ancylus fluviatilis* (a), *Pisidium casertanum* (c), *Pisidium personatum* (a)

281. Loch of Lumgair, Stonehaven
Lat. 56° 56' 11.92" N, Long. -02° 14' 23.31" W, Alt. 118 m AMSL; date 17/04/2005, T 10.20°C, C 175 µS/cm, Sal. 0.00%, pH 6.73, $[O_2]$ 8.00 mg/l, Sat O_2 73.30%, V 137 mV
Substrate covered by a very thick layer of vegetal debris, outlet flow rate: L
Pisidium milium (u)

282. Small artificial lochan situated near Bruxie Hill top, Stonehaven
Lat. 56° 54' 38.90" N, Long. -02° 17' 45.99" W, Alt. 199 m AMSL; date 17/04/2005, T 8.90°C, C 239 µS/cm, Sal. 0.00%, pH 9.36, $[O_2]$ 13.38 mg/l, Sat O_2 120.20%, V 133 mV
Gravelly-pebbly substrate with scattered boulders and sandy pockets, outlet flow rate: VL
Radix balthica (r)

283. Loch Ullachie at the outlet beginning, Ballater
Lat. 57° 02' 25.69" N, Long. -03° 05' 27.44" W, Alt. 248 m AMSL; date 23/04/2005, T 10.10°C, C 102 µS/cm, Sal. 0.00%, pH 7.28, $[O_2]$ 11.34 mg/l, Sat O_2 103.30%, V 111 mV
Gravelly-pebbly substrate with scattered boulders covered by vegetal debris, outlet flow rate: LM
Radix balthica (u), *Gyraulus albus* (a), *Pisidium lilljeborgii* (a)

284. Small bog situated on the left side of River Dee near Allanmore, Braemar
Lat. 57° 00' 24.26" N, Long. -03° 24' 50.56" W, Alt. 332 m AMSL; date 23/04/2005, T 13.10°C, C 38 µS/cm, Sal. 0.00%, pH 6.46, $[O_2]$ 9.47 mg/l, Sat O_2 93.30%, V 123 mV
Muddy-sandy substrate, no flow out
Pisidium casertanum (rr), *Pisidium personatum* (r), *Pisidium subtruncatum* (r), *Pisidium milium* (r), *Pisidium nitidum* (c), *Pisidium hibernicum* (u)

285. Lochan of Invercauld House, Braemar
Lat. 57° 00' 48.12" N, Long. -03° 21' 23.43" W, Alt. 327 m AMSL; date 23/04/2005, T 10.90°C, C 167 µS/cm, Sal. 0.00%, pH 8.39, $[O_2]$ 10.11 mg/l, Sat O_2 95.00%, V 135 mV
Muddy substrate with gravelly-pebbly pockets and scattered boulders, inlet flow rate: L
Radix balthica (r), *Galba truncatula* (r)

286. Tidal channel of River North Esk, St Cyrus
Lat. 56° 45' 12.61" N, Long. -02° 25' 44.91" W, Alt. 1 m AMSL; date 30/04/2005, T 21.20°C, C 4550 µS/cm, Sal. 2.40%, pH 8.66, $[O_2]$ 9.34 mg/l, Sat O_2 105.30%, V -95 mV
Sandy river bed with scattered boulders, flow rate: L (during low tide)
Peringia ulvae (a), *Radix balthica* (rr), *Galba truncatula* (rr), *Ancylus fluviatilis* (rr)

287. Tidal flat of River North Esk, St Cyrus
Lat. 56° 45' 06.63" N, Long. -02° 25' 51.70" W, Alt. 1 m AMSL; date 30/04/2005, T 15.20°C, C 4360 µS/cm, Sal. 2.20%, pH 7.78, $[O_2]$ 8.88 mg/l, Sat O_2 88.50%, V 133 mV
Muddy-sandy river bed, flow rate: H (during low tide)
Ecrobia ventrosa (rr), *Peringia ulvae* (a), *Radix balthica* (rr), *Ancylus fluviatilis* (r), *Pisidium personatum* (rr), *Pisidium subtruncatum* (rr)

288. Upper sector of River Ythan, 600 m south-eastward from Meadowhead, Ythanwells
Lat. 57° 25' 57.00" N, Long. -02° 35' 26.06" W, Alt. 198 m AMSL; date 01/05/2005, T 7.40°C, C 173 µS/cm, Sal. 0.00%, pH 6.97, $[O_2]$ 12.77 mg/l, Sat O_2 109.20%, V 152 mV
Pebbly-cobbly stream bed with scattered boulders, flow rate: L
Radix balthica (c), *Galba truncatula* (a), *Pisidium casertanum* (r), *Pisidium personatum* (a)

289. Artificial lochan situated on the left bank of a left tributary of River Ythan near Kingsford, Turriff
Lat. 57° 29' 31.40" N, Long. -02° 26' 52.99" W, Alt. 58 m AMSL; date 01/05/2005, T 11.50°C, C 199 µS/cm, Sal. 0.00%, pH 7.93, $[O_2]$ 10.70 mg/l, Sat O_2 99.40%, V 146 mV
Muddy substrate with rare scattered boulders, inlet flow rate: VL

Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Pisidium casertanum* (a), *Pisidium nitidum* (a), *Pisidium subtruncatum* (a)

290. Artificial lochan situated on the right bank of River Ythan near Inverythan, Fyvie
Lat. 57° 27' 52.67" N, Long. -02° 24' 47.54" W, Alt. 53 m AMSL; date 01/05/2005, T 11.30°C, C 244 µS/cm, Sal. 0.00%, pH 8.19, [O_2] 11.92 mg/l, Sat O_2 110.20%, V 143 mV
Muddy substrate with scattered boulders, inlet flow rate: L
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Bathyomphalus contortus* (c), *Gyraulus albus* (a), *Gyraulus laevis* (u), *Sphaerium corneum* (c), *Pisidium casertanum* (c), *Pisidium subtruncatum* (a), *Pisidium nitidum* (a)

291. River Ythan below the bridge of the B9005 road, Fyvie
Lat. 57° 25' 43.58" N, Long. -02° 23' 44.90" W, Alt. 47 m AMSL; date 01/05/2005, T 8.20°C, C 257 µS/cm, Sal. 0.00%, pH 7.07, [O_2] 11.30 mg/l, Sat O_2 97.00%, V 119 mV
Sandy-pebbly river bed with cobbly bars and scattered boulders, flow rate: H
Potamopyrgus antipodarum (r), *Radix balthica* (r), *Bathyomphalus contortus* (r), *Ancylus fluviatilis* (r), *Pisidium casertanum* (u), *Pisidium subtruncatum* (u), *Pisidium milium* (rr), *Pisidium nitidum* (u)

292. North-eastern shore of Loch of Fyvie, Fyvie
Lat. 57° 26' 17.91" N, Long. -02° 23' 29.46" W, Alt. 49 m AMSL; date 01/05/2005, T 10.70°C, C 239 µS/cm, Sal. 0.00%, pH 8.28, [O_2] 11.84 mg/l, Sat O_2 109.20%, V 132 mV
Muddy substrate covered by a thick layer of vegetal debris
Potamopyrgus antipodarum (rr), *Stagnicola palustris* (c), *Bathyomphalus contortus* (rr), *Gyraulus albus* (a), *Gyraulus laevis* (r), *Pisidium personatum* (r), *Pisidium subtruncatum* (r), *Pisidium milium* (u), *Pisidium nitidum* (u)

293. River Ythan near Wood of Wardford, Woodhead
Lat. 57° 26' 25.08" N, Long. -02° 15' 32.97" W, Alt. 24 m AMSL; date 01/05/2005, T 10.60°C, C 239 µS/cm, Sal. 0.00%, pH 6.54, [O_2] 21.50 mg/l, Sat O_2 197.00%, V 126 mV
Sandy-pebbly river bed with scattered boulders, flow rate: H
Potamopyrgus antipodarum (rr), *Radix balthica* (r), *Ancylus fluviatilis* (rr), *Pisidium casertanum* (r), *Pisidium personatum* (rr), *Pisidium subtruncatum* (r), *Pisidium nitidum* (rr)

294. River Ythan at the intersection with Yowlie Burn, Ellon
Lat. 57° 22' 01.23" N, Long. -02° 07' 29.78" W, Alt. 8 m AMSL; date 01/05/2005, T 11.90°C, C 247 µS/cm, Sal. 0.00%, pH 7.48, [O_2] 16.98 mg/l, Sat O_2 167.90%, V 132 mV
Pebbly-cobbly river bed with scattered boulders and sandy-pebbly pockets, flow rate: VH
Potamopyrgus antipodarum (rr), *Radix balthica* (c), *Bathyomphalus contortus* (rr), *Ancylus fluviatilis* (r), *Sphaerium corneum* (r), *Pisidium casertanum* (rr), *Pisidium personatum* (r), *Pisidium subtruncatum* (r), *Pisidium milium* (r), *Pisidium nitidum* (u)

295. Hazlehead Fountain, Hazlehead Park, Aberdeen
Lat. 57° 08' 20.41" N, Long. -02° 10' 42.78" W, Alt. 108 m AMSL; date 05/05/2005, T 14.70°C, C 132 µS/cm, Sal. 0.00%, pH 8.80, [O_2] 9.66 mg/l, Sat O_2 83.90%, V 78 mV
Concrete tank, no flow out
Potamopyrgus antipodarum (r), *Physella acuta* (a)

296. Carlochy, north-eastern slope of Muckle Cairn, Invermark
Lat. 56° 53' 51.85" N, Long. -02° 59' 28.94" W, Alt. 469 m AMSL; date 08/05/2005, T 8.30°C, C 37 µS/cm, Sal. 0.00%, pH 6.78, [O_2] 10.17 mg/l, Sat O_2 91.40%, V 133 mV
Pebbly-cobbly substrate with scattered boulders, outlet flow rate: L
Ancylus fluviatilis (r)

297. Mouth of Water of Lee at the Loch Lee boat house, Invermark
Lat. 56° 54' 10.20" N, Long. -02° 57' 49.01" W, Alt. 278 m AMSL; date 08/05/2005, T 6.60°C, C 60 µS/cm, Sal. 0.00%, pH 5.95, [O_2] 10.31 mg/l, Sat O_2 87.30%, V 92 mV
Sandy-pebbly substrate covered by a thin layer of vegetal debris, inlet flow rate: H
Pisidium casertanum (a), *Pisidium personatum* (c), *Pisidium subtruncatum* (c)

298. Northern shore of Loch Lee, 250 m westward from the Church, Invermark
Lat. 56° 54' 29.94" N, Long. -02° 56' 24.81" W, Alt. 278 m AMSL; date 08/05/2005, T 9.50°C, C 32 µS/cm, Sal. 0.00%, pH 6.60, [O_2] 10.10 mg/l, Sat O_2 94.90%, V 122 mV
Pebbly-cobbly substrate with scattered boulders
Barren

299. Bog situated 200 m northwestward from Tarfside Church, Tarfside
Lat. 56° 54' 16.72" N, Long. -02° 49' 50.50" W, Alt. 198 m AMSL; date 08/05/2005, T 19.30°C, C 221 µS/cm, Sal. 0.00%, pH 7.60, [O_2] 19.31 mg/l, Sat O_2 216.00%, V 125 mV
Muddy substrate covered by a thick layer of vegetal debris, outlet flow rate: L
Pisidium personatum (u), *Pisidium obtusale* (c)

300. River North Esk at the downstream end of Rocks of Solitude gorge, Edzell
Lat. 56° 50' 35.60" N, Long. -02° 40' 25.95" W, Alt. 78 m AMSL; date 08/05/2005, T 8.60°C, C 52 µS/cm, Sal. 0.00%, pH 6.99, [O_2] 10.36 mg/l, Sat O_2 93.80%, V 161 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: VH
*Margaritifera margaritifer*a (rr)

301. River North Esk near Mill of Pert, Edzell
Lat. 56° 47' 13.43" N, Long. -02° 35' 11.61" W, Alt. 30 m AMSL; date 08/05/2005, T 9.50°C, C 92 µS/cm, Sal. 0.00%, pH 7.37, [O_2] 10.68 mg/l, Sat O_2 94.80%, V 134 mV
Sandy-pebbly river bed with scattered boulders, flow rate: VH
Potamopyrgus antipodarum (c), *Radix balthica* (rr), *Ancylus fluviatilis* (u), *Pisidium casertanum* (r), *Pisidium personatum* (u), *Pisidium nitidum* (r)

302. River Don at the Bridge of Alford, Alford
Lat. 57° 14' 34.61" N, Long. -02° 43' 44.63" W, Alt. 135 m AMSL; date 14/05/2005, T 10.60°C, C 663 µS/cm, Sal. 0.10%, pH 7.39, [O_2] 10.53 mg/l, Sat O_2 95.00%, V 170 mV
Silty-sandy river bed with pebbly-cobbly bars and scattered boulders, flow rate: VH
Radix balthica (a), *Ancylus fluviatilis* (a), *Pisidium casertanum* (u), *Pisidium personatum* (u), *Pisidium subtruncatum* (r), *Pisidium milium* (rr)*Pisidium nitidum* (rr)

303. River Don at the bridge connecting Monymusk to Enzean, Monymusk
Lat. 57° 13' 43.28" N, Long. -02° 30' 40.76" W, Alt. 81 m AMSL; date 14/05/2005, T 11.60°C, C 148 µS/cm, Sal. 0.00%, pH 8.47, [O_2] 13.34 mg/l, Sat O_2 122.50%, V 176 mV
Sandy-pebbly river bed with pebbly-cobbly bars and scattered boulders, flow rate: VH
Radix balthica (a), *Ancylus fluviatilis* (a), *Pisidium subtruncatum* (r), *Pisidium nitidum* (rr)

304. River Don below the A96(T) road bridge, Inverurie
Lat. 57° 16' 28.89" N, Long. -02° 22' 46.55" W, Alt. 56 m AMSL; date 14/05/2005, T 12.30°C, C 158 µS/cm, Sal. 0.00%, pH 8.68, [O_2] 10.60 mg/l, Sat O_2 98.60%, V 151 mV
Silty-sandy river bed with pebbly-cobbly bars and scattered boulders, flow rate: VH
Potamopyrgus antipodarum (r), *Radix balthica* (a), *Ancylus fluviatilis* (r), *Pisidium subtruncatum* (r), *Pisidium nitidum* (r)

305. Loch Callater at the Allt an Loch mouth, Braemar
Lat. 56° 56' 10.76" N, Long. -03° 20' 10.62" W, Alt. 500 m AMSL; date 15/05/2005, T 12.70°C, C 29 µS/cm, Sal. 0.00%, pH 6.29, [O_2] 8.92 mg/l, Sat O_2 89.10%, V 111 mV
Pebbly-cobbly substrate with scattered boulders, inlet flow rate: M
Pisidium casertanum (rr)

306. First pool of Loch Kander outlet, Braemar
Lat. 56° 54' 48.75" N, Long. -03° 19' 49.06" W, Alt. 677 m AMSL; date 15/05/2005, T 10.90°C, C 27 µS/cm, Sal. 0.00%, pH 6.79, [O_2] 9.87 mg/l, Sat O_2 96.60%, V 106 mV
Muddy stream bed with scattered boulders covered by a layer of vegetal debris, flow rate: L
Radix balthica (u), *Ancylus fluviatilis* (a), *Pisidium casertanum* (a), *Pisidium subtruncatum* (c), *Pisidium milium* (c)

307. North-western shore of Loch Callater, near Lochcallater Lodge, Braemar
Lat. 56° 56' 34.77" N, Long. -03° 21' 10.95" W, Alt. 500 m AMSL; date 15/05/2005, T 10.90°C, C 28 µS/cm, Sal. 0.00%, pH 6.72, [O_2] 9.71 mg/l, Sat O_2 93.40%, V 99 mV
Pebbly-cobbly substrate with scattered boulders, outlet flow rate: M
Pisidium lilljeborgii (r), *Pisidium hibernicum* (r)

308. Northern shore of Loirston Loch, Redmoss, Aberdeen
Lat. 57° 06' 13.03" N, Long. -02° 05' 57.17" W, Alt. 78 m AMSL; date 31/05/2005, T 14.50°C, C 807 µS/cm, Sal. 0.20%, pH 8.33, [O_2] 10.41 mg/l, Sat O_2 102.20%, V 157 mV
Gravelly-pebbly substrate with scattered boulders
Potamopyrgus antipodarum (a), *Radix balthica* (u), *Physa fontinalis* (rr), *Gyraulus albus* (r), *Gyraulus laevis* (r), *Gyraulus crista* (u), *Musculium lacustre* (u), *Pisidium milium* (c), *Pisidium nitidum* (a)

309. River Dee, 200 m downstream from Victoria Bridge, Aberdeen
Lat. 57° 08' 22.75" N, Long. -02° 05' 09.21" W, Alt. 1 m AMSL; date 01/06/2005, T 12.90°C, C 27000 µS/cm, Sal. 1.30%, pH 8.06, [O_2] 11.54 mg/l, Sat O_2 107.70%, V 124 mV
Gravelly-pebbly river bed with cobbly pockets and scattered boulders, flow rate: VH
Ecrobia ventrosa (rr)

310. Parkhill House lochan, Dyce
Lat. 57° 13' 03.01" N, Long. -02° 10' 36.37" W, Alt. 39 m AMSL; date 03/06/2005, T 16.20°C, C 299 µS/cm, Sal. 0.00%, pH 7.20, [O_2] 8.36 mg/l, Sat O_2 85.70%, V 170 mV
Sandy-gravelly substrate covered by a thick layer of vegetal debris, inlet flow rate: L
Potamopyrgus antipodarum (u), *Stagnicola palustris* (rr), *Radix balthica* (r), *Physa fontinalis* (rr), *Bathyomphalus contortus* (rr), *Gyraulus albus* (a), *Gyraulus crista* (u), *Hippeutis complanatus* (c), *Sphaerium corneum* (c), *Pisidium subtruncatum* (r), *Pisidium milium* (r), *Pisidium nitidum* (c), *Pisidium lilljeborgii* (rr)

311. Cruickshank pond located in the botany garden of Aberdeen University, Aberdeen
Lat. 57° 10' 03.34" N, Long. -02° 06' 15.07" W, Alt. 21 m AMSL; date 03/06/2005, T 14.30°C, C 266 µS/cm, Sal. 0.00%, pH 6.60, [O_2] 7.17 mg/l, Sat O_2 71.30%, V 203 mV
Muddy substrate covered by a thick layer of vegetal debris, no flow out
Radix balthica (a), *Planorbis planorbis* (a), *Hippeutis complanatus* (r), *Musculium lacustre* (a)

312. River Don, 500 m before the high tide mark, Aberdeen
Lat. 57° 10' 28.99" N, Long. -02° 05' 12.40" W, Alt. 1 m AMSL; date 03/06/2005, T 13.10°C, C 1035 µS/cm, Sal. 0.30%, pH 7.46, [O_2] 5.85 mg/l, Sat O_2 56.30%, V 156 mV
Muddy river bed with scattered boulders, flow rate: VH
Pisidium personatum (rr)

313. River Don lateral channel, 200 m upstream from the A956 road bridge, Aberdeen
Lat. 57° 10' 34.97" N, Long. -02° 05' 36.66" W, Alt. 1 m AMSL; date 03/06/2005, T 15.30°C, C 411 µS/cm, Sal. 0.00%, pH 8.24, [O_2] 10.94 mg/l, Sat O_2 110.60%, V 133 mV
Gravelly-pebbly river bed with scattered boulders, flow rate: VH
Potamopyrgus antipodarum (a)

314. Eastern shore of Loch of Fasque, Fettercairn
Lat. 56° 51' 44.52" N, Long. -02° 34' 45.65" W, Alt. 89 m AMSL; date 04/06/2005, T 14.50°C, C 218 µS/cm, Sal. 0.00%, pH 6.18, [O_2] 5.91 mg/l, Sat O_2 59.10%, V 98 mV
Muddy substrate covered by a thick layer of vegetal debris
Potamopyrgus antipodarum (rr), *Radix balthica* (r), *Gyraulus albus* (a), *Gyraulus crista* (a), *Hippeutis complanatus* (a), *Anodonta anatina* (a), *Sphaerium corneum* (a), *Pisidium subtruncatum* (u)

315. Bronie Burn at the Burreldale Moss, Newmachar
Lat. 57° 18' 16.43" N, Long. -02° 17' 43.34" W, Alt. 151 m AMSL; date 04/06/2005, T 10.40°C, C 152 µS/cm, Sal. 0.00%, pH 6.60, [O_2] 6.25 mg/l, Sat O_2 57.20%, V 137 mV
Silty-sandy stream bed covered by a thick layer of vegetal debris and iron hydroxides, flow rate: VL
Pisidium milium (c), *Pisidium nitidum* (a)

316. Lochan situated on the right bank of Rack Burn, left tributary of Foveran Burn near Damhead, Newmachar
Lat. 57° 17' 48.20" N, Long. -02° 05' 17.22" W, Alt. 56 m AMSL; date 04/06/2005, T 15.50°C, C 201 µS/cm, Sal. 0.00%, pH 7.28, [O_2] 8.46 mg/l, Sat O_2 85.70%, V 145 mV
Sandy-gravelly substrate covered by a thick layer of vegetal debris, no flow out
Potamopyrgus antipodarum (r), *Pisidium casertanum* (r), *Pisidium nitidum* (c), *Pisidium hibernicum* (u)

317. River Dee below the B974 road bridge, Banchory
Lat. 57° 02' 51.03" N, Long. -02° 30' 02.56" W, Alt. 49 m AMSL; date 04/06/2005, T 11.60°C, C 47 µS/cm, Sal. 0.00%, pH 7.24, [O_2] 10.20 mg/l, Sat O_2 94.00%, V 159 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: VH
Potamopyrgus antipodarum (rr), *Radix balthica* (rr), *Margaritifera margaritifera* (rr)

318. River Dee below the Aboyne Bridge, Aboyne
Lat. 57° 04' 11.44" N, Long. -02° 47' 13.97" W, Alt. 122 m AMSL; date 04/06/2005, T 11.30°C, C 35 µS/cm, Sal. 0.00%, pH 6.82, [O_2] 9.80 mg/l, Sat O_2 90.40%, V 228 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: VH
Potamopyrgus antipodarum (a), *Radix balthica* (r), *Ancylus fluviatilis* (r), *Pisidium casertanum* (c), *Pisidium subtruncatum* (rr)

319. Clyan's Dam, Monymusk
Lat. 57° 13' 40.28" N, Long. -02° 32' 12.58" W, Alt. 114 m AMSL; date 11/06/2005, T 12.50°C, C 100 µS/cm, Sal. 0.00%, pH 6.96, [O_2] 10.43 mg/l, Sat O_2 99.10%, V 177 mV
Pebbly-cobbly substrate covered by a thick layer of vegetal debris, outlet flow rate: LM
Valvata piscinalis (a), *Potamopyrgus antipodarum* (a), *Stagnicola palustris* (rr), *Radix balthica* (r), *Gyraulus albus* (a), *Pisidium casertanum* (r), *Pisidium milium* (u), *Pisidium nitidum* (c), *Pisidium lilljeborgii* (c)

320. River Deveron below the 'Bridge of Gibston', Huntly
Lat. 57° 27' 19.08" N, Long. -02° 48' 17.22" W, Alt. 119 m AMSL; date 11/06/2005, T 12.60°C, C 155 µS/cm, Sal. 0.00%, pH 8.34, [O_2] 10.01 mg/l, Sat O_2 95.10%, V 149 mV
Rocky river bed with sandy and pebbly-cobbly pockets and scattered boulders, flow rate: H
Potamopyrgus antipodarum (r), *Radix balthica* (a), *Ancylus fluviatilis* (a), *Pisidium subtruncatum* (u)

321. River Deveron below the B9025 road bridge at Turriff (Deveron Bridge), Turriff
Lat. 57° 32' 32.49" N, Long. -02° 28' 44.19" W, Alt. 26 m AMSL; date 11/06/2005, T 14.10°C, C 209 µS/cm, Sal. 0.00%, pH 8.00, [O_2] 10.31 mg/l, Sat O_2 100.10%, V 214 mV
Pebbly-cobbly river bed with sandy-gravelly pockets and scattered boulders, flow rate: H
Potamopyrgus antipodarum (a), *Radix balthica* (rr), *Ancylus fluviatilis* (c), *Bathyomphalus contortus* (rr), *Pisidium personatum* (r), *Pisidium subtruncatum* (r), *Pisidium nitidum* (r)

322. Lochan of Castle Fraser, Kemnay
Lat. 57° 12' 39.63" N, Long. -02° 27' 33.76" W, Alt. 89 m AMSL; date 12/06/2005, T 15.30°C, C 101 µS/cm, Sal. 0.00%, pH 5.90, [O_2] 4.25 mg/l, Sat O_2 42.90%, V 205 mV
Sandy-gravelly substrate covered by a thick layer of vegetal debris
Barren

323. Southern shore of Red Loch, Fraserburgh
Lat. 57° 39' 13.96" N, Long. -02° 01' 10.38" W, Alt. 26 m AMSL; date 12/06/2005, T 14.50°C, C 243 µS/cm, Sal. 0.00%, pH 4.39, [O_2] 7.61 mg/l, Sat O_2 75.20%, V 333 mV
Sandy substrate covered by a thin layer of vegetal debris
Barren

324. Stream flowing across Bog of Minnonie, Gardenstown
Lat. 57° 38' 24.97" N, Long. -02° 21' 50.38" W, Alt. 99 m AMSL; date 12/06/2005, T 10.40°C, C 271 µS/cm, Sal. 0.00%, pH 6.54, [O_2] 7.21 mg/l, Sat O_2 65.50%, V 239 mV
Muddy-silty stream bed with some pockets of vegetal debris and iron hydroxides, flow rate: L

Pisidium personatum (u), *Pisidium milium* (a), *Pisidium nitidum* (rr)

325. River Deveron below the A98(T) road bridge, Banff
Lat. 57° 39' 46.80" N, Long. -02° 30' 44.37" W, Alt. 1 m AMSL; date 12/06/2005, T 13.70°C, C 281 µS/cm, Sal. 0.00%, pH 8.14, $[O_2]$ 12.05 mg/l, Sat O_2 117.00%, V 208 mV
Pebbly-cobbly river bed with muddy-silty pockets, no flow (during high tide)
Potamopyrgus antipodarum (r)

326. Glen Burn below the A98(T) road bridge, Cullen
Lat. 57° 41' 32.34" N, Long. -02° 49' 47.62" W, Alt. 1 m AMSL; date 12/06/2005, T 11.40°C, C 357 µS/cm, Sal. 0.00%, pH 7.65, $[O_2]$ 11.70 mg/l, Sat O_2 107.60%, V 149 mV
Sandy-gravelly river bed with scattered boulders, flow rate: M
Barren

327. Auchlossan artificial lochan, Kincardine O'Neil
Lat. 57° 06' 08.18" N, Long. -02° 42' 30.09" W, Alt. 140 m AMSL; date 28/04/2006, T 10.80°C, C 184 µS/cm, Sal. 0.00%, pH 7.53, $[O_2]$ 7.16 mg/l, Sat O_2 64.80%, V 151 mV
Sandy-gravelly substrate covered by a thin layer of vegetal debris and scattered boulders, flow rate: VL
Pisidium casertanum (a), *Pisidium personatum* (r), *Pisidium obtusale* (a)

328. Pool located along Tarland Burn, south of Mains of Hopewell, Tarland
Lat. 57° 08' 12.07" N, Long. -02° 54' 51.85" W, Alt. 180 m AMSL; date 29/04/2006, T 7.20°C, C 290 µS/cm, Sal. 0.00%, pH 7.55, $[O_2]$ 11.54 mg/l, Sat O_2 99.20%, V 164 mV
Muddy stream bed with patchy areas covered by *Carex* spp., flow rate: L
Barren

329. Bog located at the base of the eastern side of Mount Morven, Dinnet
Lat. 57° 07' 08.84" N, Long. -02° 56' 36.50" W, Alt. 188 m AMSL; date 29/04/2006, T 8.30°C, C 61 µS/cm, Sal. 0.00%, pH 3.80, $[O_2]$ 3.20 mg/l, Sat O_2 27.60%, V 269 mV
Bottom sediments only consisting of *Carex* spp. debris together with soft organic mud. *Carex* spp. colonies cover the whole area, inlet flow rate: L
Barren

330. Northern shore of Witchock Loch situated at the base of the western slope of Baderonoch Hill, Dinnet
Lat. 57° 09' 38.92" N, Long. -02° 57' 26.63" W, Alt. 365 m AMSL; date 29/04/2006, T 9.20°C, C 83 µS/cm, Sal. 0.00%, pH 6.65, $[O_2]$ 8.32 mg/l, Sat O_2 75.00%, V 139 mV
Sandy-gravelly substrate covered by a layer of vegetal debris and scattered boulders
Gyraulus albus (rr), *Pisidium casertanum* (r), *Pisidium obtusale* (a), *Pisidium subtruncatum* (c), *Pisidium milium* (r), *Pisidium nitidum* (c), *Pisidium hibernicum* (rr)

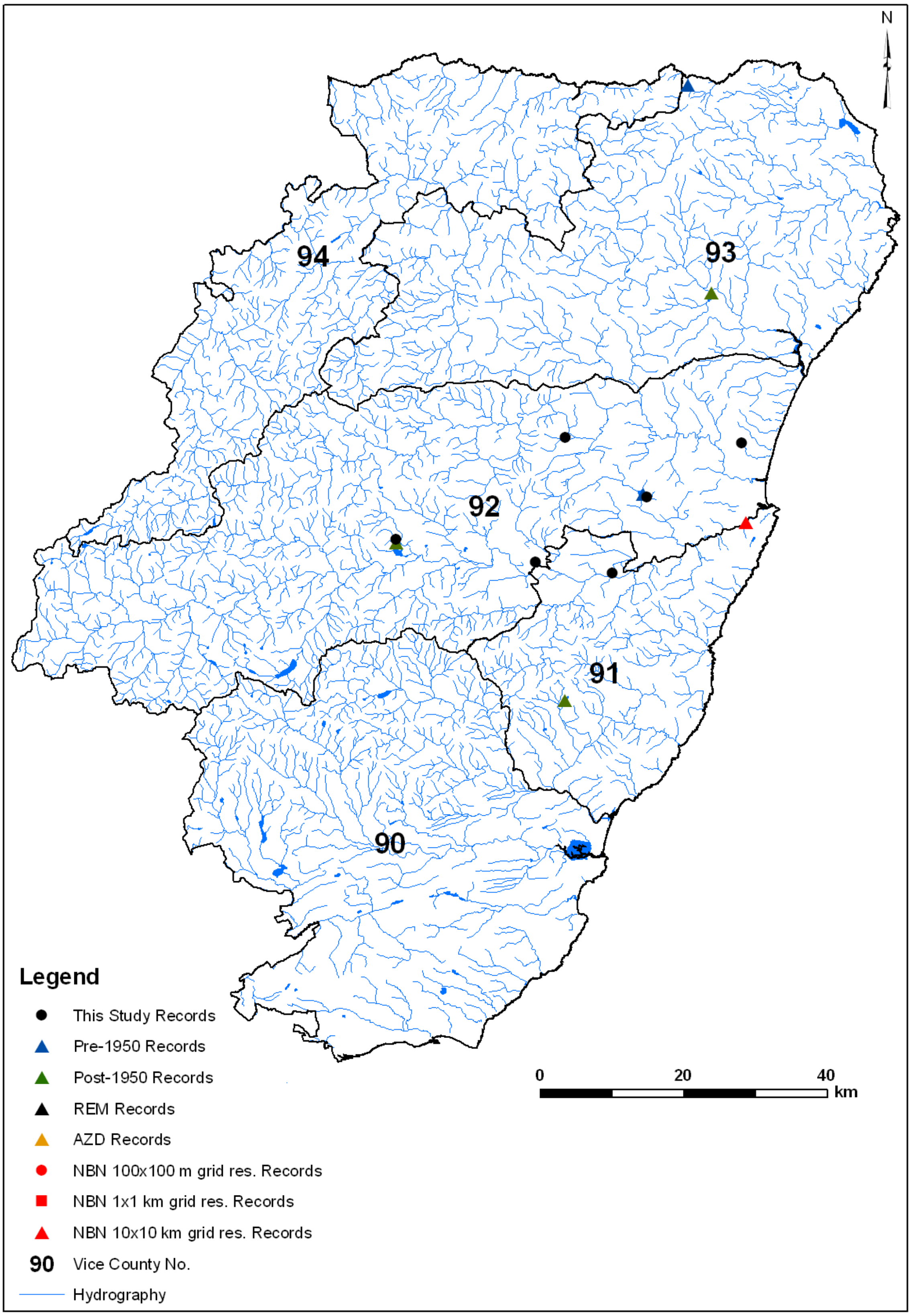
331. Southern shore of Pronie Loch situated at the base of the western slope of Baderonoch Hill, Dinnet
Lat. 57° 09' 45.45" N, Long. -02° 57' 33.87" W, Alt. 363 m AMSL; date 29/04/2006, T 11.80°C, C 137 µS/cm, Sal. 0.00%, pH 7.02, $[O_2]$ 8.93 mg/l, Sat O_2 85.40%, V 143 mV
Gravelly-pebbly substrate covered by a thin layer of organic mud and scattered boulders
Potamopyrgus antipodarum (c), *Gyraulus albus* (r), *Sphaerium corneum* (u), *Pisidium subtruncatum* (c), *Pisidium milium* (r), *Pisidium nitidum* (a), *Pisidium hibernicum* (a)

332. Overlook Loch located to the south-western slope of Baderonoch Hill, Dinnet
Lat. 57° 09' 49.17" N, Long. -02° 56' 25.58 W, Alt. 412 m AMSL; date 29/04/2006, T 10.60°C, C 44 µS/cm, Sal. 0.00%, pH 5.21, $[O_2]$ 8.93 mg/l, Sat O_2 83.60%, V 284 mV
Pebbly-cobbly substrate with scattered boulders
Barren

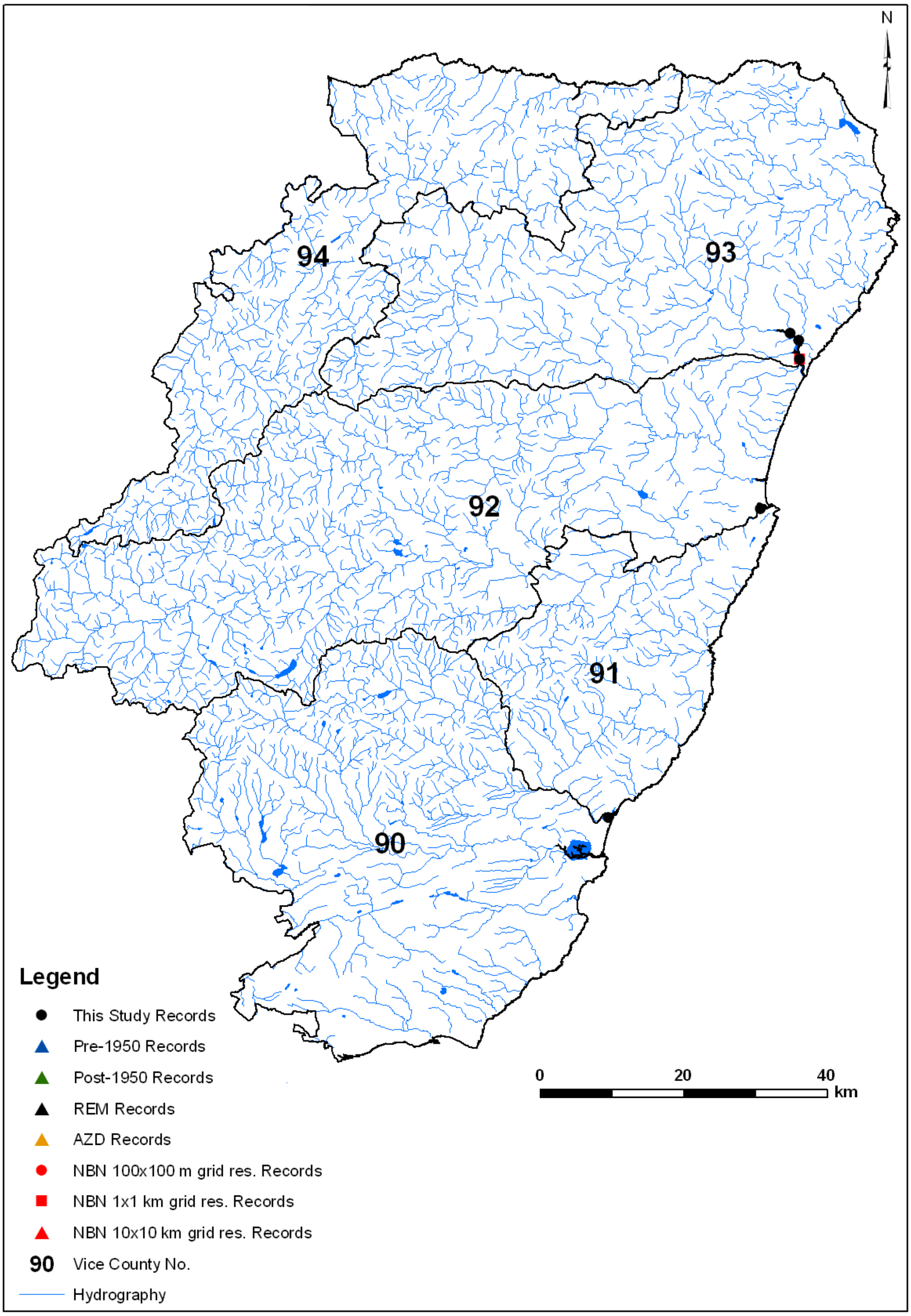
333. River Don near 'Roadside', 1.5 km upstream of Strathdon, Strathdon
Lat. 57° 11' 23.86" N, Long. -03° 04' 35.66" W, Alt. 188 m AMSL; date 29/04/2006, T 9.30°C, C 118 µS/cm, Sal. 0.00%, pH 6.01, $[O_2]$ 11.06 mg/l, Sat O_2 98.80%, V 142 mV
Pebbly-cobbly river bed with scattered boulders, flow rate: M
Ancylus fluviatilis (a), *Pisidium casertanum* (rr), *Pisidium personatum* (u)

334. Pool located along a left tributary of River Gairn, south-west of Richarkarie, Ballater
Lat. 57° 05' 46.32" N, Long. -03° 09' 36.21" W, Alt. 342 m AMSL; date 29/04/2006, T 13.80°C, C 79 µS/cm, Sal. 0.00%, pH 7.71, $[O_2]$ 9.62 mg/l, Sat O_2 95.90%, V 165 mV
Muddy stream bed, flow rate: LM
Radix balthica (rr), *Pisidium casertanum* (r), *Pisidium personatum* (r), *Pisidium subtruncatum* (a), *Pisidium milium* (rr)

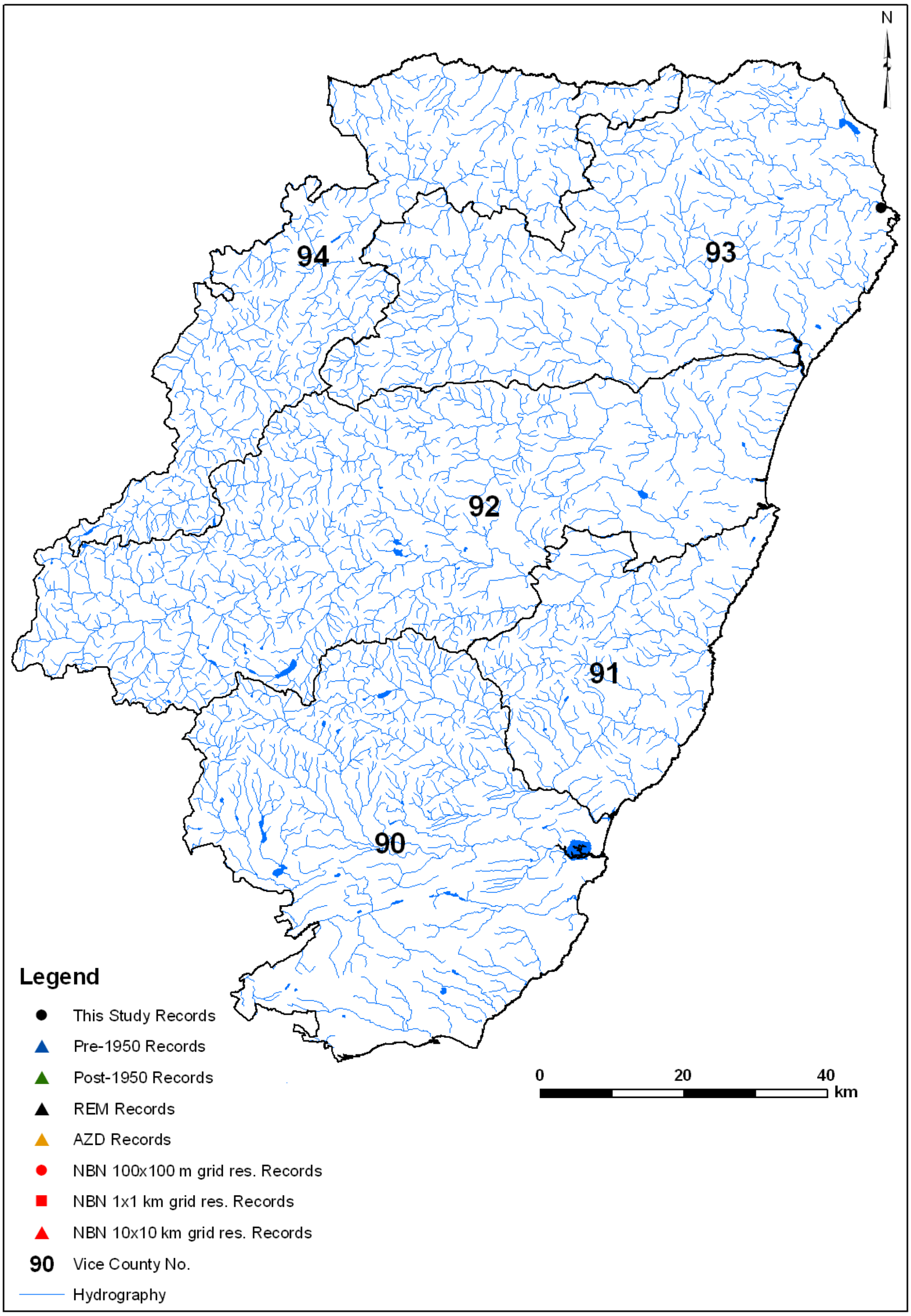
APPENDIX III - DISTRIBUTION MAPS



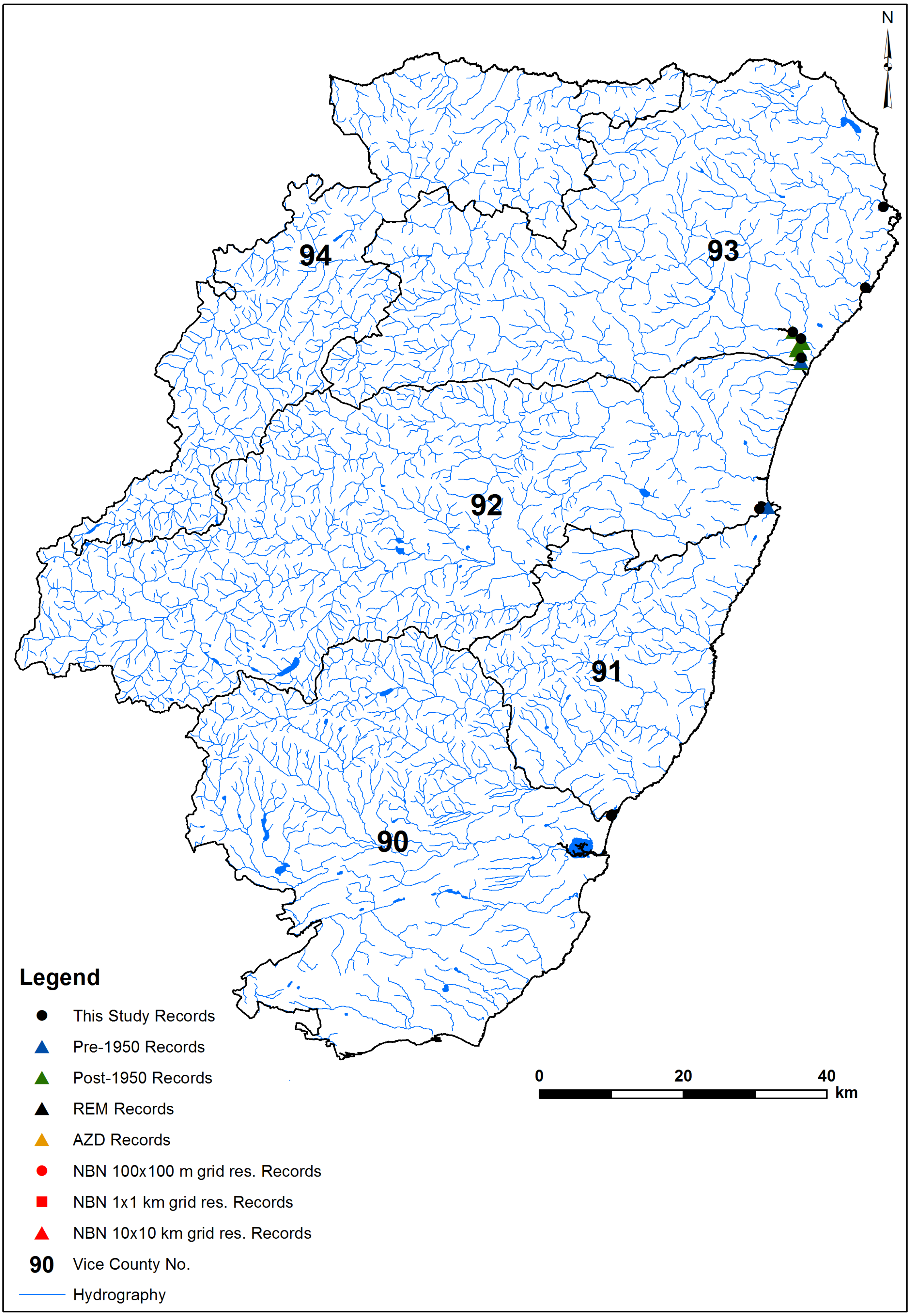
Map 1. *Valvata piscinalis* distribution area.



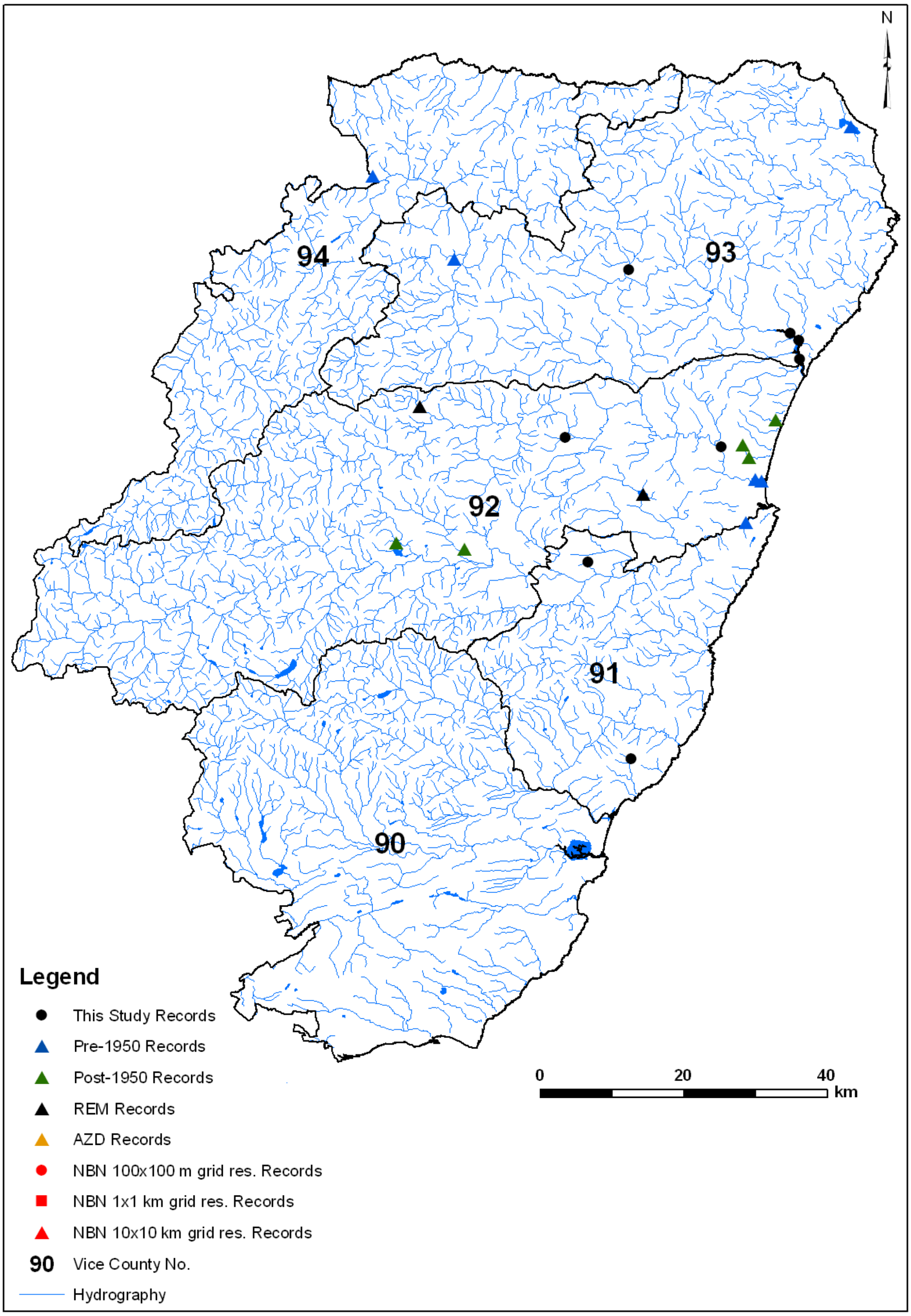
Map 2. *Ecrobia ventrosa* distribution area.



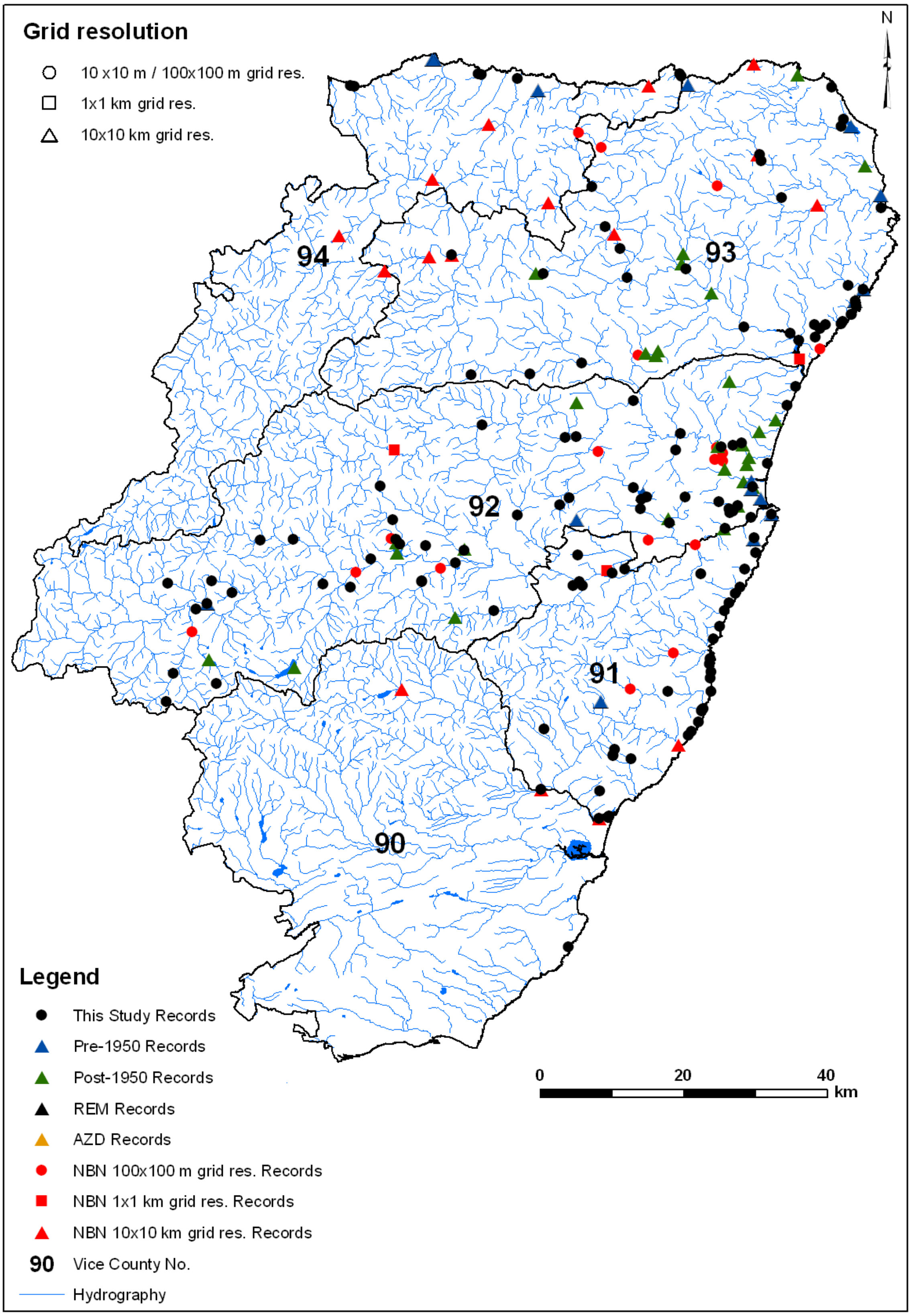
Map 3. *Hydrobia* cf. *acuta neglecta* distribution area.



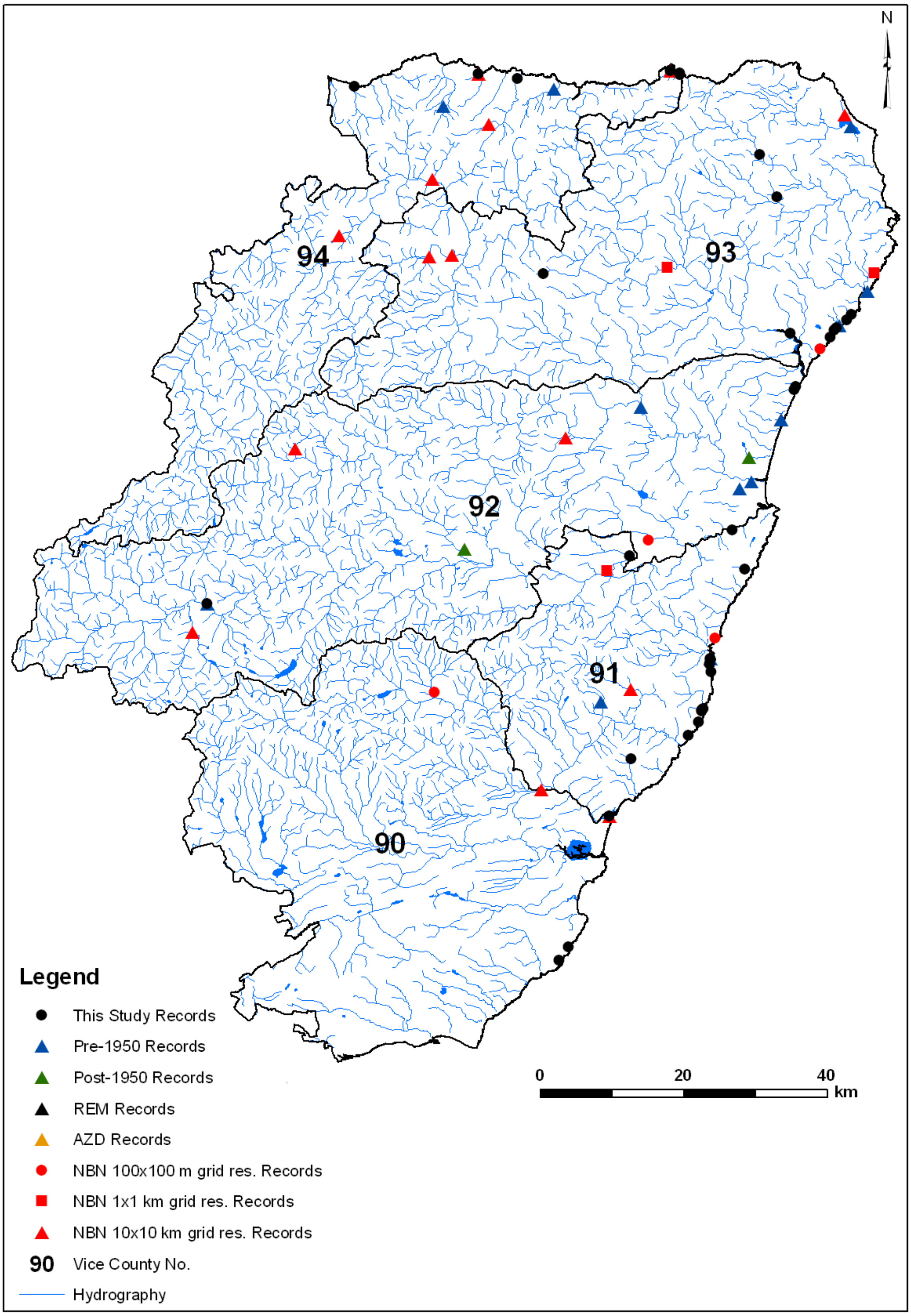
Map 4. *Peringia ulvae* distribution area.



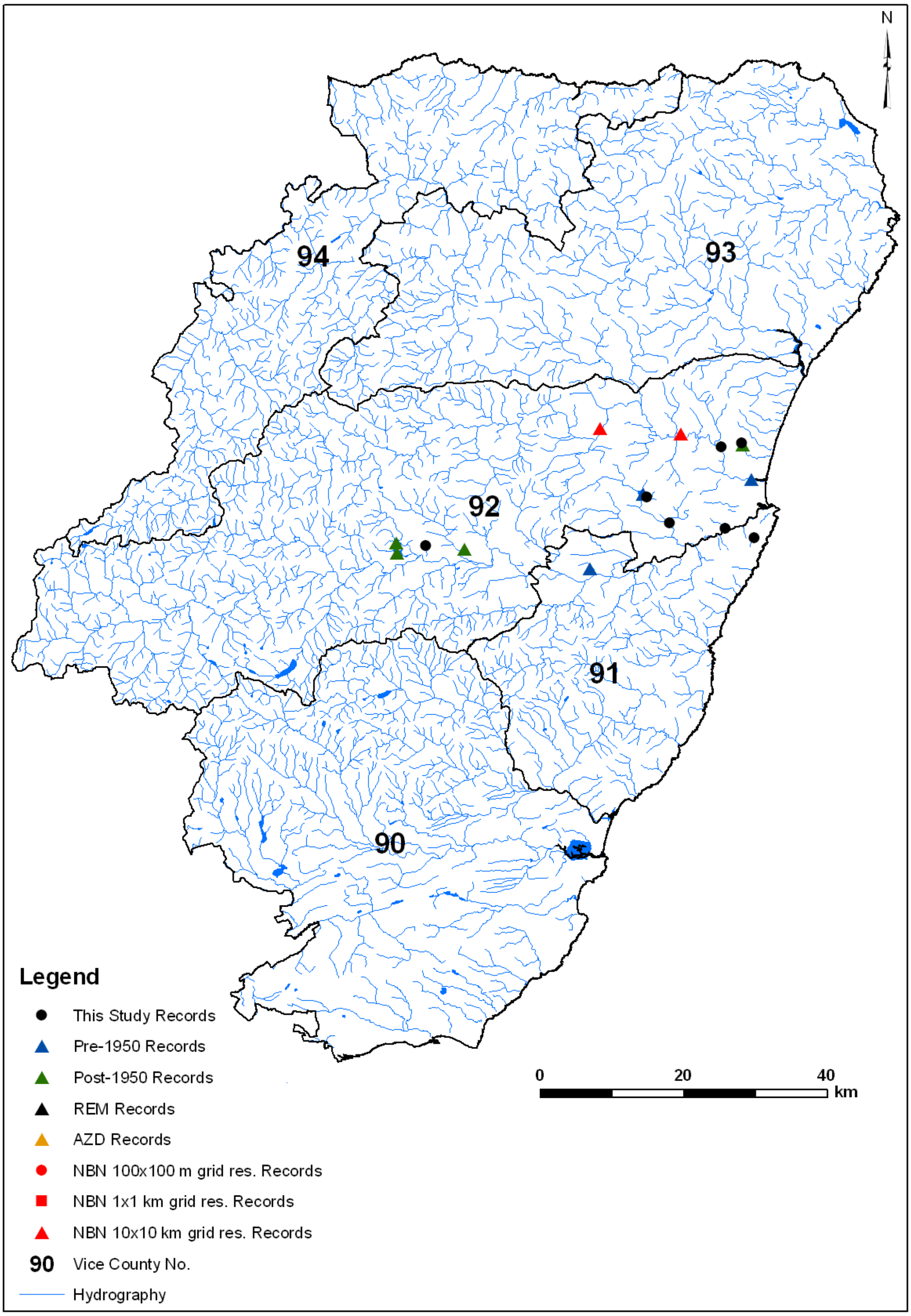
Map 5. *Stagnicola palustris* distribution area.



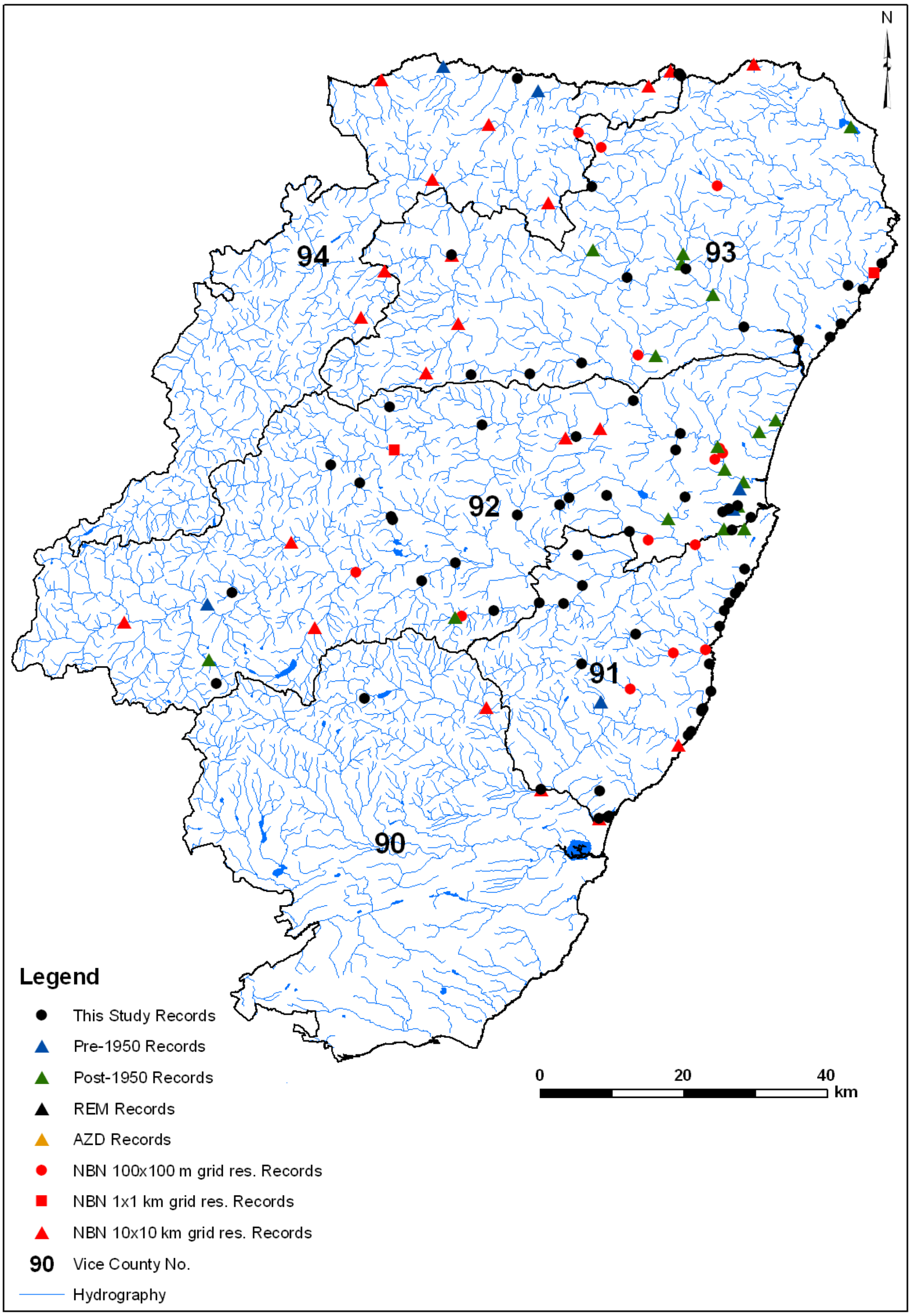
Map 6. *Radix balthica* distribution area.



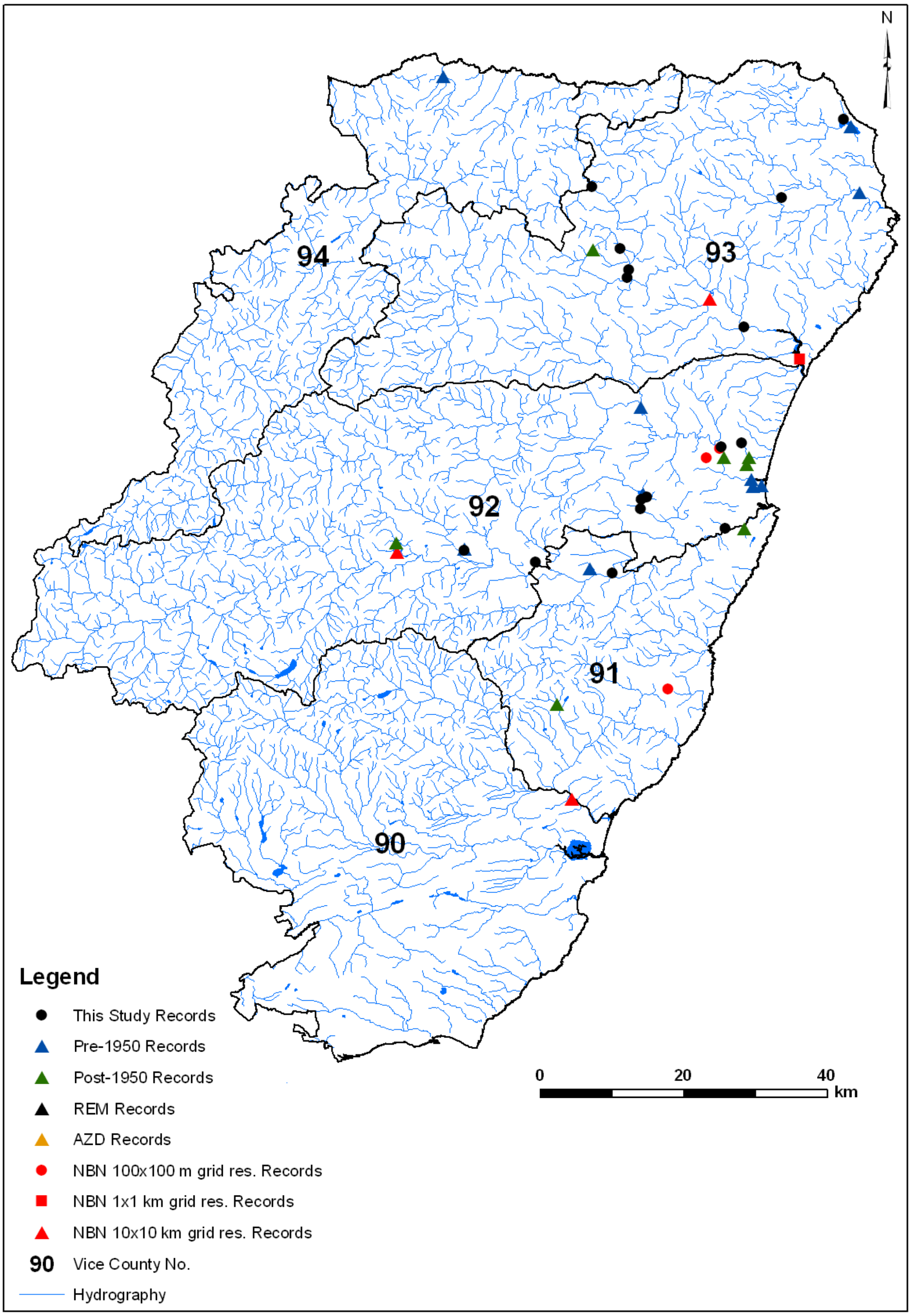
Map 7. *Galba truncatula* distribution area.



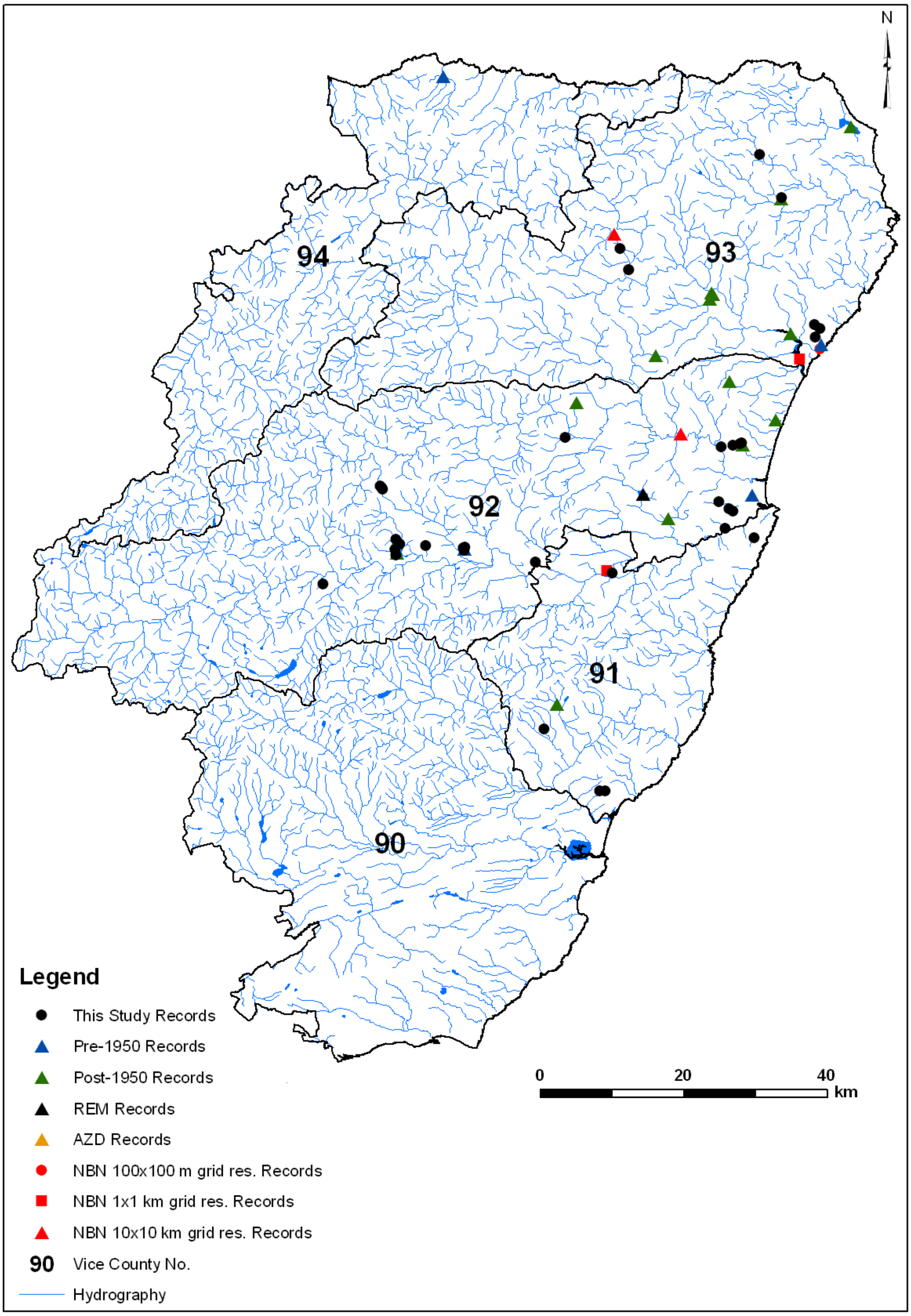
Map 8. *Physa fontinalis* distribution area.



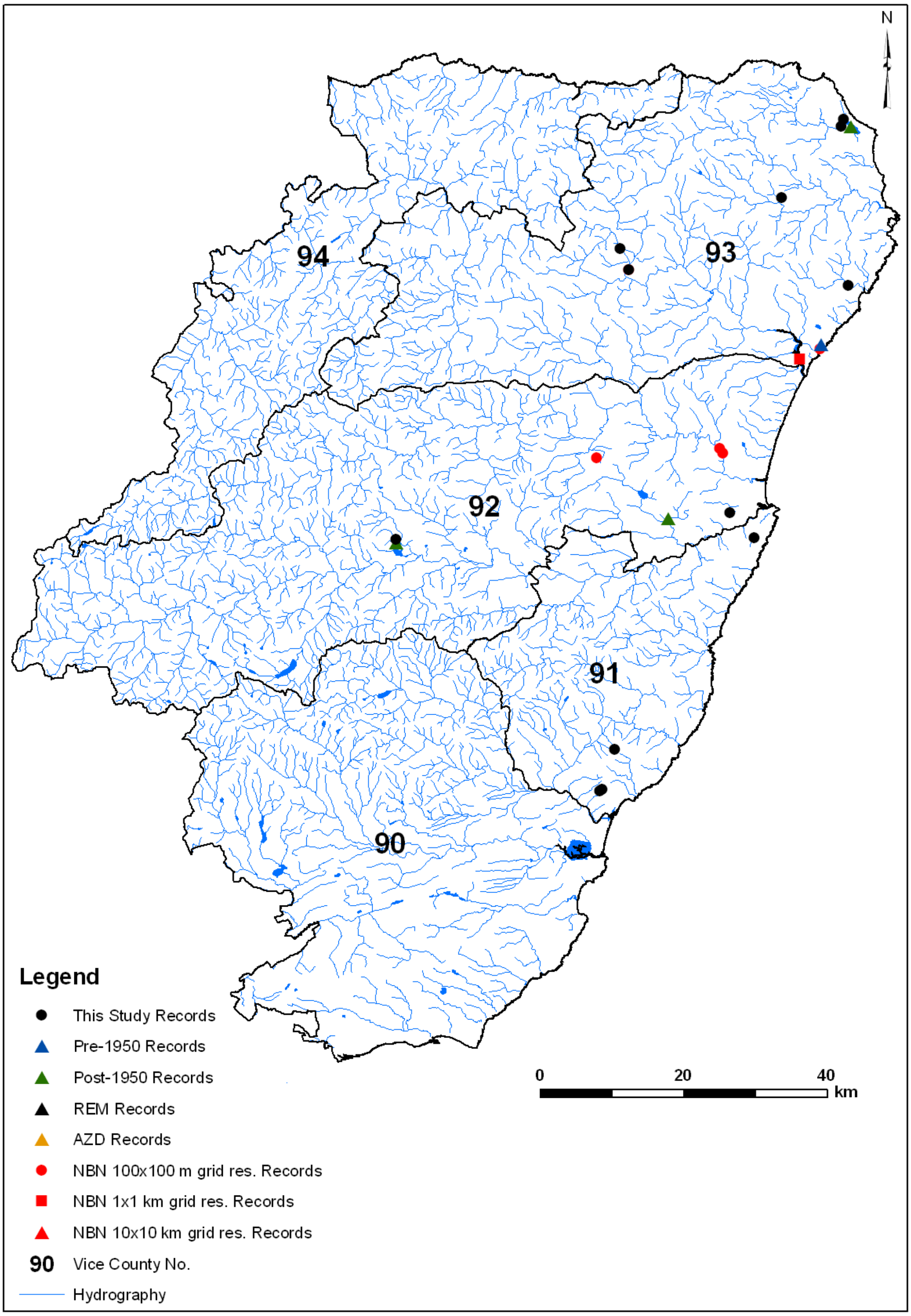
Map 9. *Ancylus fluviatilis* distribution area.



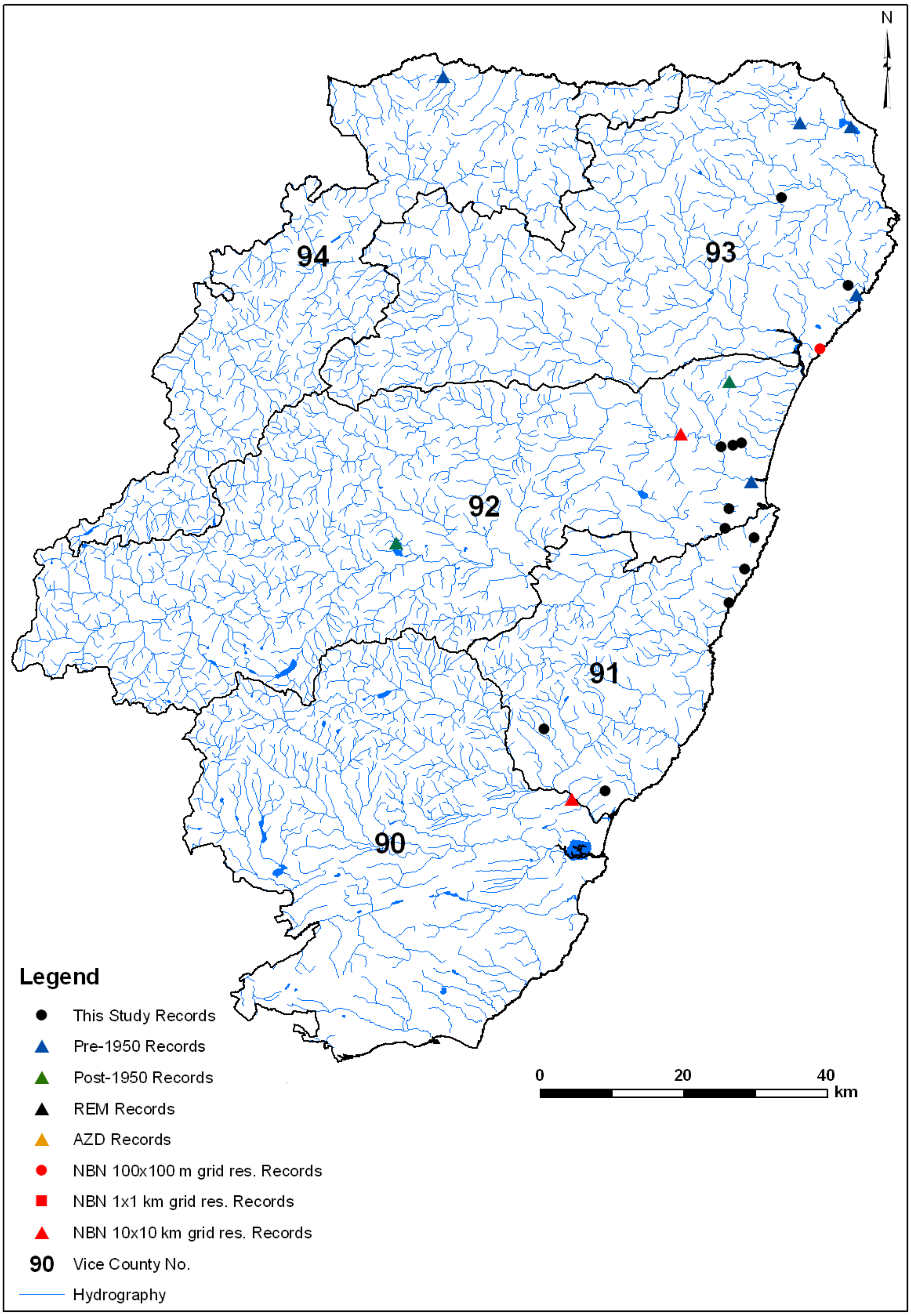
Map 10. *Bathyomphalus contortus* distribution area.



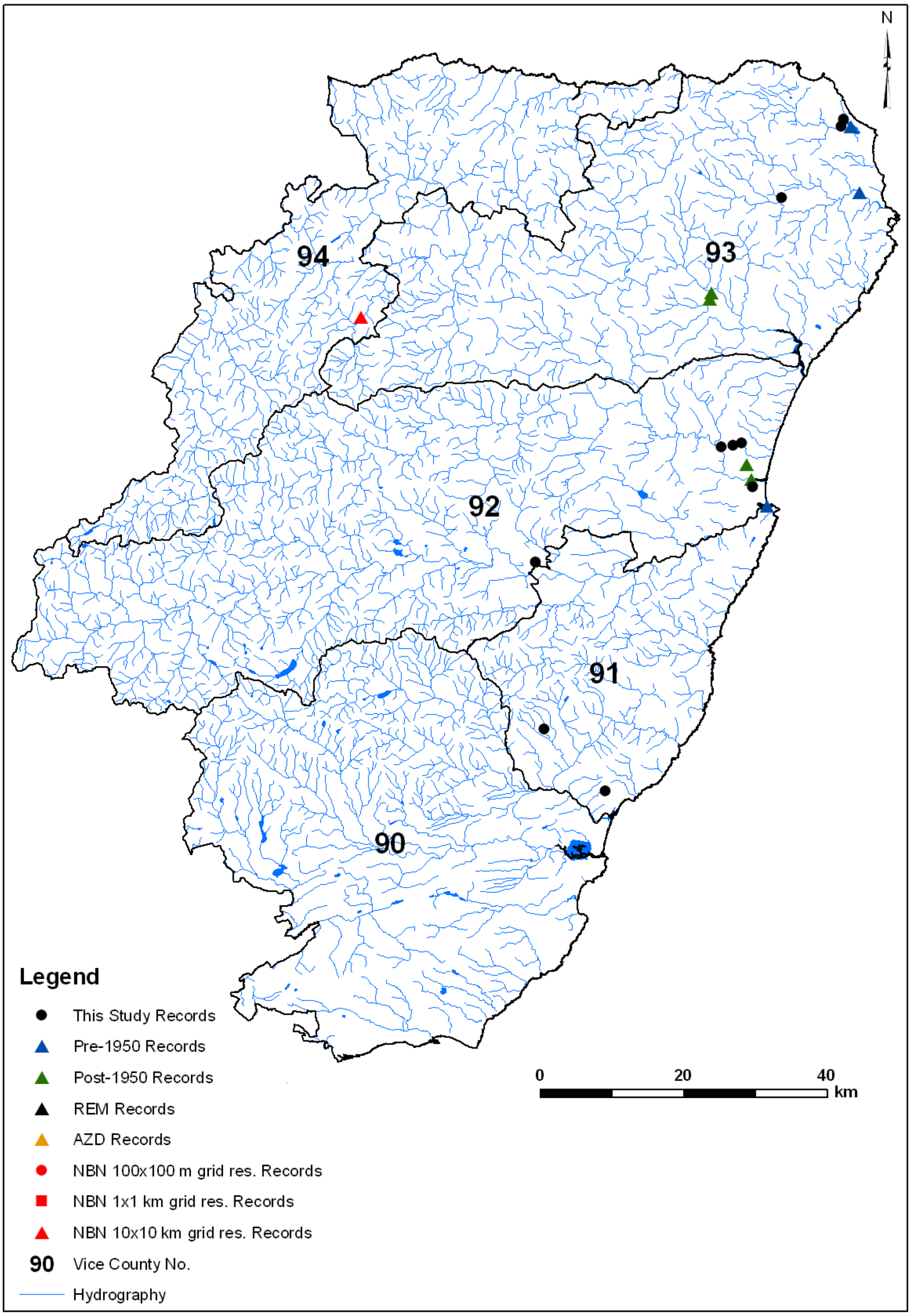
Map 11. *Gyraulus albus* distribution area.



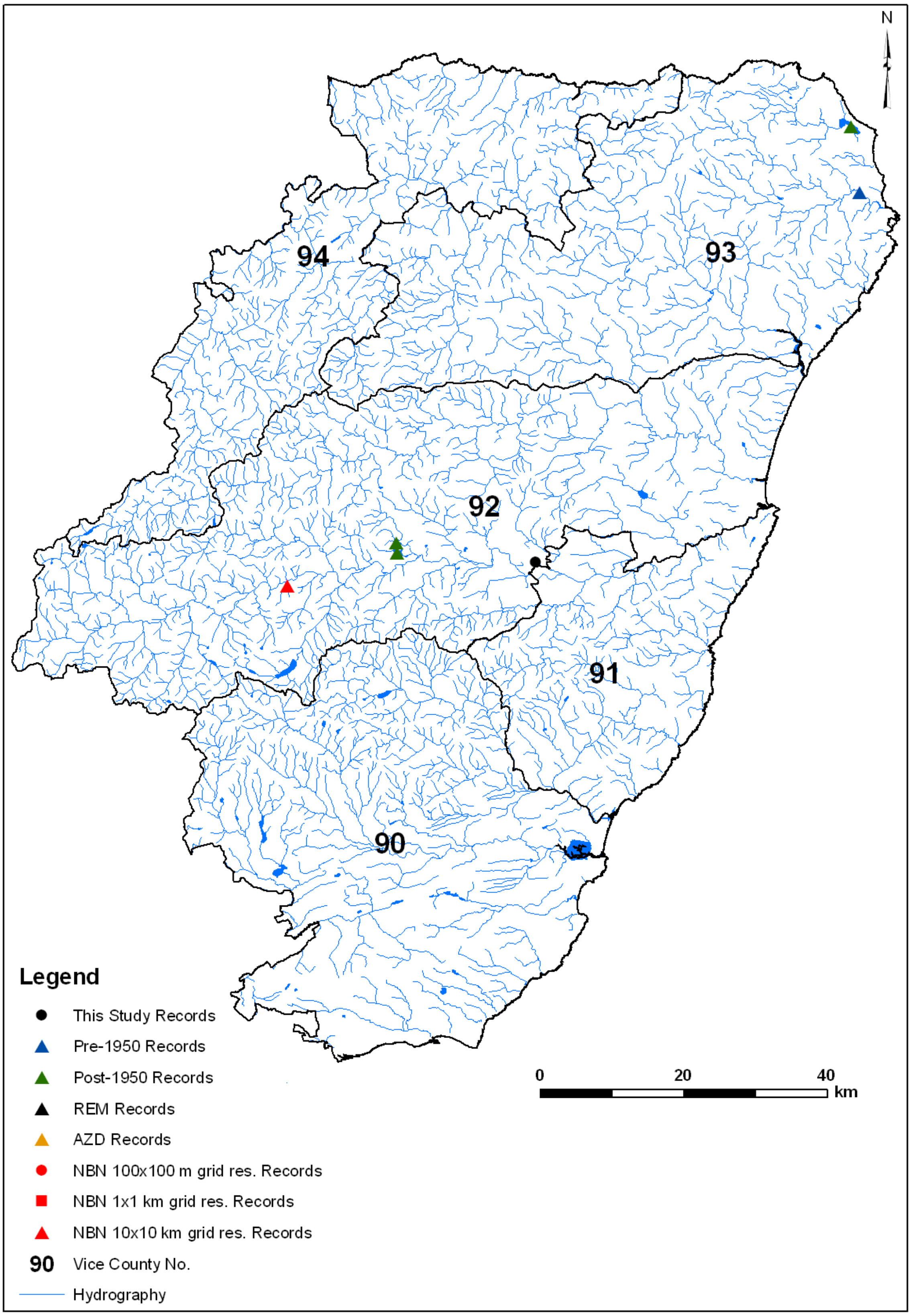
Map 12. *Gyraulus laevis* distribution area.



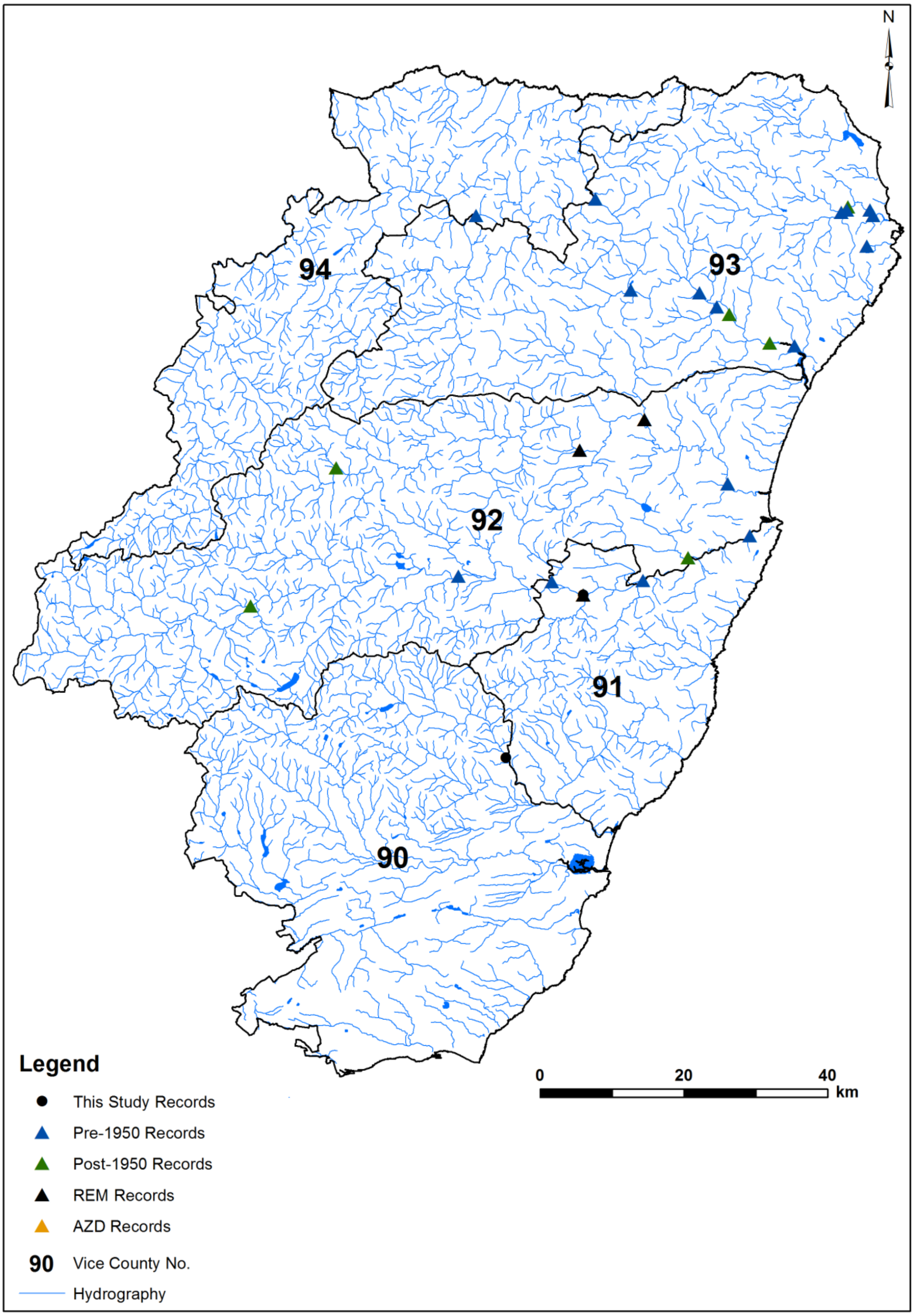
Map 13. *Gyraulus crista* distribution area.



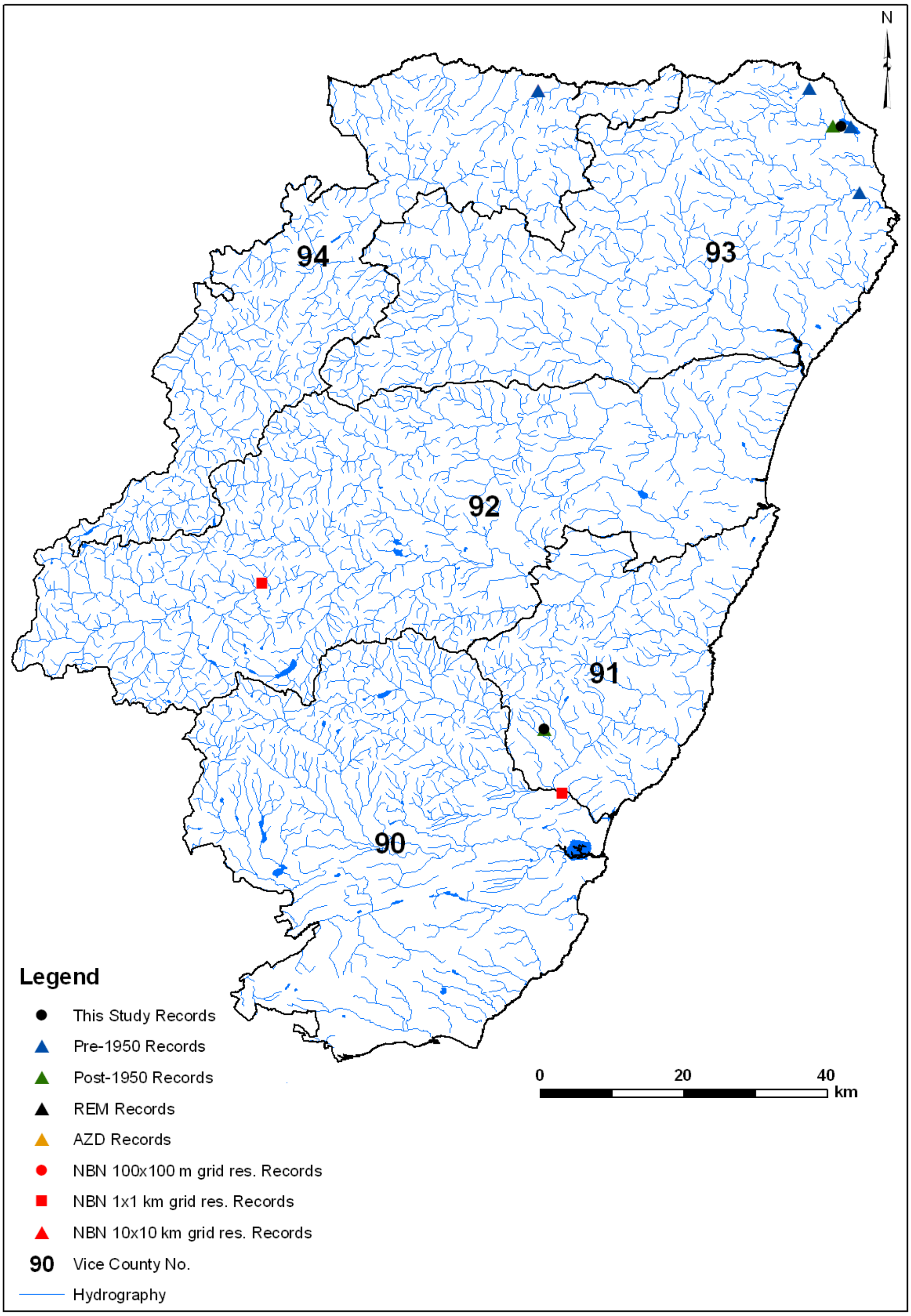
Map 14. *Hippeutis complanatus* distribution area.



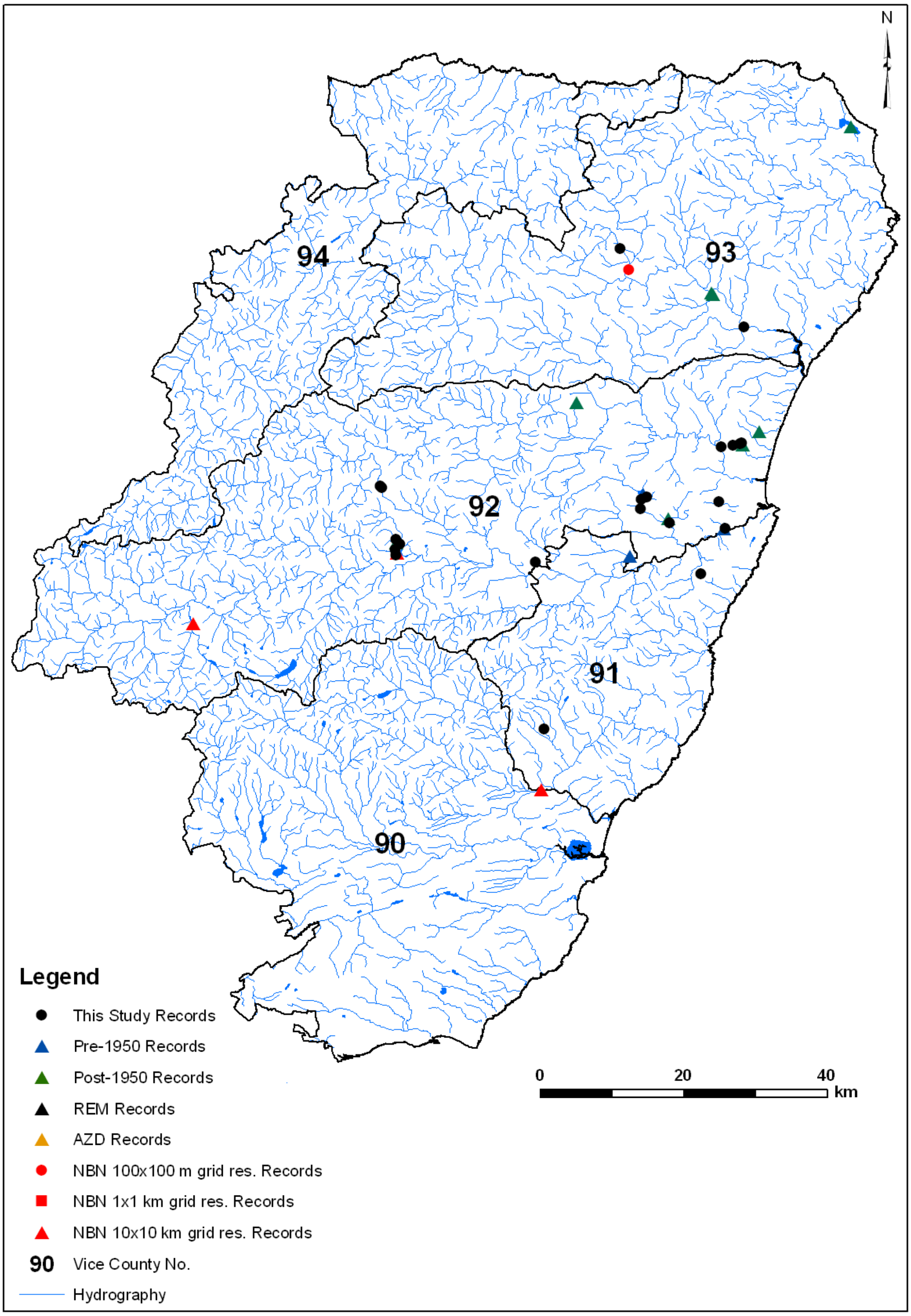
Map 15. *Acroloxus lacustris* distribution area.



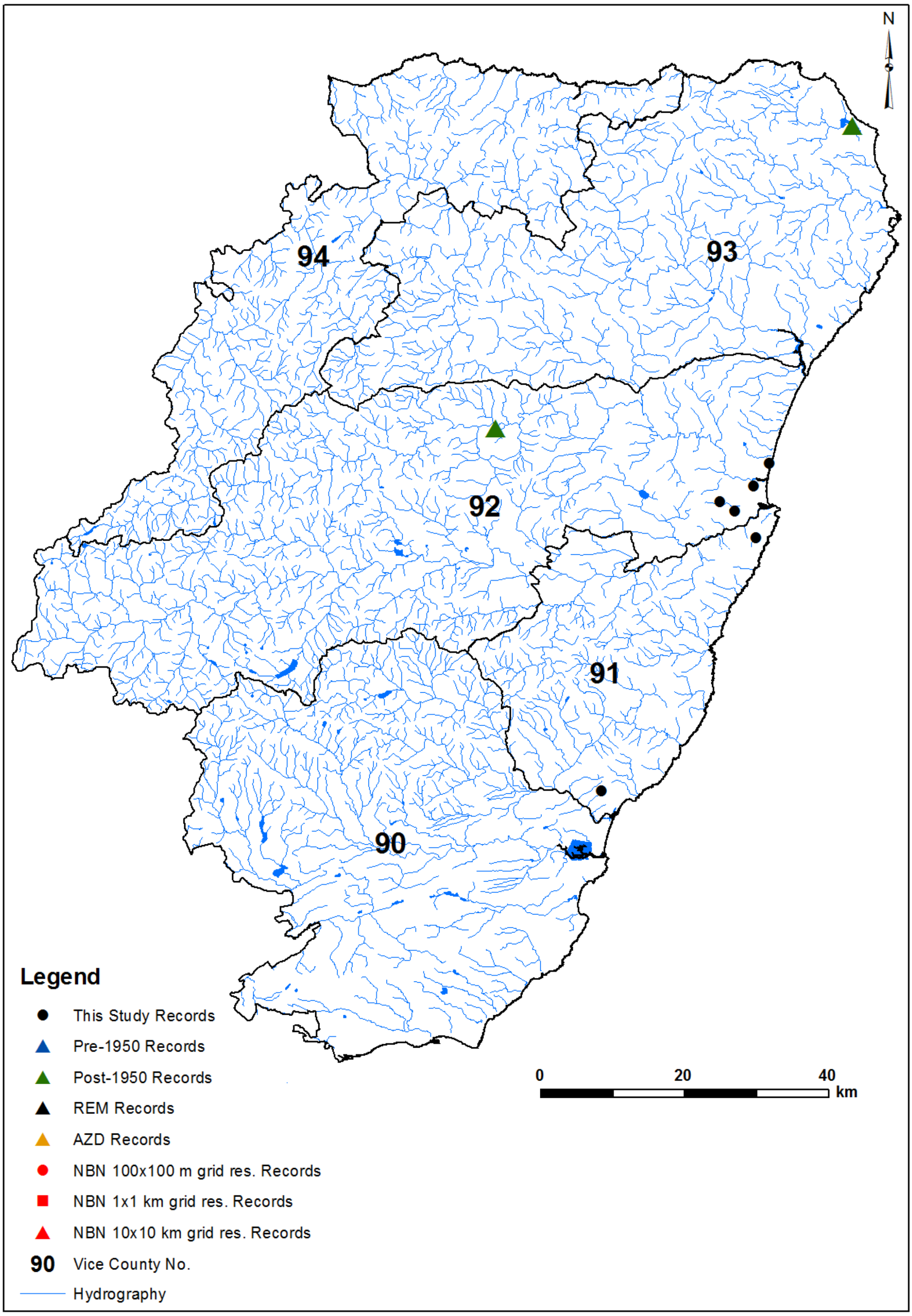
Map 16. *Margaritifera margaritifera* distribution area.
The map does not include SNH and NBN protected sites.



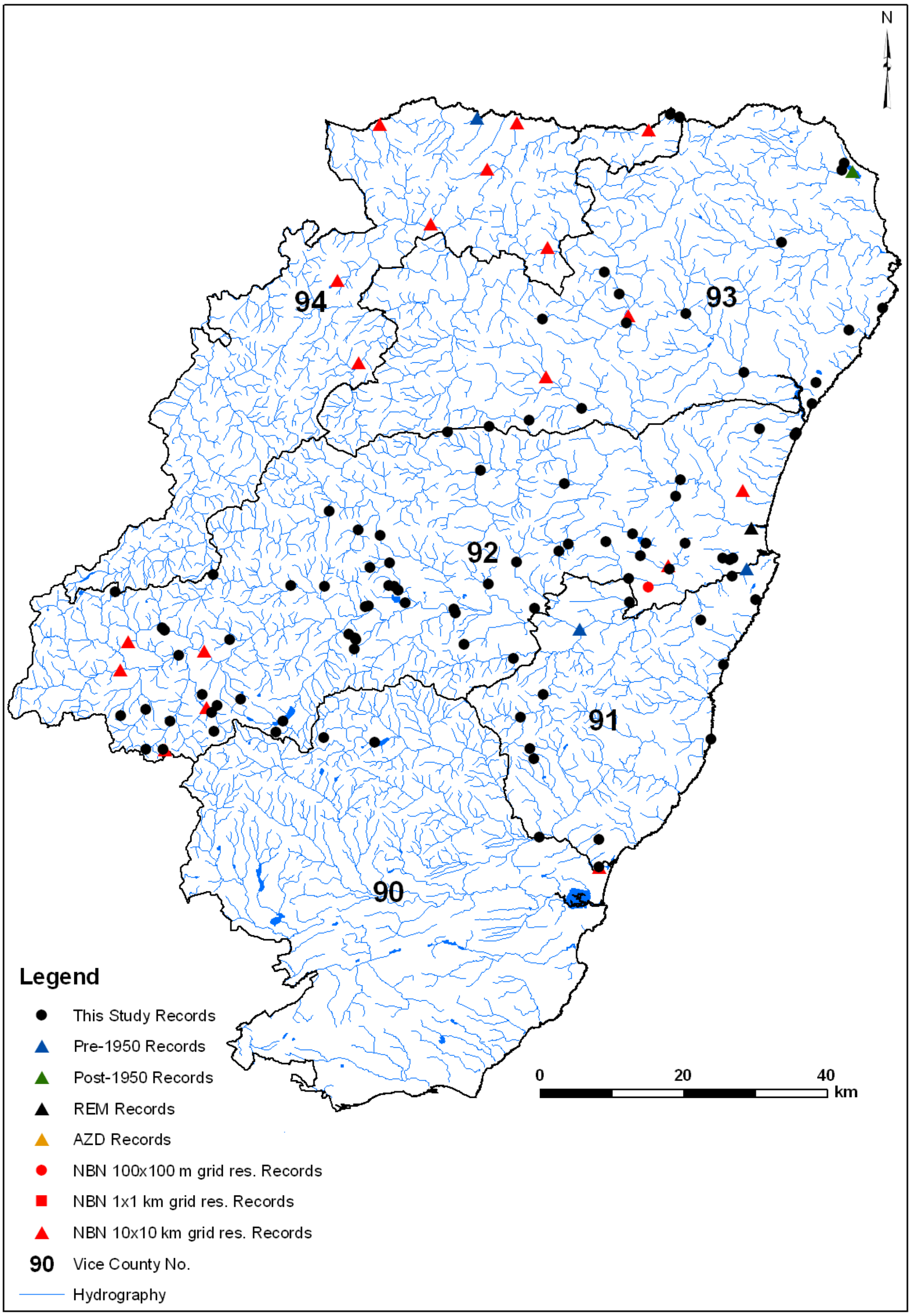
Map 17. *Anodonta anatina* distribution area.



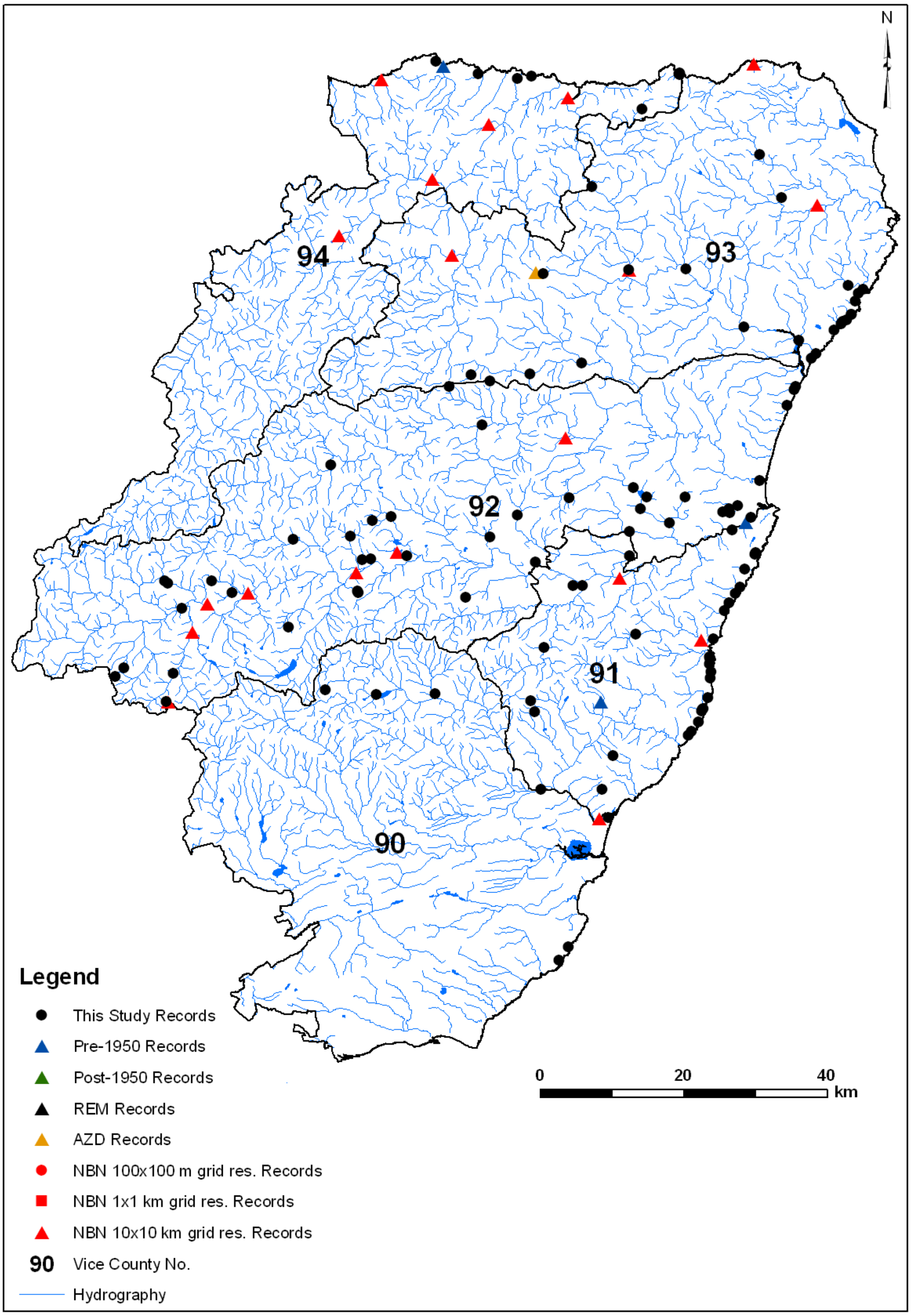
Map 18. *Sphaerium corneum* distribution area.



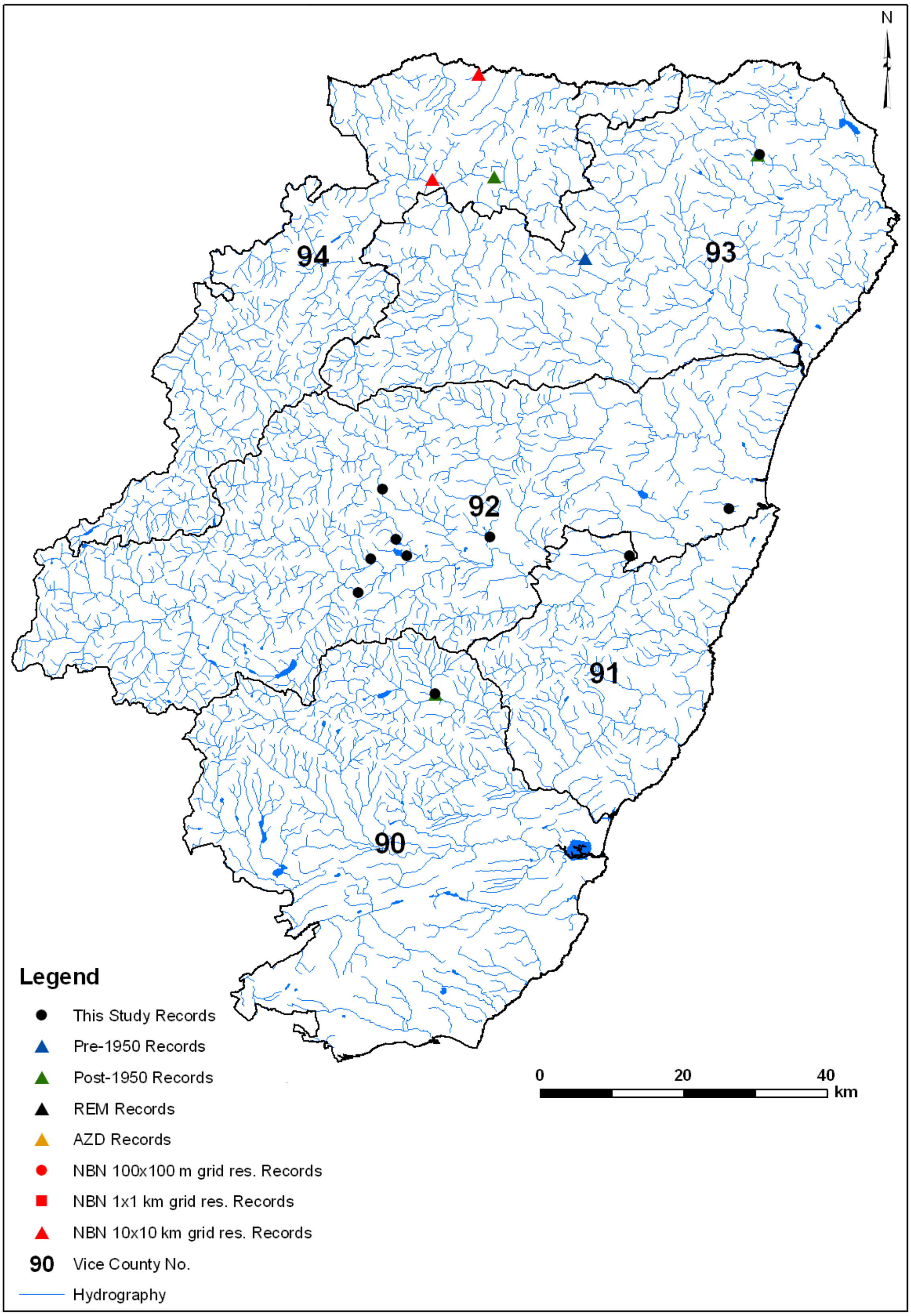
Map 19. *Musculium lacustre* distribution area.



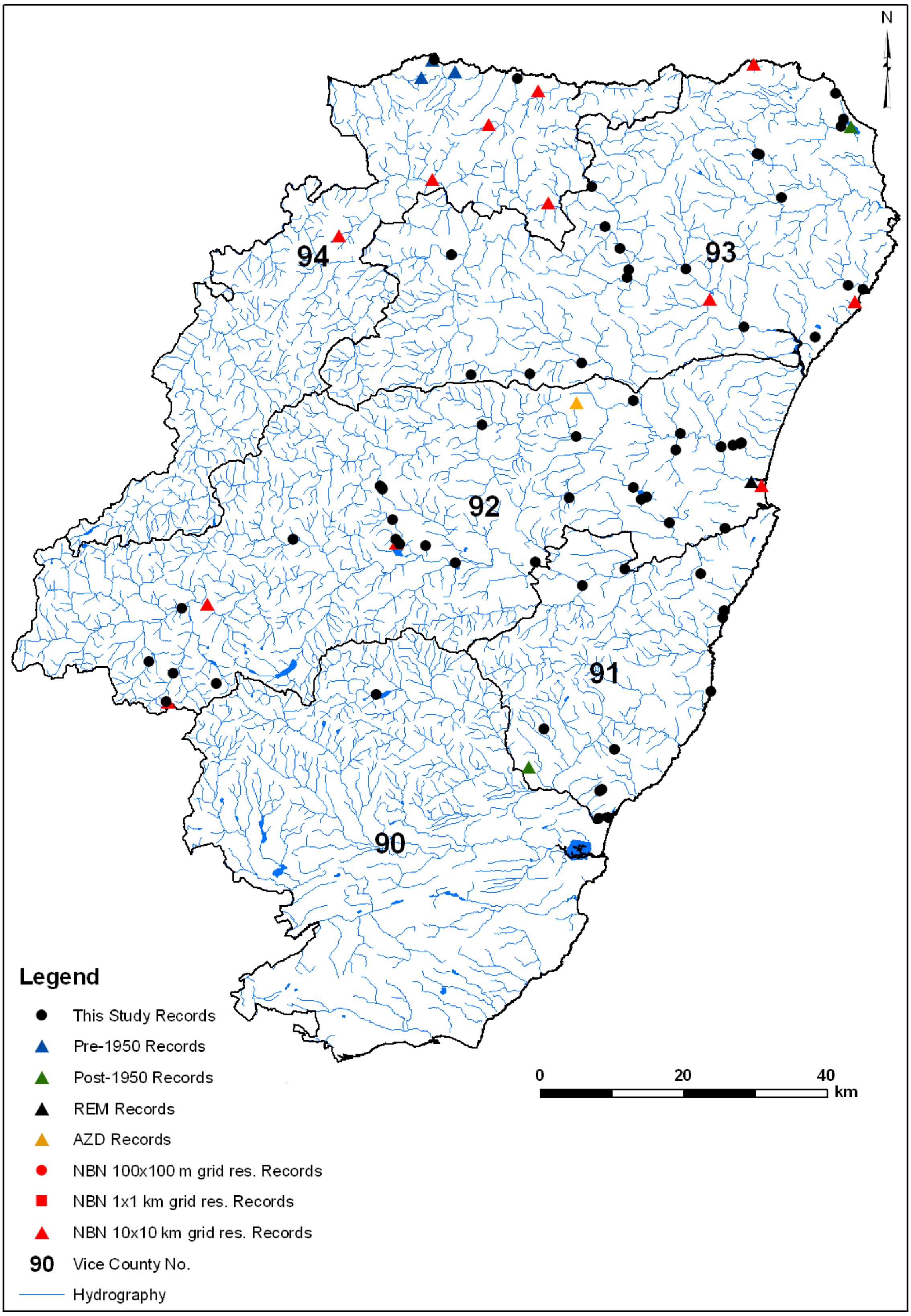
Map 20. *Pisidium casertanum* distribution area.



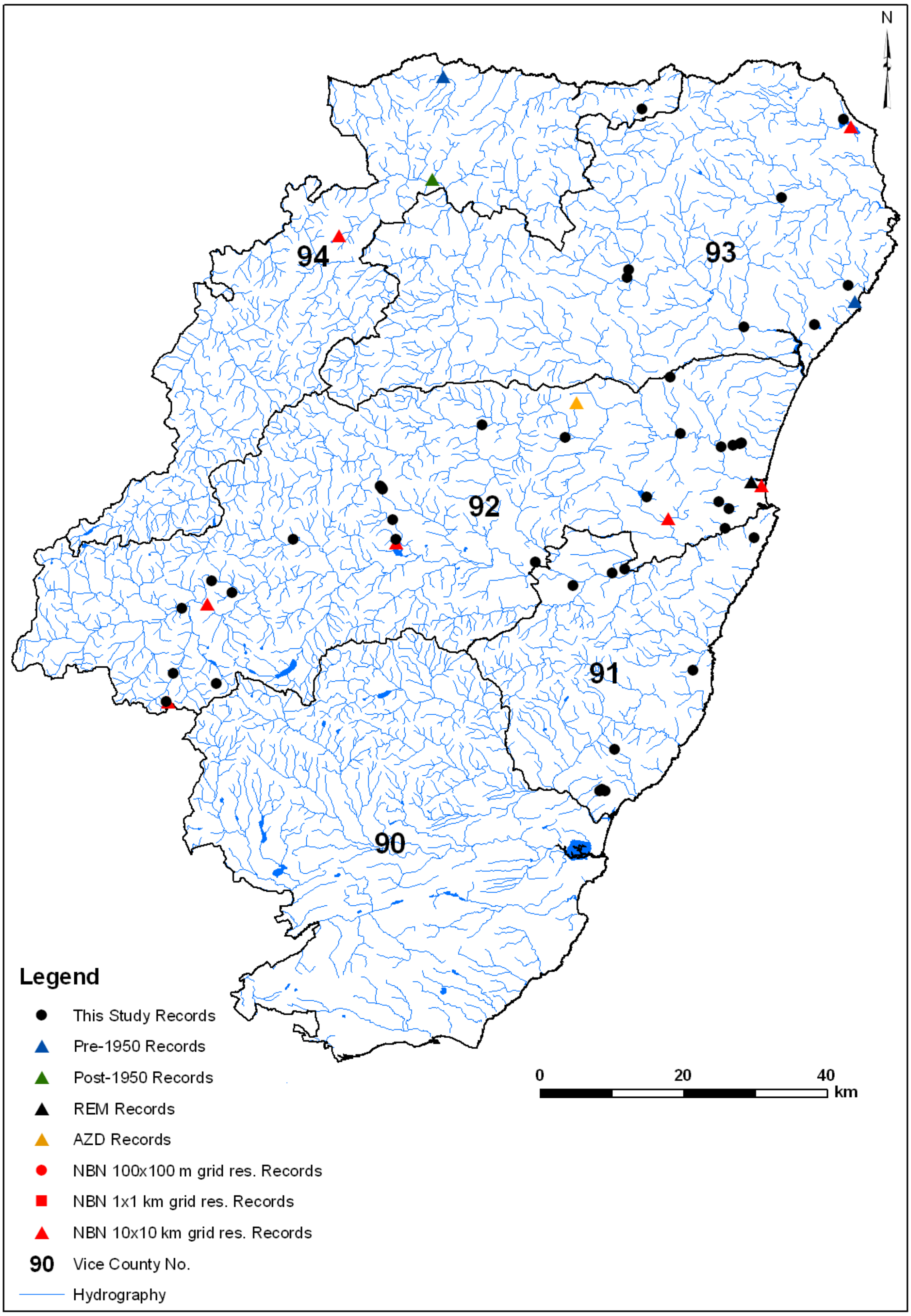
Map 21. *Pisidium personatum* distribution area.



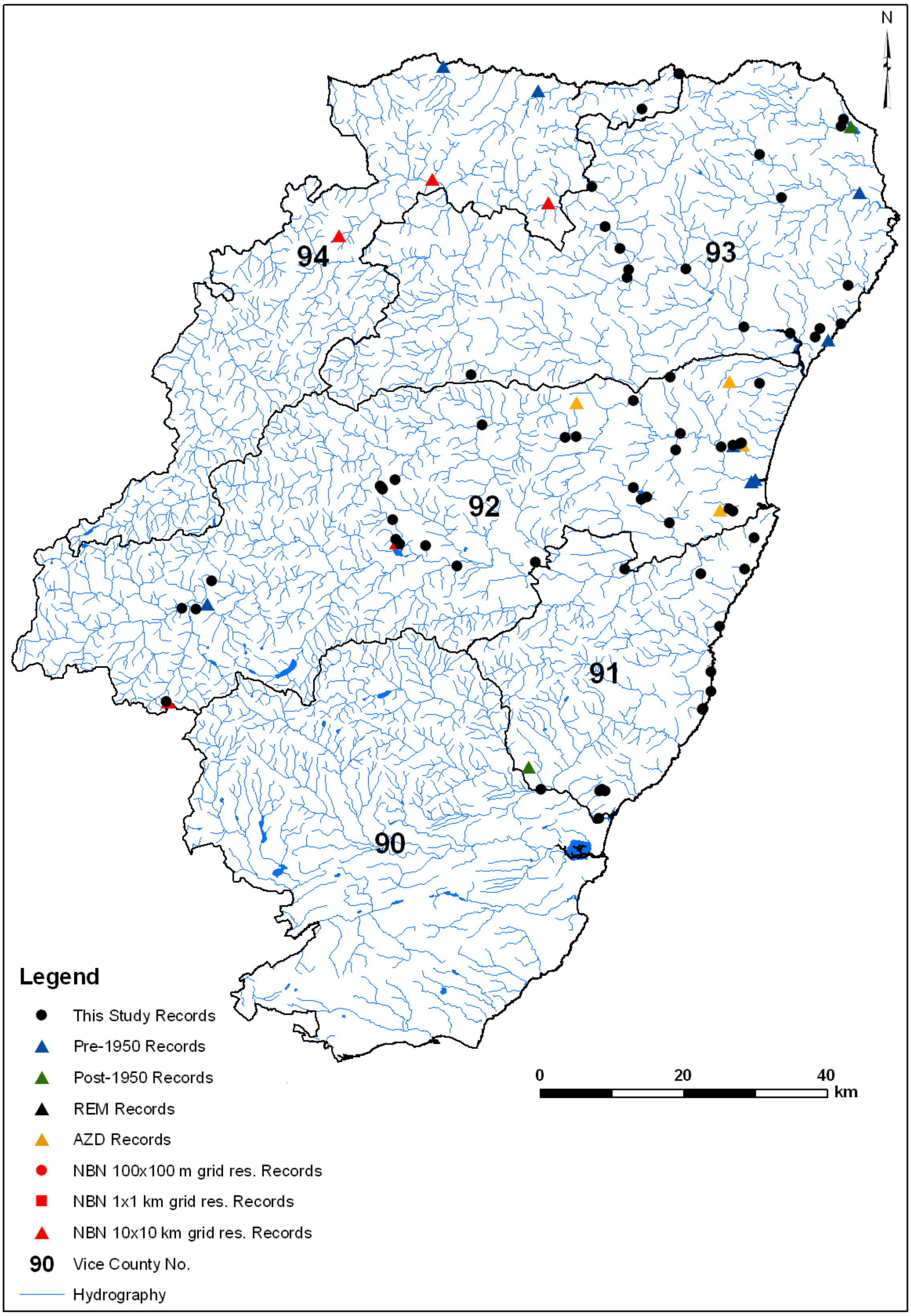
Map 22. *Pisidium obtusale* distribution area.



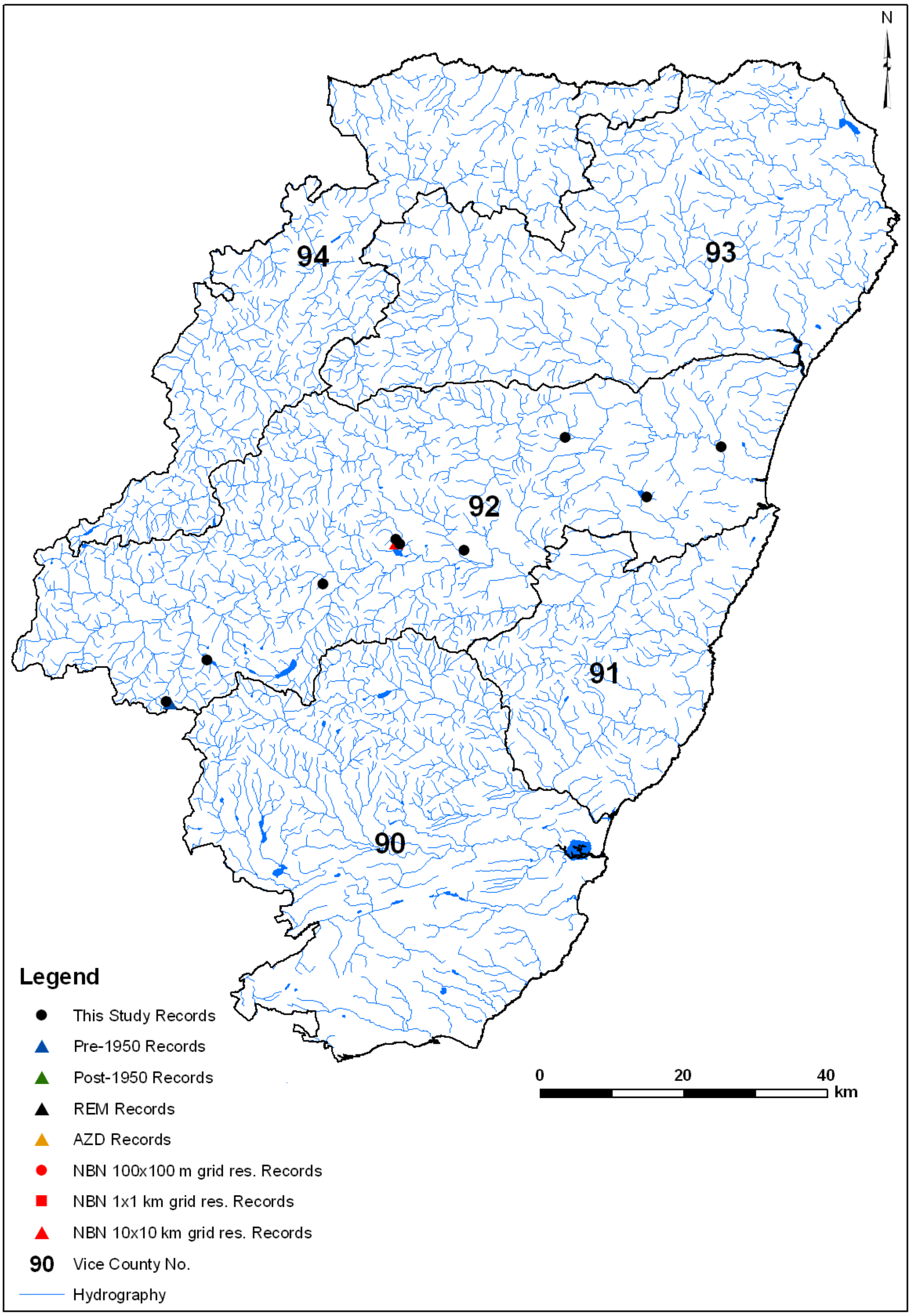
Map 23. *Pisidium subtruncatum* distribution area.



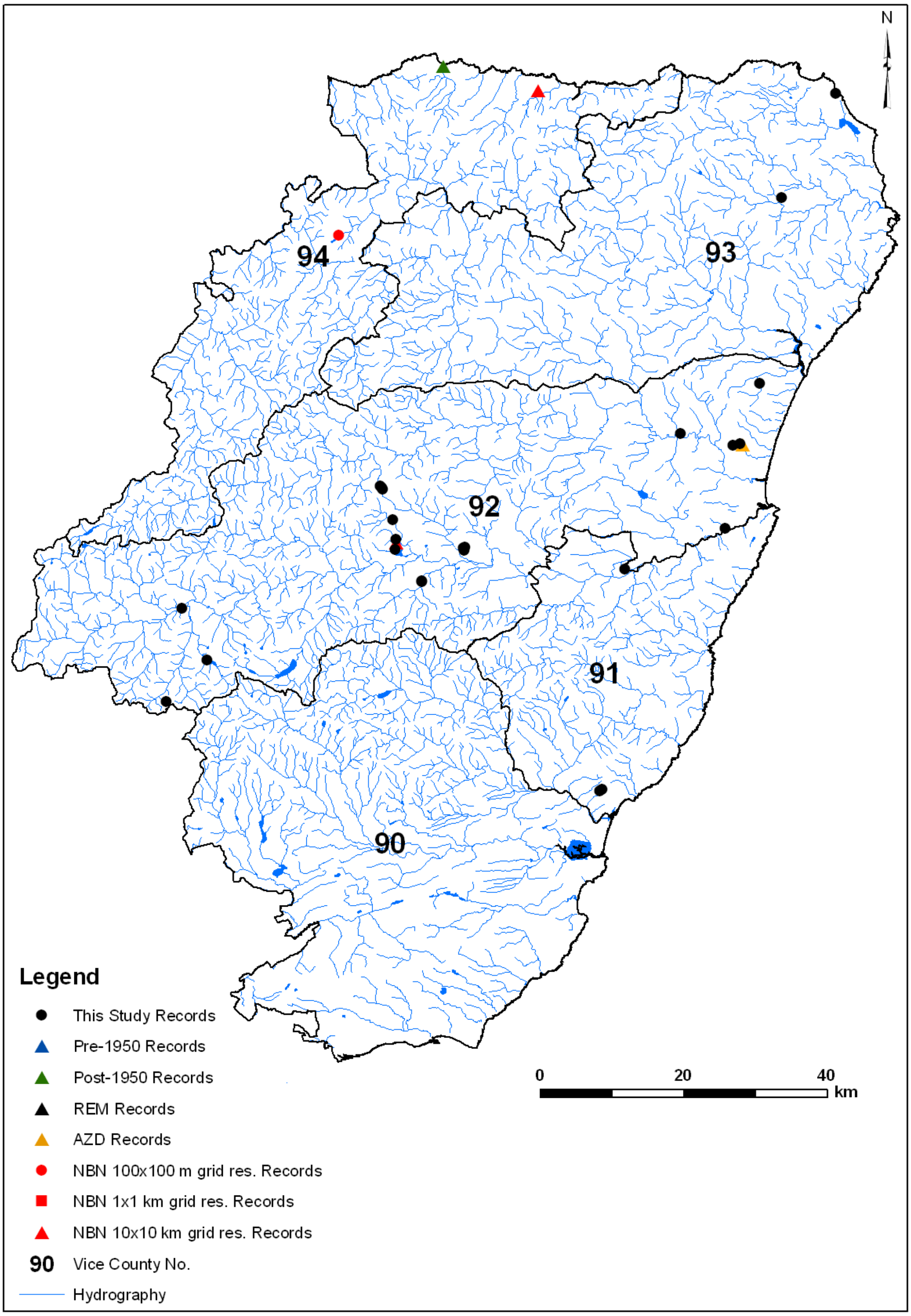
Map 24. *Pisidium milium* distribution area.



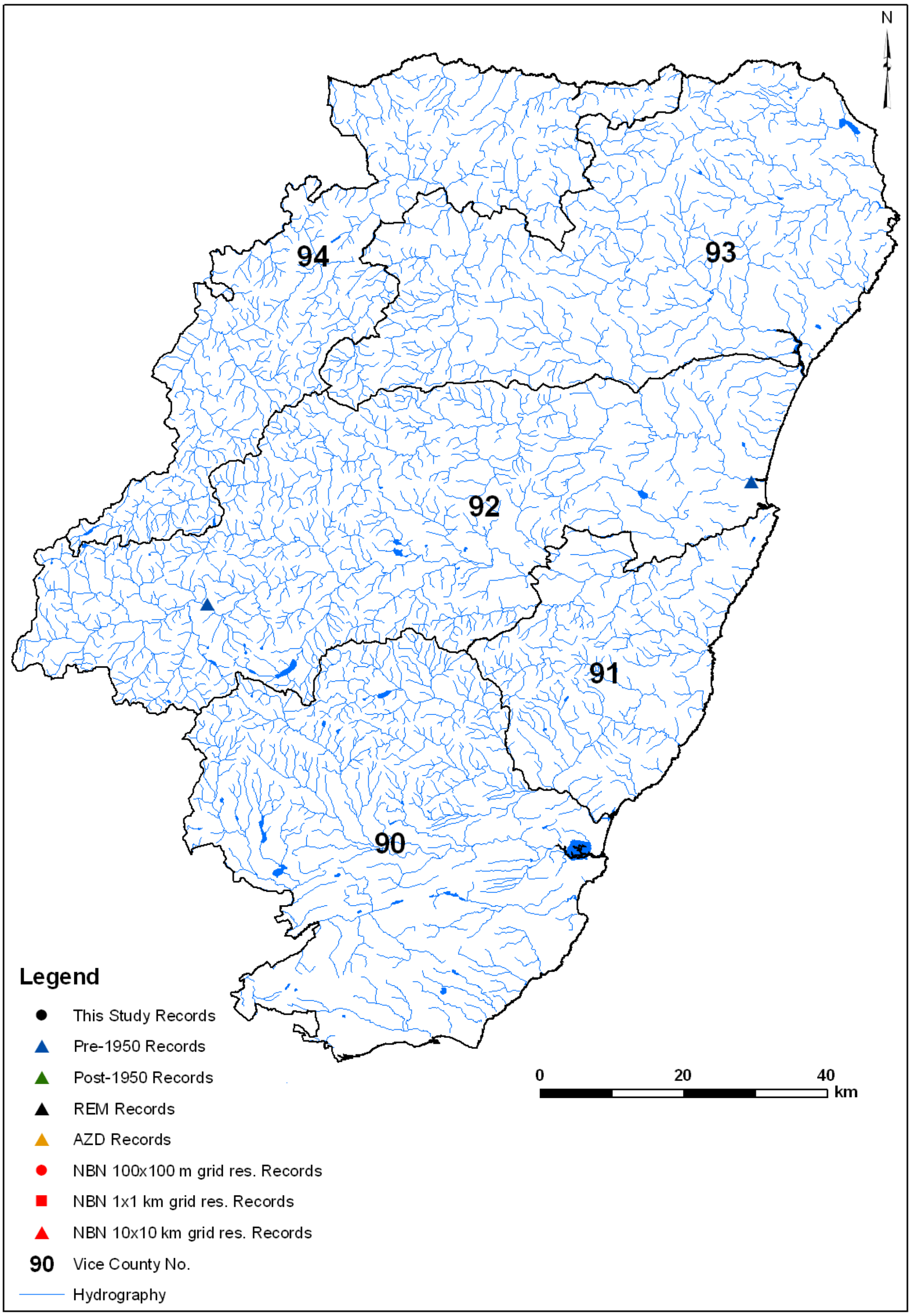
Map 25. *Pisidium nitidum* distribution area.



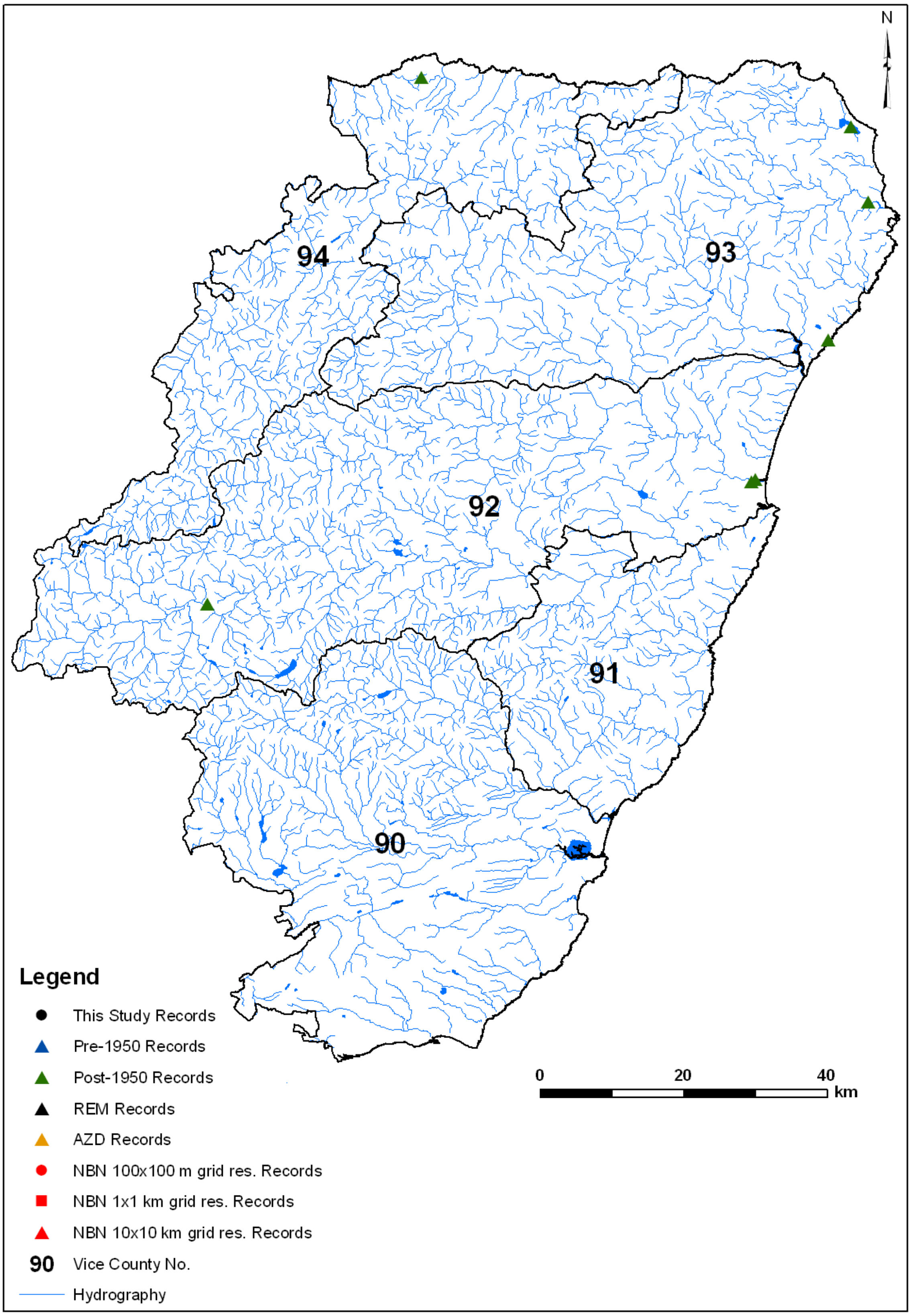
Map 26. *Pisidium lilljeborgii* distribution area.



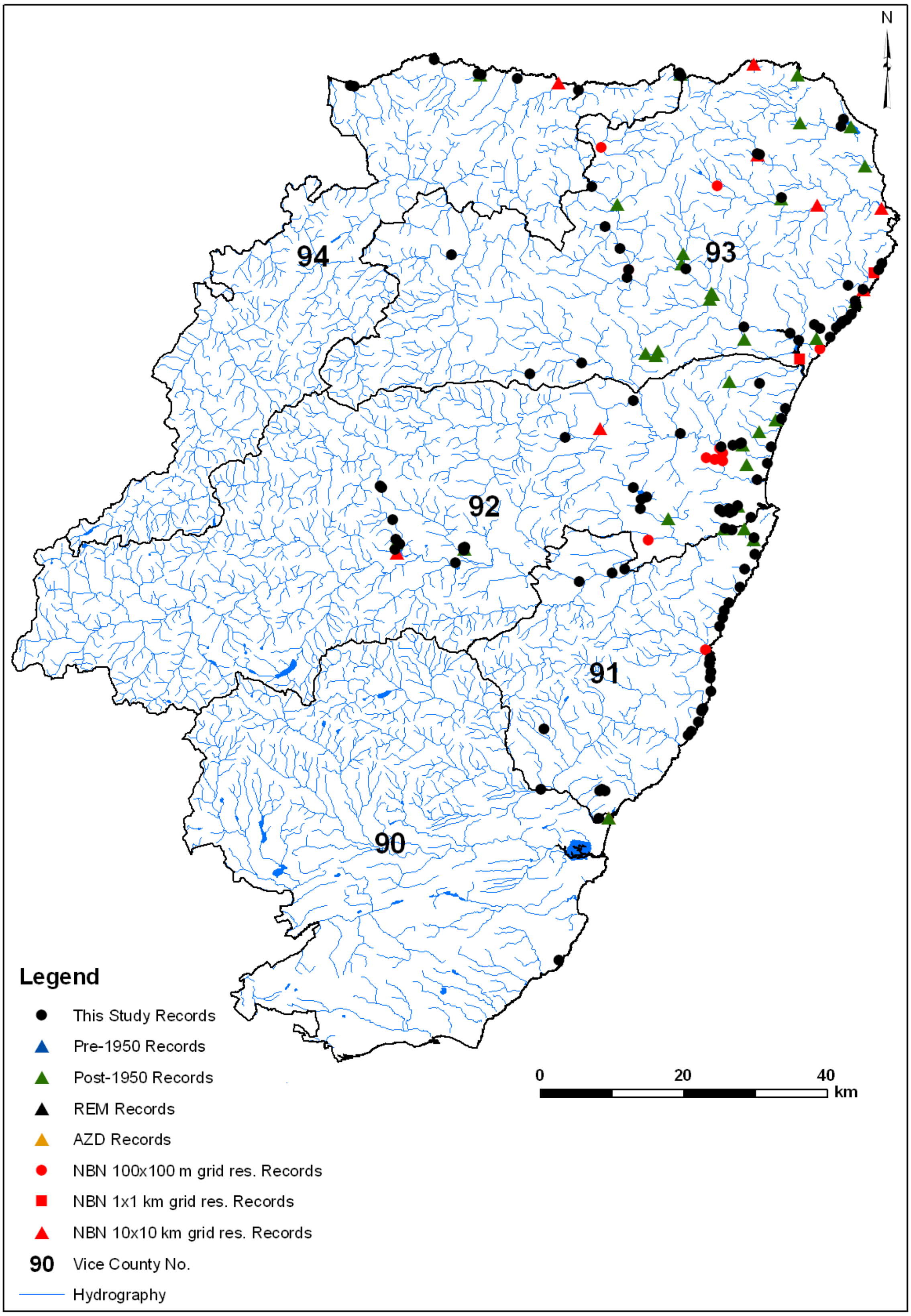
Map 27. *Pisidium hibernicum* distribution area.



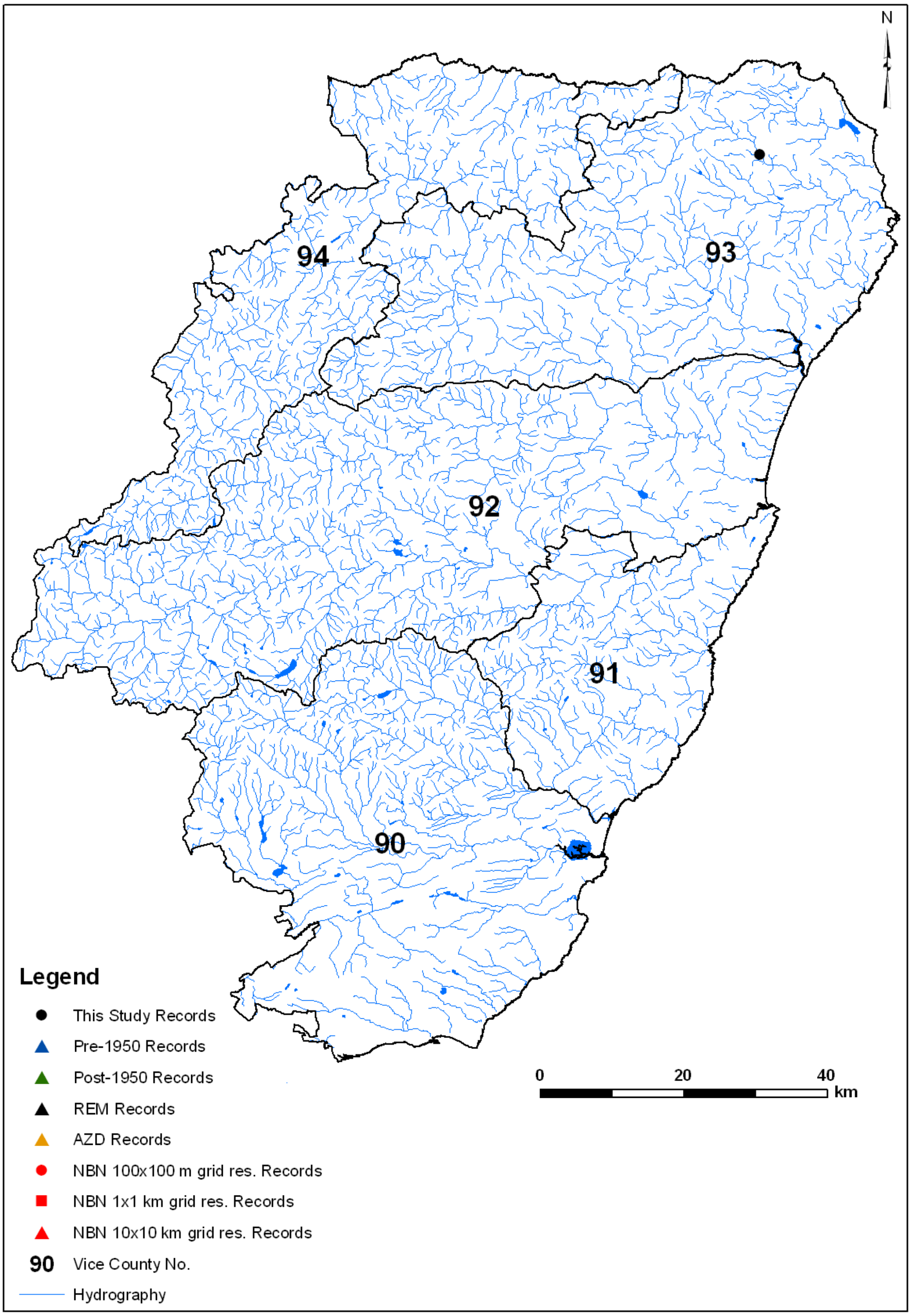
Map 28. *Pisidium fontinale* distribution area.



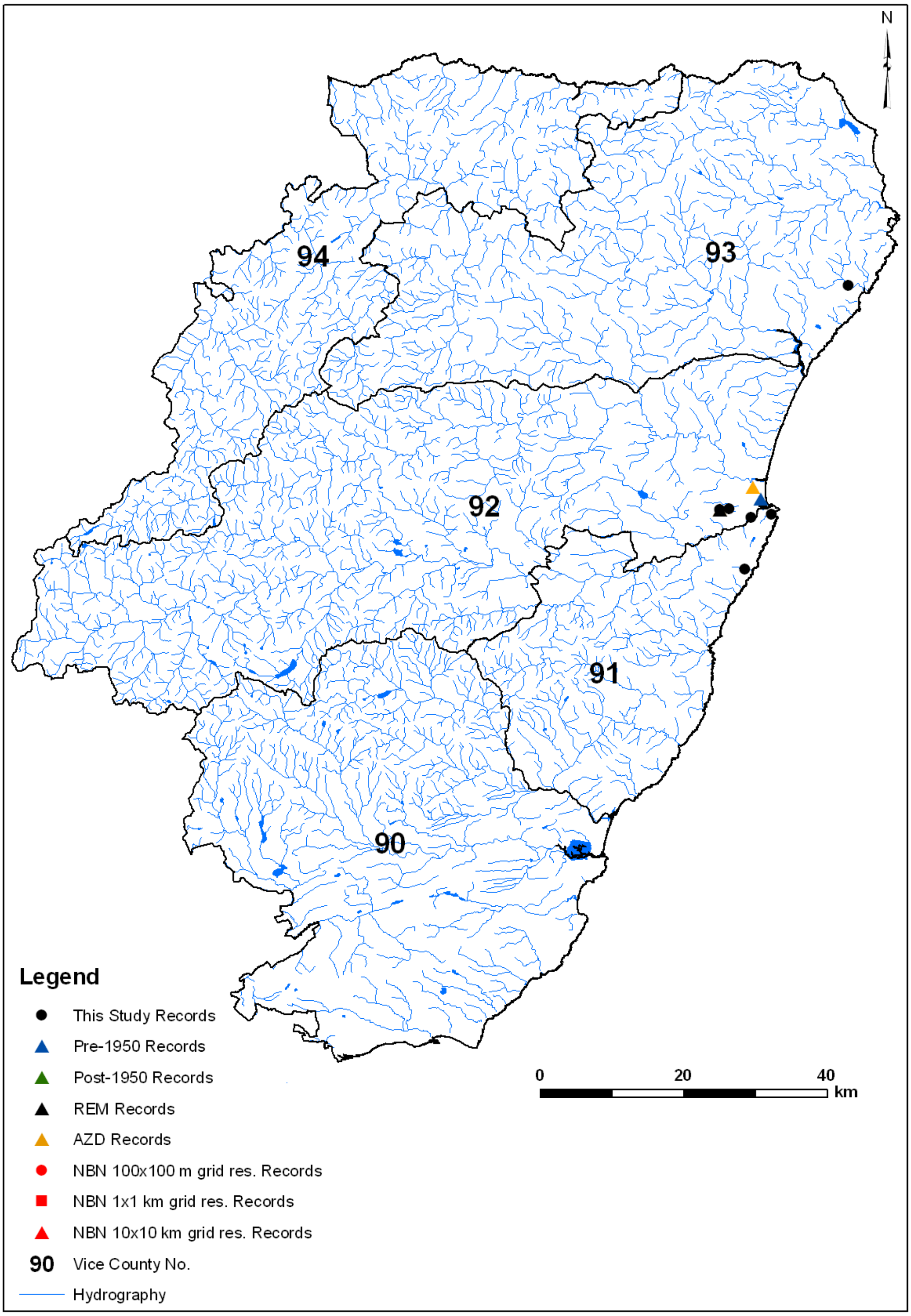
Map 29. *Pisidium pusillum* distribution area.



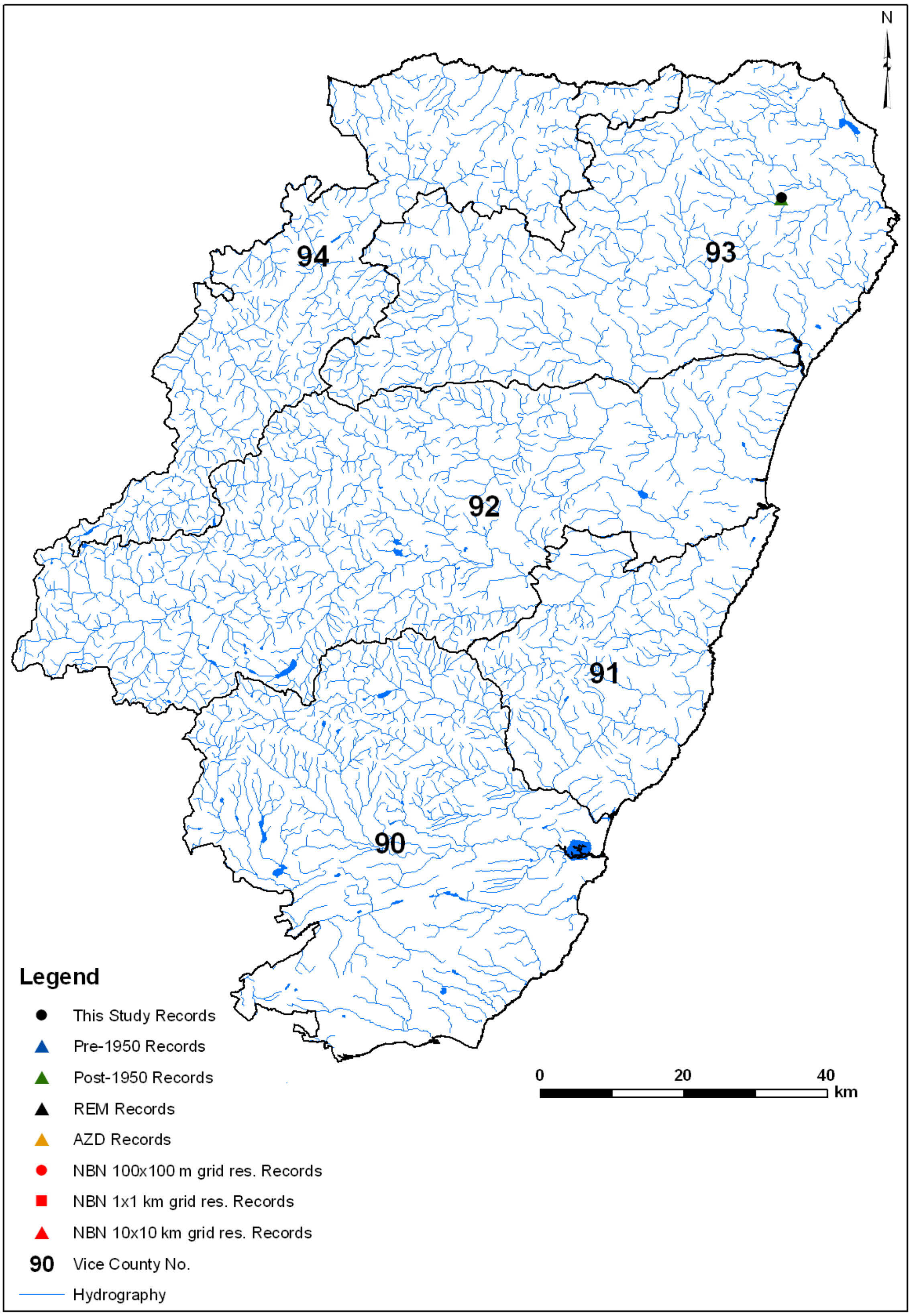
Map 30. *Potamopyrgus antipodarum* distribution area.



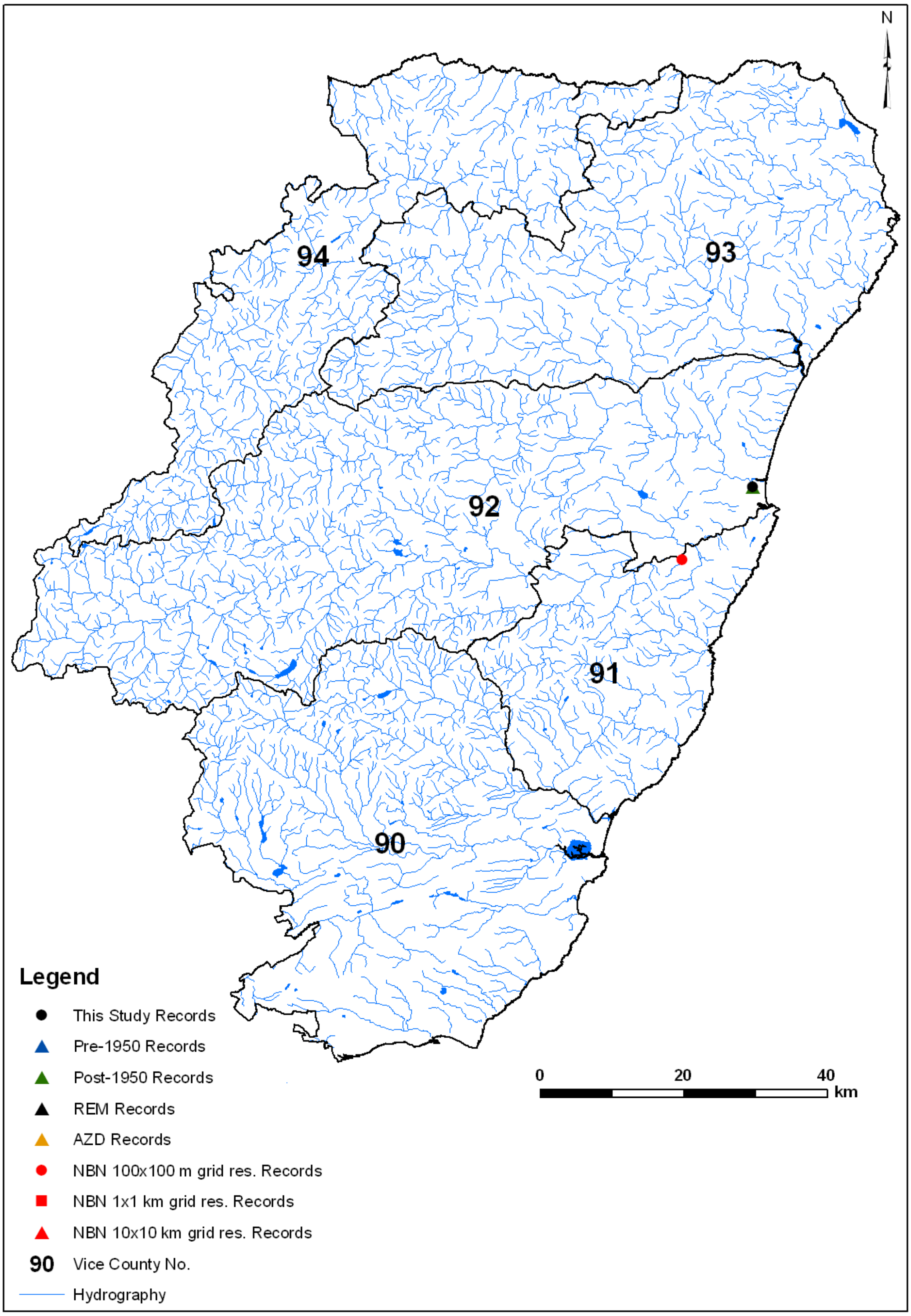
Map 31. *Lymnaea stagnalis* distribution area.



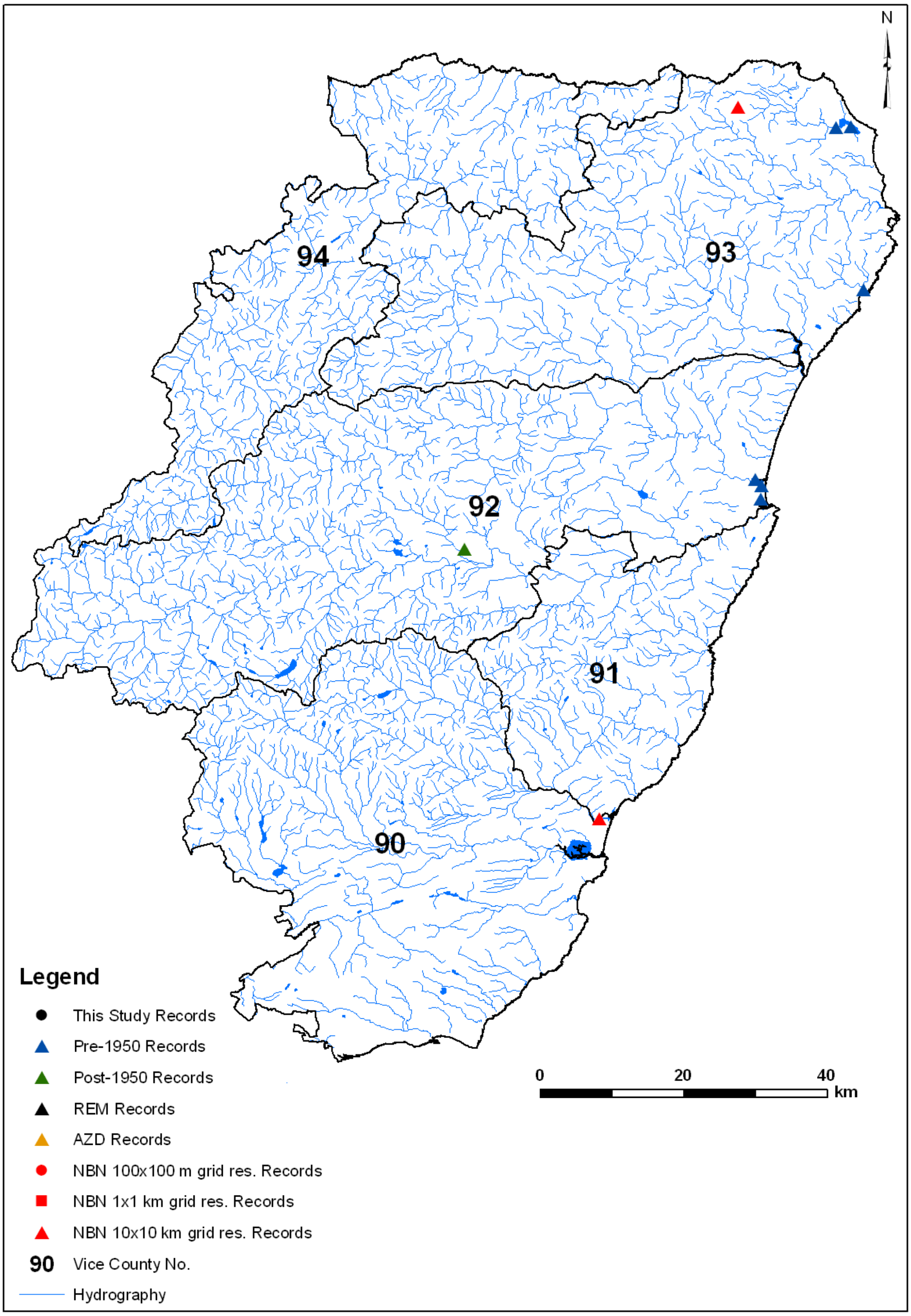
Map 32. *Physella acuta* distribution area.



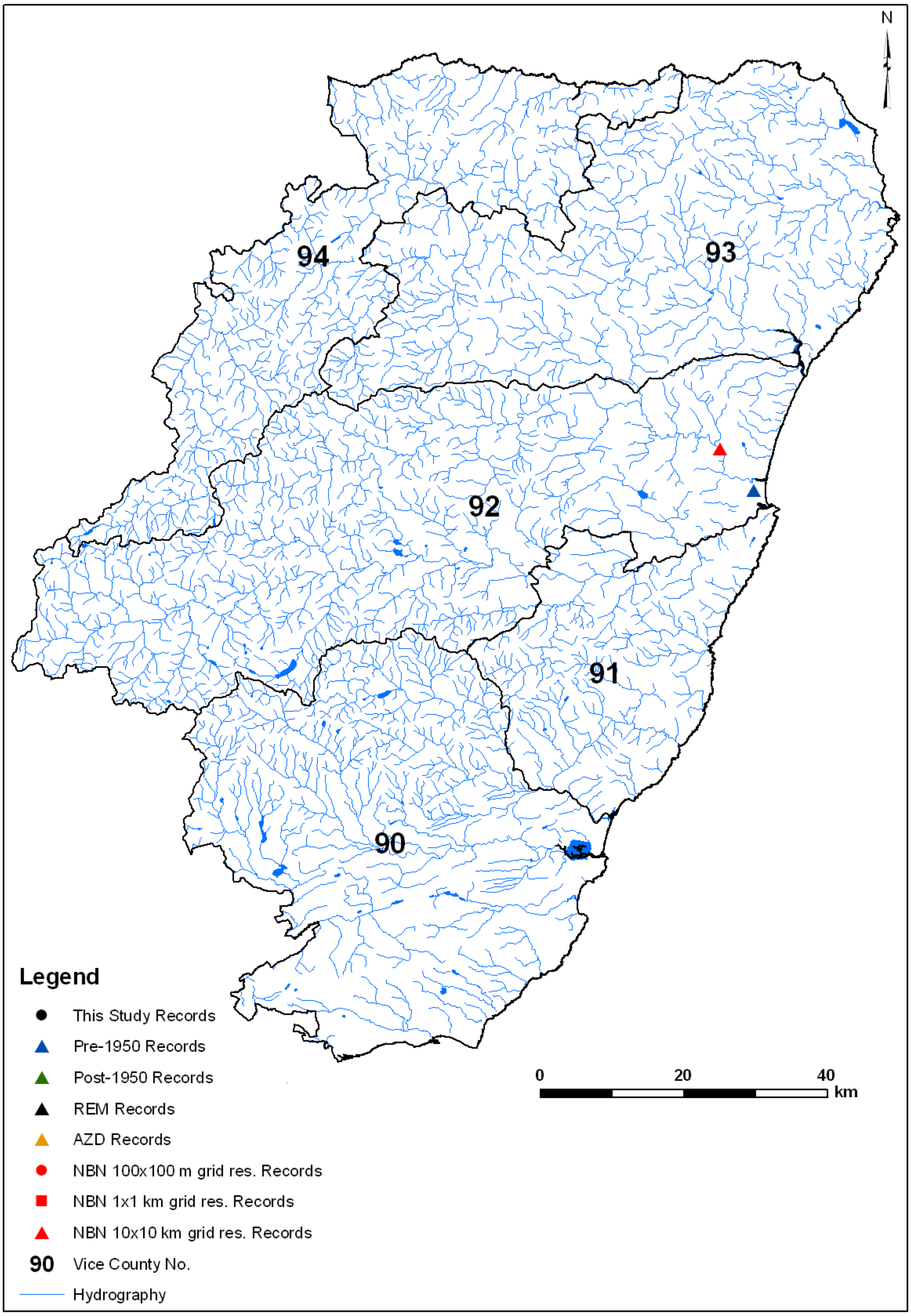
Map 33. *Planorbarius corneus* distribution area.



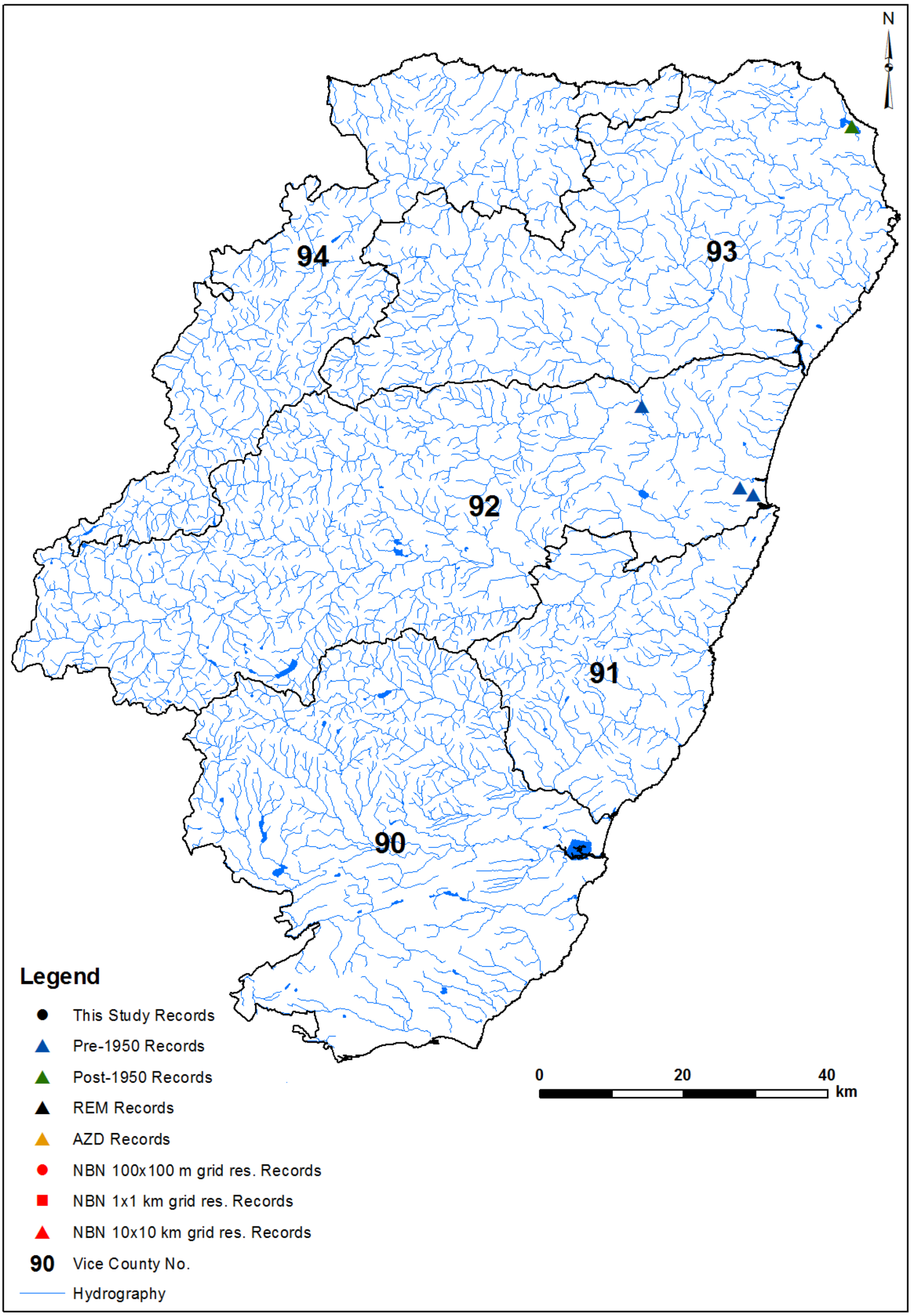
Map 34. *Planorbis planorbis* distribution area.



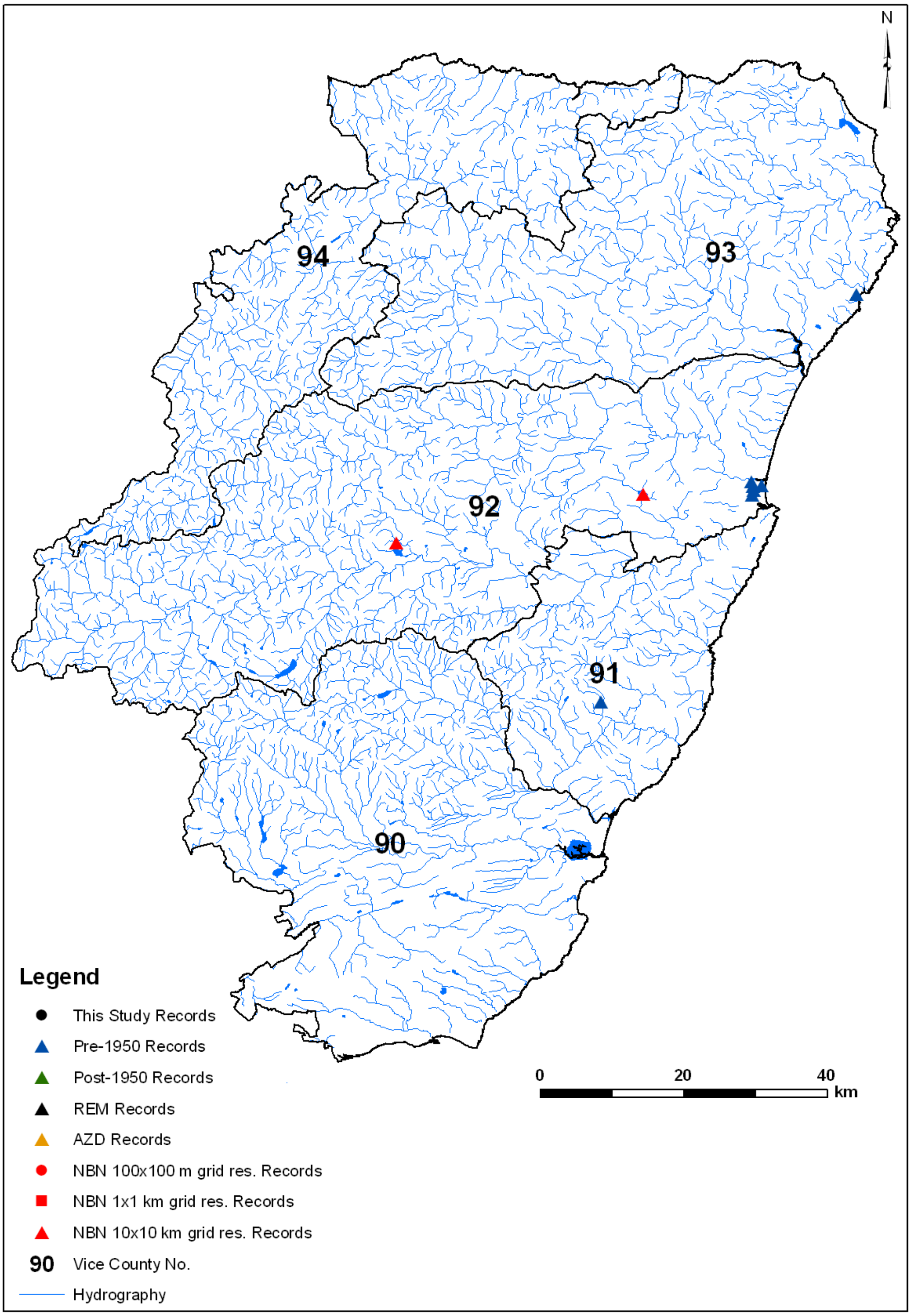
Map 35. *Anisus leucostoma* distribution area.



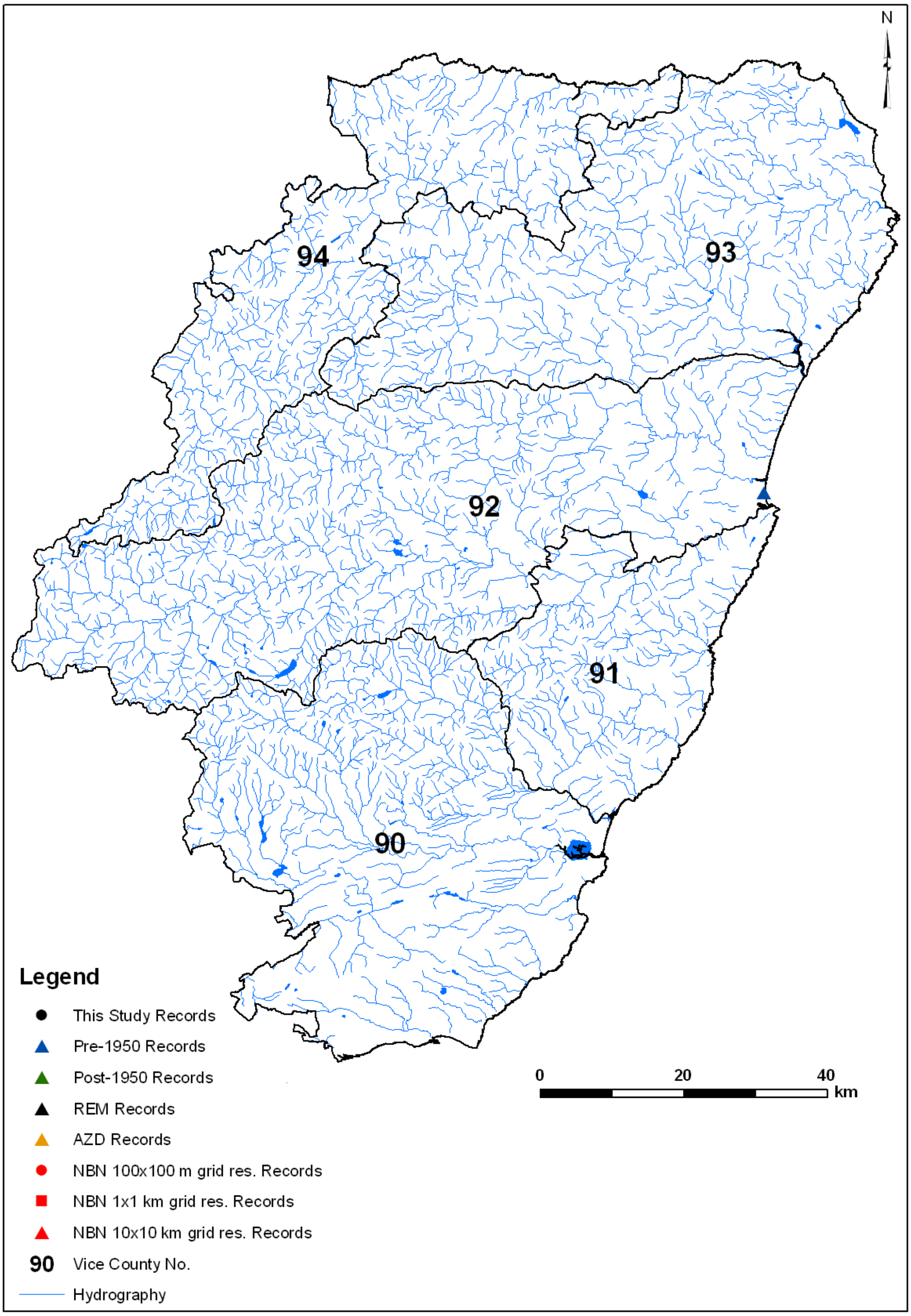
Map 36. *Anisus vortex* distribution area.



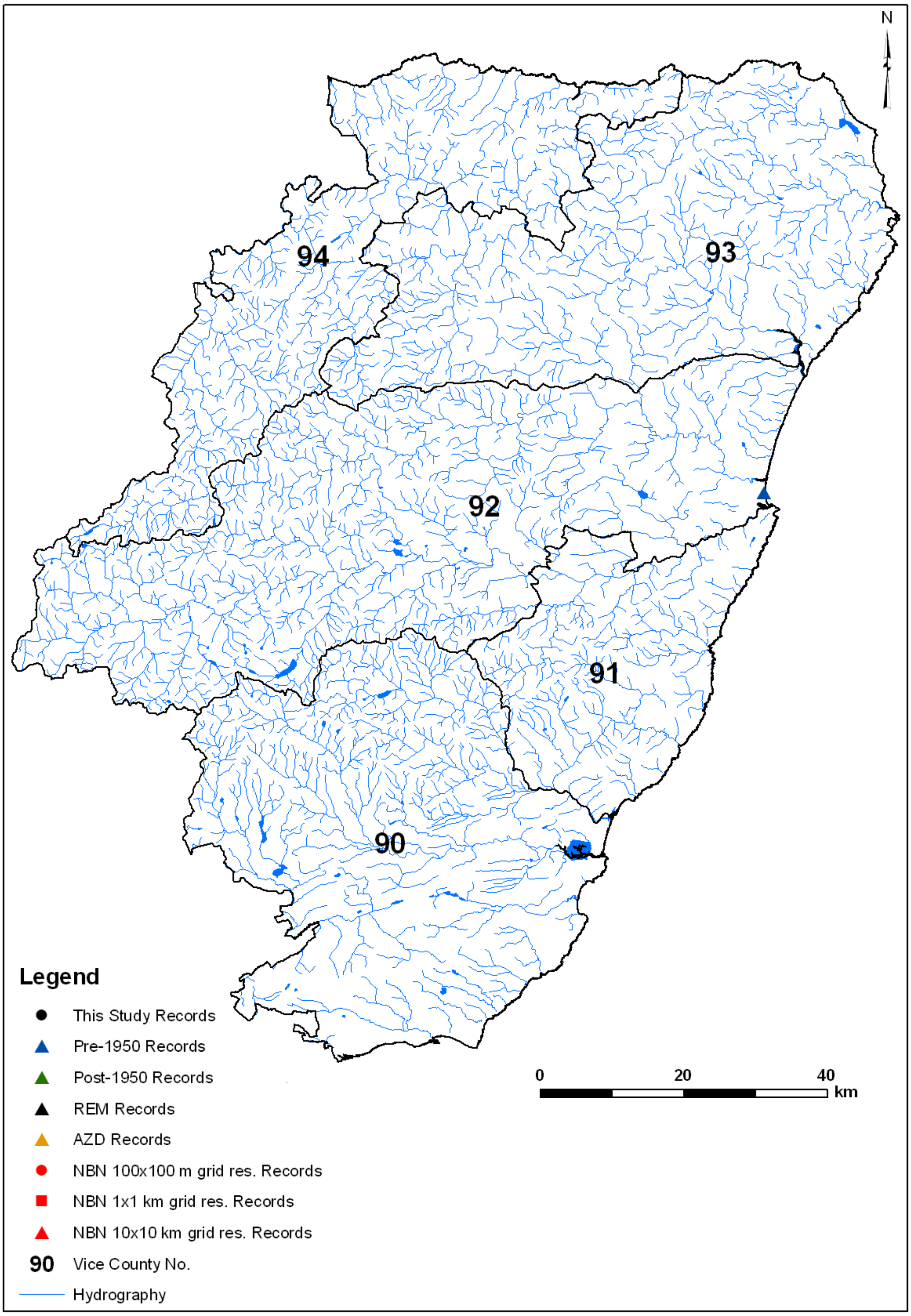
Map 37. *Pisidium amnicum* distribution area.



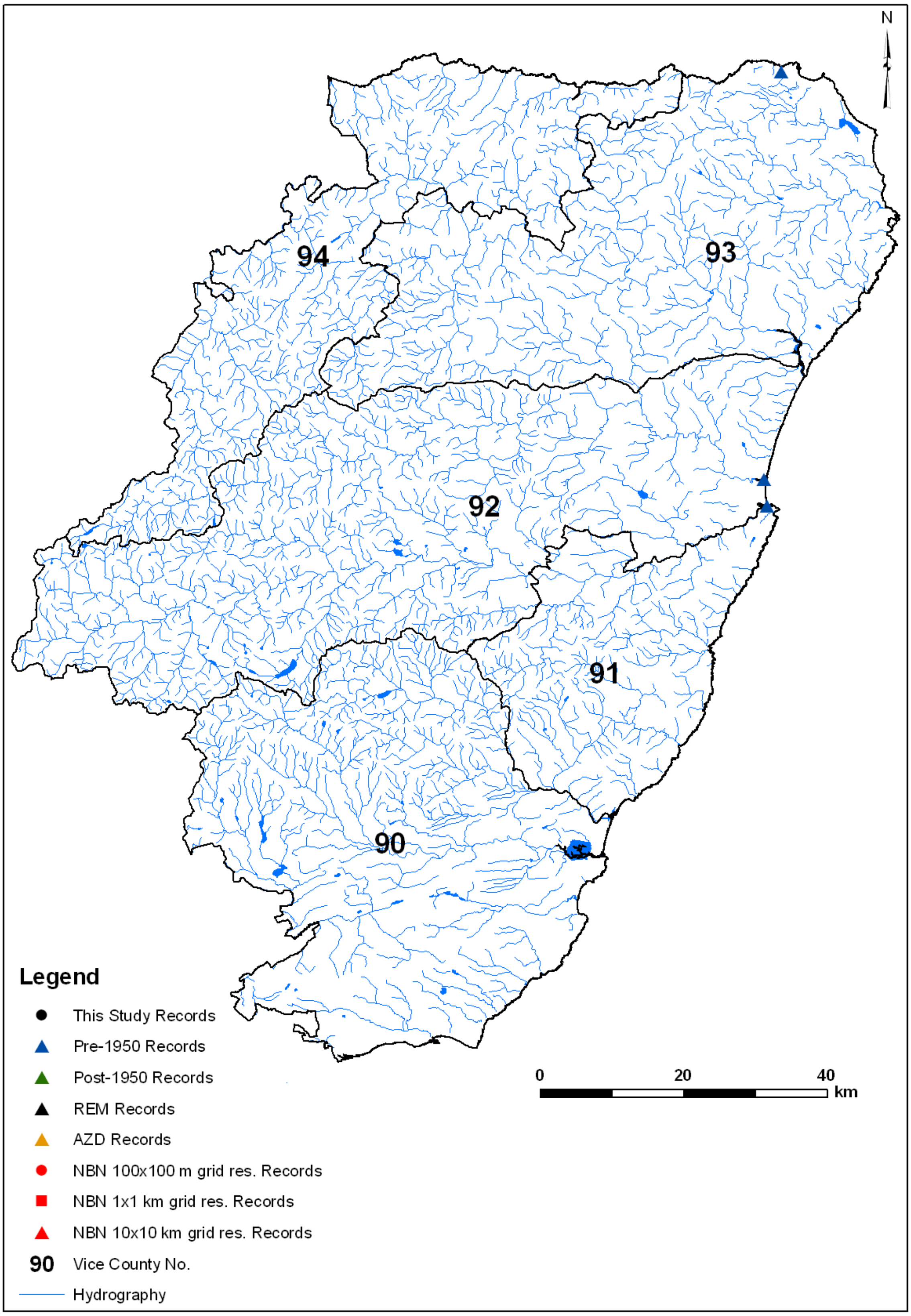
Map 38. *Pisidium pulchellum* distribution area.



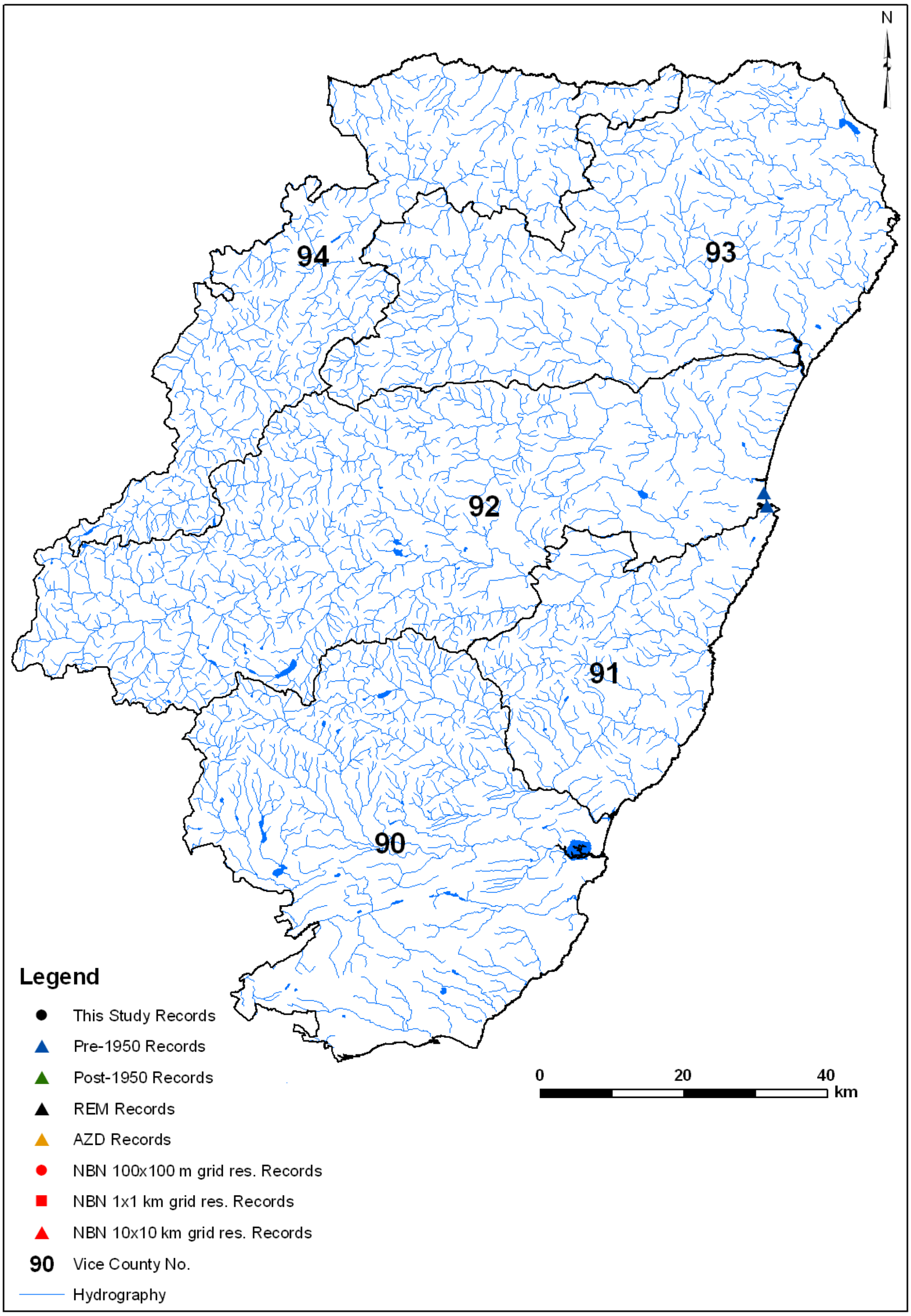
Map 39. *Theodoxus fluviatilis* distribution area.



Map 40. *Viviparus viviparus* distribution area.



Map 41. *Bithynia tentaculata* distribution area.



Map 42. *Valvata cristata* distribution area.

APPENDIX IV – TERATOLOGY IN THE SPHAERIIDAE

Teratology is frequent among sphaeriids and may affect different characters of the shell. Hinge reversal has been commonly reported by several authors, and numerous different variations described.

Eggleton & Davis (1962) examining some *Sphaerium* populations in Ohio (USA) identified the following type of reversal: posterior teeth transposed, anterior and cardinal teeth transposed and all anterior, cardinal and posterior teeth transposed.

On the other hand Heard (1969) depicted a more articulated framework integrating literature with research data. The author documented six different reversal cases as it follows: anterior teeth, cardinal teeth, posterior teeth, anterior and cardinal teeth, anterior and posterior teeth and all anterior, cardinal and posterior teeth transposed. Other hinge anomalies were also described such as tooth duplication (to anterior, cardinal and posterior teeth), tooth deletion and appearance of small denticles, documenting the existence of eight additional cases, some of them combined with reversals.

Observations here are in agreement with Heard's considerations, confirming a high variability of the hinge anomalies which cannot be reduced to a minimum number of cases as suggested by Eggleton & Davis (1962). Posterior or anterior teeth reversal evidences during this project have been observed only in a few cases, most time among *P. personatum* and *P. casertanum.* An evidence of posterior teeth reversal in a young specimen of *S. corneum* is shown in Plate-4, whilst an anterior teeth reversal is visible in a *P. personatum* individual in Plate-15.

This latter specimen is also affected by cardinal tooth duplication, which is visible on both right and left valves. A thin and sharp denticle (pseudo-tooth) derived from the dorsal side of the hinge occurs near C_3 on the right valve (Pl. 15, Fig. b), whilst a similar formation is present on the other valve, close to C_4 (Pl. 15, Fig. f).

Cardinal teeth reversal was observed in a right valve (inverted C_2 and C_4) of *P. obtusale,* whilst on the left valve a duplicated tooth is located next to the inverted C_3 (Pl. 17, Figs. b, g). A similar duplication is also visible on the left valve near A_2, where an extra small tooth does occur (Pl. 17, Fig. h).

Another shell anomaly concerns a malformation generally affecting the median part of the ventral side, where a split scar may occur. This alteration is a quite common phenomenon among bivalves known as diphyoidy (Chaix, 1973; diphyoidie in French), also reported in pulmonate gastropods such as *Limnaea [=Lymnaea] stagnalis* (Baudon, 1853; Favre, 1927), *Limnaea [=Radix] auricularia* (Moquin-Tandon, 1855; Chaix, 1973), *Limnaea peregra [=R. balthica]* (Brot, 1877), *Physa [=Physella] acuta* and *Ancylus fluviatilis* (Moquin-Tandon, 1855).

Lamarck in 1819 first described this phenomenon for the Unionidae, designating a new species mainly inhabiting large rivers of the European continent such as the Rhin and the Loire. This species named by Lamarck *Unio sinuata [=Margaritifera auricularia* (Spengler, 1793)] shows a ventral side affected by a marked sinuosity. In 1852 Bourguignat followed a similar taxonomical approach for the sphaeriids, proposing a new species *(Pisidium sinuatum)* based on the presence of grooves generating valve sinuosity. According to Baudon (1853) this phenomenon may be referred to a temporary stop of the mantle development, denying the specific attribution proposed by Bourguignat the year before and consequently assigning *P. sinuatum* to *P. cinereum [=P. casertanum]*. The same morphological anomaly was also observed by Baudon in other bivalves such as *Cyclas cornea [=Sphaerium corneum], Unio Batavus [=Unio crassus batavus* (Maton & Rackett, 1807)] and *U. Requienii [=U. elongatulus requienii* Michaud, 1831].

Geyer (1909) arrived at a similar conclusion, invoking a mechanical laceration of the mantle to justify the occurrence of this malformation.

On the other hand Sterki (1906) proposed that diphyoidy might be the result of parasitism affecting the mantle edges, or more precisely of a cercarial infection.

Afterwards Mermod (1930) reported a high presence of cercariae in diphyoidic individuals.

Moquin-Tandon (1855) first suggested that the occurrence of grooves on the valve margin may be the results of restoration after traumatic events. This was visibly observed in a teratological specimen of *Anodonta variabilis [=Anodonta* spp.] with clear evidences of mechanical cracking at the origin of the malformation. Also Pelseneer (1920) invoked the occurrence of injuries as plausible cause originating valve sinuosity in a variety of bivalves *(Pecten, Anodonta* and *Pisidium)*. Other authors who reported evidences of diphyoidy such as Chaix (1973) in *P. nitidum* and *P. milium* specimens from post-glacial deposits in Switzerland and Killeen *et al.* (2004) did not discuss any further the causes behind their genesis.

During this project a number of diphyoidic specimens have been observed, more frequently occurring with the furrow located in a nearly median position (always slightly posterior) of the ventral side of the valves *(S. corneum,* Pl. 3, Figs. a-f, Pl. 4 Figs. a-h; *P. obtusale,* Pl. 18 Figs. h-o; *P. nitidum,* Pl. 24, Figs. a-f). In a few cases the malformation was observed in a more posterior location *(P. obtusale,* Pl. 18, Figs. a-g; *P. nitidum,* Pl. 24, Figs. g-l) or even on the dorsal half of the posterior side (*P. hibernicum,* Pl. 31 Figs. a-f, g-l), interfering with the correct development of the lateral teeth.

Considering that these scars seem to affect randomly the posterior half of the valves with a morphology which differs from specimen to specimen, it is possible that they may represent evidences of damages repaired by injured individuals.

Moreover the majority of these damages, as reported in literature, occurs in the median position (or in the posterior two thirds of the valve as described by Moquin-Tandon 1855), which is from a mechanical point of view, the most vulnerable part of the shell.

Sphaeriids represent the primary food for a number of natural predators such as salmonids and cyprinids and other vertebrates (Behre, 1953; Eyerdam, 1968; Thompson, 1973; Balık et al. 2003), which swallow a consistent amount of benthic fauna during the day. It is not excluded that some of the specimens survived with injuries from the predators attacks, later on begin repairing their shells, producing the anomalies hitherto described.

To sustain this hypothesis it is worth noticing that the affected populations are located in small to medium size meso-eutrophic lochs hosting fish communities and in a less extent in small streams located in the lowlands.

Furthermore, during this research no diphyoidic specimens have been found in habitats unsuitable for fish survival, such as the oligotrophic headwaters of the Cairngorms and a varieties of water bodies spread across the high plateaux.

Certainly more studies are required to support these evidences both on the genetic and ecologic sides.

APPENDIX V – PASSIVE DISPERSAL LITERATURE REVIEW

The vast majority of authors tend to group together different dispersal vectors trying to establish macro relations between the host and the transported organism and to speculate about the maximum distance they can cover together.

A first macro distinction is made between abiotic and biotic factors, grouping within the first category all transport events related to fluids movements (anemochory and hydrochory), and within the second one dispersal events involving a variety of host organisms (ectozoochory in case of external transport and endozoochory if transport occurs after the organism survived a gut passage from the host species).

Anemochory appears to be an occasional transport phenomenon through thunderstorms and cyclones. Cyclone dispersal across tropical areas might be an important dispersal mechanism (although poorly studied), which becomes less important moving towards the temperate zones. Only a few cases of rains of snails or bivalves have been documented so far (only six reliable literature records covering a two centuries period have been identified) and all look like exceptional events rather than recurrent episodes. Rains of other animal categories such as fishes and frogs are also known in literature.

Hydrochory is certainly a powerful dispersal system allowing benthic fauna to migrate downstream and colonise new habitats within the floodplain. The peculiar habit of the majority of gastropods (e.g. Hydrobiidae, Lymnaeidae and Sphaeriidae) to float with the foot uppermost along the interface water-air is well-known. This 'pseudoplancton' dispersal is a powerful system adopted by some benthic organisms that normally spend their life grazing on plants or stones, to migrate towards a different zone. In the case of the brackish hydrobiids such as *Peringia ulvae, Ecrobia ventrosa,* and *Hydrobia acuta neglecta* this particular behaviour has been well-described and it appears to be associated with tidal fluctuations, when these gastropods alternate four different types of activities (crawling, climbing, burying and floating) related to sea level tidal variations (Anderson, 1971; Newell, 1979; Barnes, 1981; Siegismund & Hylleberg, 1987; Orvain & Sauriau, 2002). This behaviour introduces a new dynamic in the overcrowded estuarine populations allowing a periodical dispersal along estuaries, exploiting the power of the bi-directional nature of tidal currents. This is also possible because of the eurialine nature of these hydrobiids, tolerating ample salinity excursions and of their intrinsic capacity to survive in hostile environments.

A floating behaviour has been also described in *Potamopyrgus antipodarm* populations living in freshwater (Vareille-Morel, 1983; Dorgelo, 1987).

Natural drifting of benthic organisms frequently occurs in lotic environments, particularly when the current speed exceeds the minimum threshold for detaching and transporting specimens (especially young recruits) over long distances. This mechanism contrasts with active dispersal, an important behaviour particularly important at the local scale (Bilton *et al.*, 2001). Nevertheless active dispersal has been studied for a variety of aquatic organisms and it seems to be an effective migratory strategy adopted by a number of invertebrates to regain suitable upstream habitats lost during downstream drifting (Kappes & Haase, 2012). Furthermore some mollusc families such as Neritidae and Dreissenidae have a veliger larval stage, which allows an efficient downstream dispersal through drifting during the first phase of development.

Rafting transport of specimens attached to floating material, is another important mechanism for those organisms with a substratum preference. This is the case for *P. antipodarum* which has a preference for plant debris such as logs or leaves, where it deeply penetrates fractures and surface rugosities, thereby resisting strong currents.

Mollusc zoochory involving a wide range of animals such as birds, fishes, amphibians, reptiles, insects, crustaceans and mammals has been thoroughly documented in literature. The effectiveness of this dispersal mechanism depends on the nature of the interaction between the host and transported species and the distance they can cover together. Most authors indicated birds as a primary dispersal vector, because of the long distances they are able to fly; also amphibians and insects might cover an important role for short dispersal, particularly within the same watershed. If we analyse the full list of literature records, it appears quite clearly that the interaction between a host and the transported organism is highly specific, indicating that a particular taxon generally disperses through a restricted cluster of agents if not a single one.

For example if we examine all the historical records concerning sphaeriids, which show similar mechanical characteristics in terms of attachment capabilities, it appears that their favourite host is represented by amphibians (newts, salamanders, frogs and toads: 48 records in total) followed by various taxa of aquatic insects (37 records, more frequently *Dytiscus marginalis).* The other records described in literature, appear to be occasional events with an irrelevant dispersal power: 3 records with crustaceans, 2 with fishes and 2 with birds. The effectiveness of endozoochory among sphaeriids is poorly understood with some observations concerning birds described by Mackie (1979) and one field study performed by Brown (2007) with fishes.

The breeding system of sphaeriids maximizes the probability of a single colonist founding a new population, as they are simultaneous hermaphrodites in which self-fertilization is a common reproductive mechanism (Pettinelli & Bicchierai, 2009).

Amphibians were first identified as plausible candidates for bivalve dispersal (Amphibia ectozoochory) because they share the same environment (at least during the first phases of metamorphosis) and because they frequently move from water body to water body. During the breeding season (late winter-early spring) amphibians live in large colonies in ponds and quiet pools, continuously moving across the bottom and crawling on the vegetation. This behaviour causes the bivalves to firmly shut their valves on the extremities of the amphibians as soon as body parts are accidentally introduced between them, usually left open for filtering purpose. Once closed the valves may remain clamped for hours or days against the extremities of the unlucky individual, causing a reduction in motility and more rarely amputation of the digits. This phenomenon seems to be very effective over a short distance, as documented by the consistent number of records reported by several authors since the first half of the 19th century.

The effectiveness of amphibians in bivalve dispersal is controversial, because clear measurements of its efficacy are not available yet. Riches (1877) and Darwin (1882) reported two instances of frogs with *Cyclas cornea [=Sphaerium corneum]* specimens attached to their toes, found on the banks of water bodies. Kew (1893) mentioned three significant cases (two newts and one frog) where the animals were discovered with sphaeriids clamped to their extremities at a variable distance from the nearest water body between 10 and 110 m approximately.

Similarly aquatic insects (Insecta zoochory), continuously crawling on the bottom sediment, may have sphaeriids attached to various body extremities, such as legs or antennae. The small size of the insect hosts clearly represents a major limitation for passive dispersal over a long distance. Two extremely fortuitous accounts exist of specimens of *Dytiscus marginalis* captured on the wing carrying live specimens of *Sphaerium corneum* clinging to their legs (Standen, 1883; Standen in Kew, 1893). In these two cases the nearest water body was respectively at least 457 and 137 m distant, demonstrating the effectiveness of transport over a short-medium distance. Whether or not these accounts demonstrate the effectiveness of insect passive dispersal for the sphaeriids is still unclear.

These dispersal strategies cannot be compared to glochidia infections occurring on a variety of fish (most commonly Salmonidae), where the larvae spend part of their development encysted in the gills tissue, before dropping off the host. This latter mechanism, typical of freshwater bivalves most commonly belonging to the Unionidae and Margaritiferidae families, plays an important role in upstream dispersal. Salmonids are in fact excellent upstream migrants, capable of ascending rivers and streams and crossing physical obstacles such as step and pool reaches and small waterfalls.

For a long time birds have been considered among the most effective vectors for passive transport (Aves ectozoochory) in terms of distance covered, and for the wide range of wetlands visited during halts on their journeys. Charles Darwin (1859) pioneered the study of long-distance dispersal and referred repeatedly to the role of migratory water fowl in dispersing aquatic invertebrates as well as plants among isolated locations hundreds of kilometres apart.

Conversely only a limited number of instances of molluscs carried by birds are known in literature, documenting the occurrence of molluscs firmly stuck to feathers or bills. The paucity of direct evidence of bird ectozoochory does not mean it is ineffective, but only that a minority of individuals are concerned, over millions of specimens which every year commence their migratory journeys.

If we examine bird ectozoochory in some detail, we realise that it generally concerns a limited group of molluscs, which are related to feeding or other recurrent bird behaviours. Records of cockles (mostly *Cerastoderma edule)* and mussels (mostly *Mytilus edulis)* found attached to the feet or beaks of waders, ducks or other aquatic birds feeding along sea shores or freshwater bodies (in the case of the unionids), clearly represent isolated incidents occurring during predation (Jukema, 1979b; Green & Figuerola, 2005; Melville & Choi, 2013; van Gemert & Schipper, 2013). The bird's capacity to fly away with a bivalve attached is heavily reduced and most die as soon as the tide rises. Land and aquatic shells may adhere firmly to the feathers, feet or beaks of a large variety of birds, with the chance of being dropped in a new environment. This is quite often the case for pulmonates *(Succinea, Physa, Lymnaea, Helisoma,* etc.), which secrete a sticky mucous capable of fixing the snails to the feathers or skin of a bird (Ramsden, 1913; McAtee, 1914; Roscoe, 1955; Dundee *et al.,* 1967).

Some authors tried to establish the effectiveness of this dispersal mechanism (Darwin, 1859; Boag, 1986), simulating, in a laboratory, the adhering conditions and calculating retention time. Nevertheless the real importance of this passive transport in facilitating the species areal expansion remains largely unknown. Even prosobranchs such as *Potamopyrgus antipodarum* have been occasionally found clinging with the operculum to feathers or entangled in the beak's lamellae (Coates, 1922a; Bondesen & Kaiser, 1949).

Endozoochory has been debated for a long time as a possible dispersal mechanism for benthic invertebrates, particularly birds and fishes. Early accounts of bird endozoochory were reported by Ward (in Kew, 1893) who mentioned finding live gastropods of *Helix caperata [=Candidula gigaxii]* from the stomach of a shot pigeon and by Davies (in Hedley, 1894) who extracted a live freshwater mussel *Unio angasi [=Velesunio angasi]* from a cod stomach. During the last thirty years a number of studies focussed on the quantitative analysis of the endozoochory phenomenon, conducting field surveys and performing detailed laboratory analyses on a variety of birds and fish. This mechanism appears to be very effective for those operculate gastropods capable of resisting the digestive fluids secreted by gut walls. The survival of *Potamopyrgus antipodarum* specimens ingested by fish like perch, European plaice, brown trout, and rainbow trout has been well documented since the beginning of the 20th century (Dean, 1904; Hertling, 1928; Ankel, 1929; Bondesen & Kaiser, 1949; Haynes *et al.,* 1985; Vinson, 2004; Bruce, 2006). Some cichlid fishes (e.g. *Astatoreochromis alluaudi),* living in African freshwater lakes, feed upon thick-shelled gastropods (e.g. *Melanoides tuberculata),* developing a robust pharyngeal mill needed to crush the shells and digest the mollusc flesh (Greenwood, 1965). On the other hand distinct populations of *A. alluaudi* (living in different lakes) following a mixed dietary regime (mostly represented by insect larvae and thin-shelled gastropods), show thinner pharyngeal bones, with a less developed dentition as a possible consequence of the reduced calcium intake. The presence of an effective pharyngeal apparatus in fish feeding on operculate gastropods such as hydrobiids, becomes important for puncturing the shells and digesting the animal, which otherwise would pass unharmed through the gut of the predator.

Fish endozoochory appears to be an important dispersal agent within the same river basin, where fish may drop their faecal pellets at a certain distance from the feeding points.

Similarly to fish, bird endozoochory appears to be very effective, particularly for prosobranch gastropods. *Peringia ulvae* is able to survive to a gut passage from its main predators: shelduck (Cadée, 1988; Anders *et al.*, 2009) and mallard (van Leeuwen, 2010). According to van Leeuwen (2010) observations, a maximum 7h transit time was measured for the last *Peringia ulvae* specimen that survived to a mallard gut passage. This means that all the mallards which fly away from the feeding site may drop live specimens within 0-7h in a new environment, with a reasonable chance to start a new population. This mechanism appears to be very effective in estuaries, where we find quite often the same hydrobiid association, although characterised by variable densities related to taxon ecological preferences. Thus hydrobiids may disperse easily through bird endozoochory, progressively founding new populations if the environmental conditions of the new habitat are suitable for survival. Through this stepping-stone mechanism (Saura *et al.,* 2014), hydrobiids may disperse quickly over a long distance, without invoking complex transport mechanisms.

Finally passive transport related to human activities (anthropochory) is one of the most effective mechanisms responsible for the rapid expansion of some highly adaptable alien species. The invasive caspian-pontic alien *Dreissena polymorpha* in the Great Lakes region in North America is believed to have been introduced with ballast water released by ocean-going ships traversing the Saint Lawrence Seaway (Hebert *et al.,* 1989; Carlton, 1992, 1993).

Another example is *Potamopyrgus antipodarum,* a New Zealand taxon which has been accidentally transported worldwide through a variety of human-related activities. Recreational watercraft (and trailers) or even sporting equipments such as anglers' waders have been found hosting specimens of *P. antipodarum,* which can be easily transplanted to different water bodies after surviving desiccation for relatively long periods (Hosea & Finlayson, 2005; NZMS, 2007, Newhall Land and Farming Company, 2012).

Potamopyrgus antipodarum is considered to have very effective passive transport, as demonstrated by its rapid colonisation of the British Isles in less than a century. The favourite host for this species is still unclear, although some authors think that sea birds or migratory birds might be the main dispersal agent (Hunter *et al.,* 1964). The most isolated colonies of *P. antipodarum* are located in Scotland, along migratory paths taken by geese, suggesting their involvement in spreading the species (Hunter, 1953; Hunter & Warwick, 1957; Hunter *et al.,* 1964). In the River Endrick (Loch Lomond area) it was noticed that a marine specimen of *Littorina obtusata* (Linnaeus, 1758) was found together with some individuals of *P. antipodarum,* 13 miles from the sea, providing convincing evidence of passive dispersal (Hunter *et al.,* 1964). This site is regularly visited by seagulls, frequently spotted along the fields adjacent to the river banks.

The pervasive upstream dispersal of this species within some river catchments might be related to fish endozoochory, particularly with salmonids (Bondensen & Kaiser, 1949; Haynes *et al.,* 1985; Vinson, 2004; Bruce, 2006). Live individuals (30% of the ingested ones) have been regularly recovered from faeces of a variety of fish up to 24 hours after ingestion (Bruce, 2006), demonstrating the effectiveness of this mechanism in generating new colonies far from the point of origin. *P. antipodarum* has a number of natural adaptations, which make it particularly effective in colonizing new environments, such as: parthenogenetic reproduction, viviparity (i.e. internal brood-care), its tolerance to both varied salinities and desiccation, and the possession of an operculum combined with small size.

PASSIVE DISPERSAL LITERATURE RECORDS

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Gravitative - 3 references	*Arianta arbustorum*	Frequently	Downhill rolling	Individuals of *A. arbustorum* were frequently observed to fall from the vegetation and, due to their nearly globular shell, then to roll down steep slopes …	Swiss Alps	Baur (1984) in Baur, 1993
		97 out of 230 snails transported downhill for a distance of 350-550 m	Avalanche	… 97 individuals of *A. arbustorum* among a total of 230 snails were found on melting remains of avalanches of which 1.7% and 13.4% had survived. … Since the places where the avalanches started were visible, it could be estimated that the snails had been tr		
	Arianta arbustorum, Arianta chamaeleon	16 snails rolled downhill to a maximum distance of 13.5 m	Downhill rolling	The distance traveled between the starting point and the place where a snail stopped was measured to the nearest cm. A maximum distance of 1350 cm was recorded for individuals that rolled beyond the lower margin of the snowfield.	Meadow located near Lake Wolay (46° 37' N, 12° 52' E, 1,970 m amsl), southwestern Carinthia, Austria	Baur *et al.,* 1997 (reported results of a study performed in 1995)
Anemochory - 7 references	*Limax virgata [=Cernuella virgata]*	1	Shower	They fell like a shower of hail, and covered nearly an inch deep, a surface of about three acres, …	On a surface of about three acres, belonging to a farmer at Tockington near Bristol (South Gloucestershire, England, UK)	Farley (1821) in Anonymous, 1821; also in Baker, 1851
	Mussels	1	Shower	A shower of mussels, some weighing about two ounces, fell during a severe storm, on the 9th of August 1834, …	United States	Anonymous (1834) in Thomson, 1849
	Bulimus truncatus [=Bulinus truncatus]	1	Shower	… shower of molluscous animals, - *Bulimus truncatus,* - took place at Montpellier.	Montpellier (France)	Anonymous (1835) in Thomson, 1849
	Snails	1	Shower	… that village was visited by a heavy shower of snails.	Bradford, about twelve miles from Bristol (England, UK)	Anonymous (1851) in Douglas, 1851a
	Gemma gemma	1	Shower	Mr. John Ford exhibited specimens of a *Gemma gemma,* Totten, remarkable for having fallen during a storm which occurred at Chester, Pa., on the afternoon of June 6th, 1869.	Chester (Pennsylvania, USA)	Ford, 1870 (reported an event observed in 1869)
	Anodonta anatina	1	Shower	A yellowish cloud attracted the attention of several people, both from its colour and the rapidity of its motion, when suddenly it burst, a torrential rain fell with a rattling sound, and immediately afterwards the pavement was found to be covered with hu	Paderborn (Germany)	Anonymous (1892a) in Anonymous, 1893
	Truncatellina rothi	-	Wind	The maximum flight distance for one specimen of *Truncatellina rothi* in a storm of a wind velocity of 100 km h^{-1}, when starting at an altitude of 100 m above sea level, is calculated to be approximately 3,300 m. If wind velocity is reduced to 50 km h^{-1}, th	Laboratory, empty shells collected in Gávdos Island (UTM KU3559 and KU3460, Greece)	Kirchner *et al.,* 1997
Hydrochory - 169 references	Limacibus and planorbes [=Lymnaeidae and Planorbidae]	Occasionally	Floating	On a summer's day any one may see the Limnæi (Fig. 21) and Planorbes thus traversing the surface of ponds and ditches in an easy undulating line; …	-	Lister, 1694; also in Johnston, 1850
	Pond mussel	Very rarely	Floating	[Pond mussels swim within the water, & move to the surface, but very rarely.]	-	Mery, 1710
	Perwinkles [generic for Gastropoda]	Regularly	Floating	The perwinkles or water-snails, whether in the sea or in the rivers, have the same mode of motion; we may observe them swimming on the surface of the waters, with their whole body and shell reversed in the water; …	-	Bradley, 1721
	Cyclas calyculata [=Musculium lacustre]; Physa Hypnorum [=Aplexa hypnorum]	Frequently	Floating	… readily and frequently ascending the sides of the vessel, and walking, like *Physa Hypnorum,* on the under side of the surface of the water.	In an aquarium	Jenyns, 1832
	Eolidina paradoxum [=Aeolidiella glauca]	Regularly	Floating	[We know that almost all gastropods can crawl, let's say, on the surface of a liquid, reversed on the back. In this position, the lower surface of their feet almost coincides with the surface layer of the liquid, and it is seen to contract, wrinkling in v	-	de Quatrefages, 1843
	Pisidium Jenynsii [=Pisidium subtruncatum?]	Sometime	Floating	At other times it ascends to the surface, where it proceeds in the same manner, with the shell reversed, the umbones being beneath.	In a ditch, between Aberdeen and the Spital (Scotland, UK)	Macgillivray, 1843
	Rissoa [=Peringia] ulvae	Regularly	Floating	These animals creep with great rapidity, and float with the foot uppermost by means of an hydrostatic apparatus, as air-bubbles are seen continually to proceed from the aperture; they are strictly littoral, and inhabit in myriads the green oozes of the es	-	Clark, 1850
	Cyclas [=Sphaerium/Musculium/ Pisidium], Pisidium Kelliae [=Kelliidae], Amphidesmæ [=Semelidae], Lymneæ [=Lymnaeidae]	-	Floating	... *Cyclas* and *Pisidium,* and some marine species (Kelliae, Amphidesmæ) allied to them in character and bulk, have the same power as the Lymneæ, of ascending to the surface of their ponds, or pools, and traversing them from side to side, in a reversed posi	-	Johnston, 1850
	Limnæus pereger [=Radix balthica]	1	Floating	Mr. Martin states that he has often been amused in watching the movements of this species in the old canal north of Inchbroom, when hundreds of these creatures were seen sailing from one end of the canal to the other, foot uppermost.	In an old canal north of Inchbroom, Moray (Scotland, UK)	Martin in Gordon, 1854
	Ancylus fluviatiles [=fluviatilis]	1	Floating	[I saw fluvial Ancyles, dead, or displaced for some reason, floating or washed away by the current. I also saw several individuals, thrown into the water, floating for a while, because of their light weight; ...]	-	Moquin-Tandon, 1855
	Pisidium	Regularly	Floating	They possess the same faculty as the Sphæria of floating, or creeping in an inverted position under the surface of the water.	-	Jeffreys, 1862
	Hydrobia similis [=Mercuria confusa], Hydrobia [=Ventrosia] ventrosa	Regularly	Floating	[both species are able to float with rapidity along the under surface of the water]	-	Jeffreys, 1862
	Planorbis [=Anisus] vortex, P. carinatus, P. [=Hippeutis] complanatus, P. [=Planorbarius] corneus *P. [=Bathyomphalus] contortus, Physa [=Aplexa] hypnorum, P. fontinalis* *Limnæa [=Radix] auricularia, L. [=Lymnaea] stagnalis, L. [=Lymnaea] glabra*			[all these species are fond of floating along the under surface of the water]		

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Tectura [=Iothia] fulva, Trochus [=Margarites] helicinus, T. occidentalis [=Calliostoma occidentale]*	Regularly	Floating	[these species float in an inverted posture]	-	Jeffreys, 1865
	Odostomia albella [=unidentata], O. turrita, Eulima distorta, Lamellaria perspicua, Velutina plicatilis *V. læevigata [=velutina], Nassarius incrassatus, Columbella haliæeti [=Amphissa acutecostata]* *Defrancia [=Teretia] teres, D. Leufroyi [=Raphitoma leufroyi], D. linearis [=Raphitoma linearis]* *Utriculs truncatulus [=Retusa truncatula], Bulla [=Haminoea] hydatis*	Regularly	Floating	[these species float in an inverted posture]	-	Jeffreys, 1867
	Planorbes *[=Planorbis* spp.], Lymnées *[=Lymnaea* spp.]	Regularly	Floating	[As planorbes, the snails often come to the surface of the water, where they swim with the shell reversed; …]	In aquaria	Pizzetta, 1872
	Agadina	Regularly	Floating	The single species was found floating near an iceberg …	60° S. latitude and 106° 20' E. longitude	Tryon, 1883
	Gemella hyalina [probable prosobranch larval stage]	Regularly	Floating	The little animal creeps with great rapidity, and by hollowing the disk of its foot into a boat-form, like *Limnæa,* it floats upon the surface of the seas.	-	Tryon, 1883
	Nassa	Occasionally	Floating	They may be occasionally seen floating with the foot upwards.	-	Tryon, 1883
	Limnæa *[=Lymnaea] stagnalis*	Sometime	Floating	[Sometimes we see them moving along the bottom, sometimes along the stems and leaves, sometimes at the surface of the water; they seem to be slipping, suspended by their feet to the surface level, with the shell reversed downwards]	-	Brehem, 1884
	Limnées [=Lymnaeidae], Planorbes [=Planorbidae], Paludines [multiple prosobranch families]	Regularly	Floating	[In summary, freshwater gastropods to slide at the surface of the water in inverted position, start adhering at the thin surface film which always cover the water of pools and ponds; then they crawl to the underside of a thin mat of mucus that their foot	In ponds or in aquariums	Willem, 1888
	Hydrobia [=Peringia] ulvae	1	Floating	[Juvenile specimens without velum were caught with a plankton net and put in a tank glass, where they started crawling along the walls and sliding upside down at the air-water interface.]	Sylt, Wadden Sea (Germany)	Henking, 1894 (reported results of a study performed in 1893)
	Helix aspersa, Helix [=Cepaea] hortensis	1 *H. aspersa* specimen; 15 *C. hortensis* specimens	Floating	A specimen of *Helix aspersa,* in this condition, for instance, thrown into the river Lud, floated freely with the current, but I soon lost sight of it. Fifteen specimens of *H. hortensis,* with the animals fully extended, all floated.	River Lud, Lincolnshire (England, UK)	Kew, 1893
	Lymnées [=Lymnaeidae], *Cyclas [=Sphaerium/Musculium/ Pisidium]*	Occasionally	Floating	[I would like to talk about the reptation or, at least, suspension, beneath the surface of water, of some molluscs (Lymnées, *Cyclas),* of some worms (Turbellaires, Némertiens, Piscicole) and Hydres.]	-	Brocher, 1910
	Alectrion trivittata [=Nassarius trivittatus]	Occasionally	Floating	As it moved along the surface of the water the cilia could be seen in motion and carmine grains were swept with the mucus down the foot.	Laboratory	Copeland, 1919
	Polinices [=Euspira] heros	Occasionally	Floating	A young *Polinices heros* was also noted moving in a similar manner in an inverted position along a band of mucus laid down on the surface film of the water.	Laboratory	Copeland, 1922
	Mytilus edulis	Regularly	Floating	At the close of the larval or prodissoconch stage the young of *Mytilus edulis* which fail to secure immediate attachment may remain pelagic through the secretion of gas into the mantle chamber. Short distances may be covered through the aid of a holdfast secreted on the surface film or through holding the foot or the tentacles of the incurrent siphon in the surface film.	Frenchman Bay, Mount Desert Island; Mount Desert Island Marine Biological Laboratory, (Maine, USA)	Nelson, 1928 (reported results of a study performed during 1924-27)
	Hydrobia [=Peringia] ulvae	-	Floating	… living specimens of *Hydrobia ulvae* floating ...	-	Schwarz (1929) in Cadée, 1994a
	Hydrobia [=Peringia] ulvae	-	Floating	[Dry shells are difficult to get wet by the incoming tide current and float on its surface, moving away from their settlement area.]	Jade Bight (Germany)	Linke, 1939
	Hydrobia [=Peringia] ulvae	Regularly	Floating	*Hydrobia* has the habit of floating upside down from the surface film, and may in this way be dispersed away from the *Zostera* beds to the sandy areas, which are not its normal habitat.	Mouth of the Exe Estuary (England, UK)	Holme, 1949 (reported results of a study performed in 1947-48)
	Fresh-water snails	-	Floating	Certain fresh-water snails crawl upside down along the under-surface of the water.	-	Goldacre, 1949
	Urosalpinx cinerea	Regularly	Floating	When crawling under the meniscus, as on other surfaces, newly hatched drills secrete copious quantities of mucus. This forms a sheet behind and sometimes about the foot which further buoys them. ... it is principally wind currents moving surface strata of	Bogue Sound (North Carolina, USA)	Carriker, 1957 (reported results of a study performed in 1956)
	Urosalpinx cinerea	Regularly	Floating	Some years ago, T. C. Nelson (pers. com.) observed the transport of newly hatched *U. cinerea* a distance of at least 40 feet on *Zostera* floating in a tidal stream.	-	Nelson in Carriker, 1957
	Hydrobia [=Peringia] ulvae	Regularly	Floating	Experiments in the laboratory and observations on the shore suggest that under natural conditions the animals float on the surface film of the water by means of a mucous raft, which also acts as a food net.	Shores and laboratory	Newell, 1962
	Mytilus edulis	Regularly	Floating	... plantigrades possess a relatively very long and ciliated foot. They frequently protrude this foot fully, so exposing more surface to water friction. This, together with the active beating of the pedal cilia, permits the plantigrades to be transported	Menai Straits, North Wales (UK); Marine Science Laboratories, Menai Bridge, Anglesey	Bayne, 1964 (reported results of a study performed during 1962-63)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Hydrobia [=Peringia] ulvae*	Considerable number of floating snails (March-November > 200)	Floating	... if weather conditions were calm the snail rapidly extended the foot so as to contact the water-surface. The combined actions of buoyancy of the dry shell and the movement of both snail and water, caused the animal to break away from the bottle to floa	Ythan Estuary, (Scotland, UK)	Anderson, 1971 (reported observations during 1966-67)
	Hydrobia [=Ecrobia] ventrosa	Regularly	Floating	My data suggest that floating increases with increased crowding when ready access to the air-water interface (rocks, seaweed, or a rising tide) is available.	A pond near Kalo castle ruin and a sand flat at Lendrup Strand, on the Limfjord (Denmark), then laboratory	Levinton, 1979 (reported results of a study performed in 1974)
	Hydrobia [=Peringia] ulvae	0-6.2% of the population; > 1% only in one instance	Floating	Floating appears to be an accidental phenomenon, brought about by a variety of mechanisms. It may aid species dispersal.	Gibraltar Point, Brancaster, Seasalter, Calshot, Weston and Barry tidal flats (England, UK) and laboratory	Little & Nix, 1976 (reported results of a study performed during 1974-75)
	Potamopyrgus jenkinsi [=Potamopyrgus antipodarum]	Occasionally	Floating	Personal observations have shown that *Potamopyrgus (Hydrobia) jenkinsi* floats in the laboratory, but this species is not known to float in its natural habitat.	In an aquarium	
	Limnaeidae	Occasionally	Floating	The Limnaeidae float readily in aquaria, …	In aquaria	
	Hydrobia [=Ecrobia] ventrosa, H. [acuta] neglecta	Regularly	Floating	In four out of the five significant tests, the frequency of *H. neglecta* among floating snails was larger than in the sediment (St. 2 and 7 in May and St. 4 and 5 in June). This might suggest that *H. neglecta* had a higher proportion of its population float	Kysing Fjord, east coast of Jutland (Denmark)	Siegismund & Hylleberg, 1987 (study results performed in 1978)
	Hydrobia [=Peringia] ulvae	36.4% and 10.4% (mean) floated under laboratory conditions	Floating	One minute after the water level passed the tops of the sticks, those snails which had floated off and remained floating were still doing so passively by virtue of the buoyancy conveyed by trapped air bubbles or dried mucus: very few had extended their fo	Cockle Bight (TF 798 467), on Scolt Head Island, (north Norfolk, UK) and laboratory	Barnes, 1981 (reported results of a study performed in 1978-79)
	Helcion pellucidus	Occasionally	Floating	When dislodged, however, *H. pellucidus* quickly produces abundant mucus which forms a sticky 'sail' giving the limpet a nearly neutral boyancy and enables the snail rapidly to recolonize its habitat.	-	Vahl, 1983
	Potamopyrgus jenkinsi [=Potamopyrgus antipodarum]	Regularly	Floating	Juveniles can float freely on the water surface without a substrate …	-	Vareille-Morel (1983) in NZMS, 2007
	Corbicula fluminea	Regularly	Floating	Small adult *Corbicula* … were found to be capable of floating after being exposed to gentle water currents produced by an aquarium filtration system (current speeds, 10 to 20 cm/sec).	Tallahala Creek near Runnelstown (Mississippi, USA) then laboratory	Prezant & Chalermwat, 1984
	Potamopyrgus jenkinsi [=Potamopyrgus antipodarum]	Occasionally	Floating	Floating was observed only in Lake I, and only during the occurrence of the highest densities on the sediment.	Lake Maarsseveen I (the Netherlands)	Dorgelo, 1987
	Planorbis [=Planorbarius] corneus	Regularly	Floating	In the third type of feeding behaviour, the whole sole was flattened under the water surface (Fig. 4D), the cilia beat intensively, and the snail moved under the water surface at the normal locomotor velocity (about 1.5 mms^{-1}).	Laboratory	Deliagina & Orlovsky, 1990
	Hydrobia [=Peringia] ulvae	Regularly	Floating	Numbers of floating mud snails *Hydrobia ulvae were* low in June, when individuals > 2 mm shell length dominated the collection of drifting individuals.	Southern Oddewatt, Königshafen Wadden outer area near the Island of Sylt (North Sea, the Netherlands)	Armonies, 1992 (reported observations performed in 1991)
	Sinonovacula constricta	-	Floating	Post-larvae were able to climb the glass wall and float on the water surface after ca 1 wk of development.	Laboratory of the Department of Oceanography, Xiamen University. Xiamen, Fujian, China	Wang & Xu, 1997
	Hydrobia [=Peringia] ulvae	Frequently	Floating	… "floating activity": it floats within the water column, resuspended by tidal currents or suspended beneath the air/water interface in calm conditions (this last process only takes place after "climbing activity") ...	CREMA (CNRS-IFREMER, UMR 10) Laboratory, l'Houmeau (France)	Orvain & Sauriau, 2002
	Heleobia australis	1	Floating	… the reinvasion of depopulated areas by adult individuals [13] of *H. australis*, mainly due to its floating/sinking mechanism, ...	Guanabara Bay, Rio de Janeiro (Brazil) and laboratory	Echeverría *et al.,* 2010 (study performed during 2005-2006)
	Sorbeoconcha, Physidae	Occasionally	Floating	… this particular snail can crawl beneath the water surface at speeds as high as 0.2 cm/s, comparable to its speed on solid substrates, and perform a 180° turn in 3 s. It is rendered neutrally buoyant by trapping air in its shell.	Fresh Pond, Cambridge (Massachusetts, USA) and laboratory	Lee *et al.,* 2008
	Aquatic univalves	Usually	Rafting (trees)	In rivers and lakes, on the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away, during floods, from tributaries to the main streams, and from thence to all p	-	Lyell, 1832
	Æolis [=Aeolidia]	1	Rafting (trees)	A small brown nudibranch *(Æolis)* was abundant on the log, and there were plenty of its eggs disposed in small rounded white patches amongst the bases of the *Lepas* -stems.	Station 30, St. Thomas to Bermuda, 191 miles south of Bermuda, Lat. 29° 5' N., Long. 65° 1' W	Moseley in Murray, 1895 (reported an observation made in 1873)
	Limnæa peregra acuminata [=Radix balthica]	Often	Rafting (macrophytes)	In mild weather they often crawl on the top of the duckweed, and if a breeze blows them up to one end of the pond they are to be obtained in great numbers.	In the largest pond north of the railway at Hob moor, York (Yorkshire)	Christy, 1881
	Notarchus [=Plakobranchus] ocellatus, Scyllæa, Bornella digitata, Glaucus	Regularly	Rafting (algae)	… living in floating masses of sea-weed.	-	Tryon, 1883
	Stenothyra	Regularly	Rafting (macrophytes)	The species are found either attached to the under surface of floating leaves, or crawling out of the water on the muddy margins of ponds, …		
	Septaria	Regularly	Rafting (macrophytes)	... are usually found on the banks of rivers adhering to floating sticks and to the petioles and roots of the Nipah palms and other plants that live near the rivers; ...		
	Unio fuscatus [=Elliptio occulta]	Occasionally	Rafting (trees)	In Florida I have collected handfuls of *Unio fuscatus* and other species among the matted roots of trees just under the surface of the water. Such trees, washed out and carried down stream, would take some of their molluscan inhabitants with them.	Florida (USA)	Kew, 1893
	Planorbis boissyi [=Biomphalaria alexandrina]	Regularly	Rafting (trees)	On investigating this bathing pool and the canal, we found many snails of the species *Planorbis boissyi* floating down stream, attached to debris or joined together in masses to form rafts.	Nile delta area (Egypt)	Manson-Bahr & Fairley, 1920 (study performed during 1916-18)
	Bullinus [=Bulinus] spp.			It feeds upon various kinds of aquatic plants which choke these channels in the summer season and may then be found in clusters attached to the under surface of the floating leaves.		

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Urosalpinx cinerea*	Regularly	Rafting (algae)	The young drills may be distributed by current if they become attached to floating algae, debris, etc.	Hampton Roads and its tributaries (Virginia, USA)	Federighi, 1931 (reported results of a study performed in 1927)
	Biomphalaria sp., *Gyraulus* spp., *Bulinus* sp., *Lymnaea* sp., *Bellamya* sp.	1	Rafting (trees)	The snails were mostly collected from floating leaves fallen from the surrounding trees.	Lake Tana, near Bahrdar (Ethiopia)	Ayad, 1956 (study performed during 1951-52)
	Bradybaena [=Fruticicola] fruticum	1	Rafting	… *Bradybaena fruticum* rafting on Hungarian rivers ...	Hungarian rivers	Frömming (1954) in Baur & Bengtsson, 1987
	Urosalpinx cinerea	Regularly	Rafting (various debris)	Agility and adhesiveness of the foot insure quick and sure anchorage to firm substrata of all sorts, including floating materials. Capacity of young drills to cling to floating debris promotes emigration and wider dispersion.	Bogue Sound (North Carolina, USA)	Carriker, 1957 (reported results of a study performed in 1956)
	Fissurella mutabilis, Thais [=Semiricinula] squamosa, Coryphella [=Flabellina] capensis *Aulacomya ater, Chlamys tinctus [=Talochlamys multistriata], Hiatella arctica, Tanystylum brevipes*	1	Rafting (algae)	... The research vessel « Capricorne », having on board a team of researchers from the Oceanographic Research Centre of Abidjan, identified a wreck of a large laminar ... 14 species of invertebrates were collected …	100 nautical miles ca. to the south-east of the Sainte Hélène Island (18° S and 4° W)	Arnaud *et al.,* 1976 (reported observations made in 1971)
	Lacuna spp., *Margarites pupillus, Littorina sitkana, Mytilus edulis*	Regularly	Rafting (algae)	Gastropods were considerably more abundant in the Beaverton [drift algae] Cove samples ... At both locations members of the genus *Lacuna* were predominant (88%). Other species included *Margarites pupillus* (Gould 1849) and *Littorina sitkana* Philippi 1845.	Mitchell Bay and Beaverton Cove, San Juan Island; Friday Harbor Laboratories, San Juan Island, Washington (USA)	Highsmith, 1985 (reported results of a study performed during 1982-84)
	Potamopyrgus jenkinsi [=Potamopyrgus antipodarum]	Regularly	Rafting (algae)	… snails have been reported to raft on floating algae mats and other vegetation …	-	Vareille-Morel (1983) in NZMS, 2007
	Potamopyrgus jenkinsi [=Potamopyrgus antipodarum]	-	Rafting (algae)	[In June, floating filamentous algae of the genus *Cladophora* were seen in Lake Zürich, holding a large numbers of *P. jenkinsi* grazing on.]	Lake Zürich (Switzerland)	Ribi & Arter, 1986
	Pinctada maculata, P. albina, Crassostrea amasa [=Saccostrea scyphophilla], Astraea sp.	1	Rafting (corallum)	When found, the corallum was covered in crustose coralline and filamentous blue-green algae and supported a variety of other organisms, including ... pearl and reef oysters *Pinctada maculata* (n = 2), *P. albina* (n = 7), and *Crassostrea amasa* (n = 16), gast	Great Barrier Reef (Australia)	De Vantier, 1992
	Zebra mussel *(Dreissena polymorpha)*	Regularly	Rafting (macrophytes)	Post-metamorphic *D. polymorpha* can readily return to the water column through a number of mechanisms. The most obvious are rafting on macrophytes and other flotsam (Lewandowski 1982b; Martel 1993; J. D. Ackerman, unpublished observation) …	-	Ackerman in Ackerman *et al.,* 1994
	Dreissena polymorpha	2,620 +/- 86 mussels per day	Rafting (macrophytes)	The average daily number of zebra mussels collected from those drifting macrophytes was 2620 +/- 86. Wild celery *(Vallisneria americana)* accounted for 60% of the macrophyte mass transported downstream and carried 90% of the zebra mussels (Table 1).	Christiana Creek (outflow of Christiana Lake), southwestern Michigan (USA)	Horvath & Lamberti, 1997
	Hydrobia spp., *Cerastoderma glaucum*	Regularly	Rafting (algae)	The numerically most abundant taxa in algal mats were *Hydrobia* spp., Chironomidae, Ostracoda and newly settled larvae of *Cerastoderma glaucum* …	Archipelago of the Åland Islands (Finland)	Norkko *et al.,* 2000
	Cepaea hortensis	Max distance: 8.6 km in 1.4 h	Rafting	[Field experiments have shown that lotic waters can carry live land snails over long distances.]	Field experiments in the Lahn River (Hessen, Germany)	Tenzer, 2001
	Arianta arbustorum, Helix pomatia	Max distance: *A. a.* 20.8 km in 5.6 h, *H. p.* 19.8 km in 4.9 h	Rafting	[Field experiments have shown that lotic waters can carry live land snails over long distances.]	Field experiments in the Elbe River (Saxony-Anhalt, Germany) and Lahn River (Hessen, Germany)	Tenzer, 2003 (reported results of a study performed in 2001)
	Dreissena polymorpha	Regularly	Rafting, boat hull fouling, drifting larvae	The construction of canals in the 18th century, connecting the Dnieper, Neman and Vistula rivers was the beginning of its westward expansion … (i) attached to rafts by which timber was transported through canals and rivers ... (ii) attached to ship's hull	Europe	Bij de Vaate & Jazdzewski, 2002
	Potamopyrgus antipodarum	Occasionally	Rafting (algae)	… *P. antipodarum* has been observed drifting downstream on floating algae in the Madison basin (BLK, personal observation) …	Madison basin (USA)	Kerans *et al.,* 2005
	Heleobia australis	1	Rafting (various debris)	Several specimens were also seen in situ attached to floating debris, as leaves, plastic bags, etc., …	BG-10 station, Guanabara Bay, Rio de Janeiro (Brazil)	Echeverría *et al.,* 2010 (study performed during 2005-2006)
	Succinea caduca	1	Rafting (trees)	In simple laboratory trials (B. S. H., unpublished), live *S. caduca* attached to tree bark were placed in a salt water aquarium ... After 12 h of immersion, all specimens were alive, indicating that sea water is not immediately lethal and suggesting the po	Laboratory, specimens collected from 24 sites on six islands of the Hawaiian Archipelago	Holland & Cowie, 2007
	Bulinus truncatus, Neritina nilotica	Regularly	Downstream drifting	It is seen that no snails were found on the very surface but that some snails were carried by the current in the upper layers (third to fifth rung). ... It seems that except for *Neritina,* which are usually found in the lower levels, the snails were not ab	Streams and canals in the Fayoum Province (Egypt)	Azim & Ayyad, 1948 (study performed during 1943-46)
	Cardium [=Cerastoderma] edule	Regularly	Drifting	It has been observed that frequently animals up to 2,000 µ are transported by the currents, so that current velocities must be of great importance.	Zeehondenplaat, western part of Dutch Waddensea (the Netherlands)	Baggerman, 1953 (reported results of a study performed in 1950)
	Polynices duplicata [=Neverita duplicata]	1	Drifting (tidal ebb)	... the young *Polynices* lifted the forward portion of the foot and curling the sides of the foot downward and inward, rolled over onto their sides. In this position, with a large mucus mass issuing from the fully extended foot, the snails drifted shorewar	Tidal flats at Pierces, Delaware Ray, Cape May County (New Jersey, USA)	Shuster, 1951
	Mya arenaria	1	Drifting (tidal ebb)	Indeed, many of the 2-4 mm. clams spent part of their journey downstream out of contact with the flat, their movement being a combination of rolling and jumping. ... Within 5 minutes 89.4% of the total number of clams were in the trap, and at the end of 3	Fishery Laboratory in Boothbay Harbor (Maine, USA)	Baptist, 1955 (reported results of a study performed in 1953)
	Bulinus truncatus, B. forskalii, Biomphalaria alexandrina, Lymnaea [=Radix] natalensis *Melanoides tuberculata, Cleopatra bulinoides [=bulimoides]* *Lanistes carintus [=carinatus], Pila ovata*	Regularly	Downstream drifting	Out of a total of 6477 snails caught in the samplers, 2654 were *Bulinus (B.) truncatus* and 205 were *Biomphalaria alexandrina.* Besides these two species, the following snails were also trapped: …	Gezira Canal, 7 km downstream from the Sennar Dam on the Blue Nile (Sudan)	Rahman & Sharaf ed Din, 1961 (study performed during 1959-60)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Ancylastrum fluviatile [=Ancylus fluviatilis], Potamopyrgus jenkinsi [=P. antipodarum]* *Limnaea [=Lymnaea* spp.], others	*A f.* 0.45%, *P. a.* 4.74% *L.* spp. + others 0.12%	Downstream drifting	The results of thirty samples taken during 1961 in the River Yarty are summarized in Table I, to show the percentage composition of drift.	River Yarty (east Devonshire, UK)	Bailey, 1966 (reported results of a study performed in 1961)
	Biomphalaria alexandrina, Bulinus truncatus	6.13% of 1,044 *B. alexandrina,* 0.7% of 428 *B. truncatus* released	Downstream drifting	The snails, which were marked with white nail polish, were found 750 m downstream after 30 minutes, 3 km after 5 hours, 3 ½ and 4 km after 1 day and 5 km after 9 days.	Qafla Canal, Alexandria, (Egypt)	Dazo *et al.,* 1966 (reported results of a study performed in 1962)
		3.2% of 2,526 *B. alexandrina,* 0% of 528 *B. truncatus* released	Downstream drifting	Half an hour after the release of snails in lot (c), two *Biomph. alexandrina* were observed floating 650 m downstream from the point of release.	Khatt el Nar Canal, Alexandria, (Egypt)	
	Australorbis glabratus [=Biomphalaria glabrata]	-	Downstream drifting	For *Australorbis glabratus,* a velocity exceeding 33 cm/sec at shell height produces a hydrodynamic drag force sufficient to dislodge the snail from its position on the solid boundary of a canal.	Hydrodynamics Laboratory, Department of Civil Engineering, Massachusetts Institute of Technology (Cambridge, USA)	Jobin & Ippen, 1964
	Stagnicola palustris nuttalliana, Physa [=Physella] propinqua	Regularly	Downstream drifting	Maximum dislodgment from sand was obtained as soon as a velocity of 1 ft/sec was established. Dislodgment fromn clay at low velocity showed wide fluctuation; for example, more snails were dislodged from clay at 0.5 ft/sec than at 2.0 ft/sec (Fig. 4).	Laboratory of the Department of Zoology, Washington State University (Washington, USA)	Moore, 1964
	Mussels, freshwater gastropods	Occasionally	Downstream drifting	[Mollusc quantitative distribution is influenced by flooding events. Mussels populations have been found washed down along the river for several kilometers. Freshwater gastropods where less affected by floods.]	Danube River (Slovakia, Hungary)	Richnovszky, 1982 (reported results of a study performed during 1964-66)
	Hydrobia [=Peringia] ulvae	Regularly	Drifting (tidal ebb)	… submerged *Hydrobia* about 2 mm long were capable of detaching from a shore object and drifting horizontally in the tide, neither gaining nor losing height.	Ythan Estuary, (Scotland, UK)	Anderson, 1971 (reported observations during 1966-67)
	Macoma balthica	Regularly	Drifting (tidal ebb)	Sufficiently large numbers of *Macoma* of this age and size to account for this immigration were found to be transported by tidal currents over distances up to some five or ten kilometers during the periods January to April inclusive.	Western part of the Wadden Sea (the Netherlands)	Beukema, 1973
	Hydrobia [=Peringia] ulvae	-	Drifting (tidal ebb)	Many *Hydrobia* were observed being swept along the sediment surface by the flooding tide: dispersal over considerable distances appeared to be achieved passively by this means.	Cockle Bight (TF 798 467), on Scolt Head Island, (north Norfolk, UK)	Barnes, 1981 (reported results of a study performed in 1978-79)
	Physa [=Physella] gyrina	533,000 specimens per m^3/s	Downstream drifting	Daily drift of up to 533,000 *P. gyrina* Say per m^3/s was observed in a small, second-order stream in southwestern Minnesota (USA).	Fort Ridgely Creek, Nicollet and Renville counties (Minnesota, USA)	Marsh, 1980
	Biomphalaria glabrata, Lymnaea peregra [=Radix balthica], Lymnaea stagnalis *Planorbis [=Anisus] vortex, Planorbis planorbis, Bulinus jousseaumei, Physa fontinalis*	-	Downstream drifting	The range of maximum velocities endured by a variety of species (adult snails) investigated here spans between 0.70 and 0.86 m/sec	Oxford University laboratory	Dussart, 1987 (reported results of a study performed in 1985)
	Macoma balthica	Regularly	Drifting (tidal ebb)	From these points it only can be deduced that in the upper part of the flat (B3), the 0-group of the bivalve consisted mainly of immigrating post-larvae. For this reason the small stages found here in May may be individuals that settled in the deeper part	Intertidal sandflat south of the Island of Borkum (53° 35' N, 6° 45' E), Ems estuary, German Bight, North Sea (Germany)	Günther, 1991 (reported results of a study performed in 1986)
	Bulinus globosus	Regularly	Downstream drifting	After releasing the snails into the water, most of them sank immediately to the bottom, while some floated away with the current. After 5 minutes these snails had drifted 12 m.	Stream located some 18 km NE of Ifakara, in the village of Kikwawila (Tanzania)	Marti & Tanner, 1988
	Gemma gemma	1 (smallest larva measured was 272 X 295 µ)	Drifting larvae	*Gemma* is viviparous and the larvae are retained in the mantle cavity of the adult until they are ready to metamorphose. As a result larvae occur in the plankton only on rare occasions as after particularly heavy storms, when recently liberated specimens a	Malpeque Bay, Prince Edward Island (Canada)	Sullivan, 1948 (reported results of a study performed in 1945)
	Gemma gemma	1	Drifting larvae	Gem clam juveniles were found in all of the 12 traps which were set out for 1-2 weeks, the openings of which were covered with screening having an aperture size ranging from 360-670 µ. The "catch" of the 3 most successful traps totalled 113 *Gemma.*	-	Carriker in Sellmer, 1967 (reported results of a study performed in 1955)
	Gemma gemma	1	Drifting larvae	… 20 liters of water passing over a sand bar were collected by dipping the wave crests to avoid disturbing the bottom sediments and strained through a No. 18 plankton net. ... Fifteen juvenile *Gemma,* lengths ranging from 330-510 µ, were found in the sampl	Union Beach (New Jersey, USA)	Sellmer, 1967 (reported results of a study performed in 1956)
	Limpet spp. juv.	Regularly	Drifting larvae	In addition, the presence of unidentified juvenile limpets (Table I) in off-bottom collectors suggests that drifting plays a role in the life history of some limpet species found in the study area (see Vahl, 1971, 1983).	Prasiola Point, Bamfield Marine Station (48° 50' N, 125° 08' W), Barkley Sound, Vancouver (British Columbia, Canada)	Martel & Chia, 1991a (reported results of a study performed during 1988-89)
	Dreissena polymorpha	Regularly	Drifting larvae	... the results indicate that (1) *Dreissena* larvae are able to survive their passage through the waterfalls at Schaffhausen, and (2) these middle-sized larvae from September are large enough to reach their final size during downstream transportation ...	River Rhine down to the waterfalls at Schaffhausen (Germany and Switzerland)	Borcherding & de Ruyter van Steveninck, 1992 (1990 survey)
	Zebra mussel *(Dreissena polymorpha)*	1	Drifting larvae	Moreover, pediveligers and plantigrades were detected in the plankton and on freshly developed substrates in the spring of 1991. There is reason to believe that these observations represented the movement of post-larvae from overwintering populations rath	Lake Erie, Ontario (Canada)	Ackerman & Claudi, 1992 (reported results of a study performed in 1991)
	Zebra mussel *(Dreissena polymorpha)*	1	Drifting larvae	Only the presence of veliger larvae in the plankton samples were recorded for this part of the study. ... Primary dispersal occurs through the pelagic state by transport of the veligers and post-veligers by lake currents.	Great Lakes region (North America)	Mackie, 1991
	Zebra mussel *(Dreissena polymorpha)*	Regularly	Drifting larvae	Plankton samples taken near collectors also confirmed the presence of postmetamorphic stages in the water column. Most drifting juveniles ranged from about 300 µm shell length to 800 µm (some up to 1–2 mm).	Shallow-water area (2–7 m) near Wheatley, Lake Erie (Canada)	Martel, 1993 (reported results of a study performed in 1991)
	Zebra mussel *(Dreissena polymorpha)*	Regularly	Drifting larvae	Juvenile translocators were first found during weekly inspections at the end of April 1992, when water temperature exceeded 8°C ... Later in the summer, juveniles - 1 mm in length were found in plankton tows, indicating that mussels could be resuspended i	Lake Erie, Ontario (Canada)	Claudi *et al.,* in Ackerman *et al.,* 1994 (study performed in 1992)
	Dreissena polymorpha	Regularly	Drifting larvae	Abundance in terms of larvae/s were similar for both years with an estimated 1.935 x 10^{14} larvae passing by our site in 1994, and 2.131 x 10^{14} larvae passing by in 1995 … larvae produced throughout the year ... would likely travel a minimum of 304.6 km (1	Illinois River between Lake Michigan and the confluence with the Mississippi River (Illinois, USA)	Stoeckel *et al.,* 1997 (reported results of a study performed during 1994-95)
	Bulla Fontinalis [=Physa fontinalis]	Regularly	Drifting threads	... transports itself by adhering to the surface of the water, with the shell downwards: against which it crawls with as much apparent ease as on a solid body; and will sometimes let itself down gradually by a thread affixed to the surface of the water, .	-	Montagu, 1803

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Bombyxinus uva, B. melanostoma [=Litiopa melanostoma]*	Regularly	Drifting threads	[... I found on this plant *(Fucus natans),* some small molluscs that I can not relate to any known species. ... I often saw the molluscs remaining suspended over a long distance by an imperceptible thread, like that of a small spider. This thread started f	24° 32' Latitude, 55° 14 Longitude West, Atlantic ocean, offshore Terranova Island (Canada)	Bélanger in Lesson 1831 (reported an event observed in 1826)
	Rissoa parva	Regularly	Drifting threads	*Rissoa parva* has the power of emitting a glutinous thread, by which it attaches itself to floating sea-weeds, and is enabled, when displaced, to recover its previous position.	-	Gray, 1833
	Polycera quadrilineata nonlineata	Regularly	Drifting threads	When placed in a phial of sea-water, they were generally to be seen suspended by their threads from the surface, the body at the same time moving freely about with much grace.	In an aquarium	Thompson, 1840
	Nudibranchs	Occasionally	Drifting threads	While floating in this manner the nudibranchs occasionally drop suddenly down, suspending themselves from the surface by a thread of mucus, which is fixed to the tail or posterior extremity of the foot.	In an aquarium	Alder & Hancock, 1845
	Polycera Lessonii [=Palio dubia]	Regularly	Drifting threads	It is not an active animal, and when kept in a glass, may be seen suspended by a film of mucous matter from the surface of the water for hours together. It also frequently hangs in the water by its tail, which it spreads out on the surface as a float.		
	Cyclas lacustris [=Musculium lacustre]	1	Drifting threads	One of them also commenced crawling on the under surface of the water. Its foot was now spread out very widely, after the fashion of the Limnæadæ; and, while preparing for its exploit, it was apparently kept near the surface by a minute thread fastened to	In a small pool close to the church of St. Erme, near Truro (Cornwall, UK); in an aquarium	King, 1845
	Limnea [=Lymnaea] stagnalis	Regularly	Drifting threads	A *Limnea stagnalis* had glided its way along a young and short leaf of the *Vallisneria* which terminated below the surface of the water, and having reached the extremity launched itself off from it; …	In an aquarium	Warington, 1852 (reported a series of observations made in 1849)
	Limnea [=Mixas] glutinosa	Regularly	Drifting threads	On another occasion a *L. glutinosa* gradually rose from the surface of a piece of submersed rock, and when at the distance of about 3 or 4 inches from it stayed its progress, floating about in a circumscribed horizontal direction for some time; …		
	Planorbis [spp.], *Neritina [=Theodoxus] fluviatilis, Physa fontinalis*	Regularly	Drifting threads	… the thread or web which some species of the freshwater snail form to effect or facilitate their passage from one spot or object to another, ... I have now to state that the varieties of *Planorbis,* as also *Neritina fluviatilis* and *Physa fontinalis,* have,	In an aquarium	Warington, 1854
	Young cyclades *[=Sphaerium, Musculium],* young Pisidia *[=Pisidium]*	Regularly	Drifting threads	The young Cyclades and Pisidia are very active, climbing about submerged plants and often suspending themselves by byssal threads;	-	Woodward, 1854
	Valvata piscinalis	Regularly	Drifting threads	[Several individuals who laid a thick mucus on the surface of the water, were forced to drop to the bottom. They descended slowly down or remained hanging by a thread in the mucus of the floating plate.]	-	Laurent in Moquin-Tandon, 1855
	Aplysiopterus [=Elysia] viridis	Regularly	Drifting threads	Its favourite position is floating rather below the surface of the water, back downwards and with the edges of the mantle expanded nearly horizontally, … leaving a mucous filament attached to the glass; and it ascends by this filament, apparently eating i	Swanage Bay, Dorset (England, UK); in an aquarium	Gray, 1859
	Doris amabilis [=Chromodoris aspersa]	Occasionally	Drifting threads	At night it crawls out of its hiding place and creeps along the sides of the glass, and is sometimes seen floating on the surface of the water on its back.	In an aquarium	Kelaart, 1859
	Alaba picta	Regularly	Drifting threads	The creature spins, with great rapidity, a pellucid thread from a viscous secretion emitted from a gland near the end of the tail, and swims, shell downwards, at the surface of the water.	-	Adams, 1862
	Sphærium lacustre [=Musculium lacustre]	1	Drifting threads	Dr. Lukis afterwards informed me that he had detected the byssal filament in *S. lacustre.* He says, "I have this morning watched one, which had reached the surface, spin its filament, and descend to half an inch below the surface, where it remained suspend	In an aquarium	Lukis in Jeffreys, 1862
	Kellia suborbicularis	Regularly	Drifting threads	The byssal sinus is about halfway up the foot on the posterior side; and from it the animal produces a very delicate thread, and suspends itself freely (with the beaks of its shell downward) by a single almost inconspicuous fibre, which is strengthened by	-	Alder in Jeffreys, 1863
	Crenella decussata	Regularly	Drifting threads	They seemed fond of getting to the surface of the water, when the *Crenella* would spin with its foot a single pellucid thread, which it fixed to the side of the vessel, and it would hang (like a *Sphærium)* for hours thus suspended, the beaks of the shell be	-	Jeffreys, 1863
	Limopsis aurita			On reaching the top it spun with its foot a very fine and almost transparent but tenacious thread, the end of which it fixed to the inside rim of the vessel; and it remained for twelve hours thus suspended, with the beaks of its shell downwards.		
	Cyclas [=Sphaerium]	Regularly	Drifting threads	... making vigorous use of its foot, progressing by sudden jerks, performing a rotary motion in the water by forced ejectments of it, floating by its foot in contact with the under surface of the water, and even suspending itself by a few byssus-like thre	-	Reeve, 1863
	Lacuna	Occasionally	Drifting threads	They occasionally secrete slimy threads (like the *Limax arborum),* by which they suspend themselves from the frond or stalk of a seaweed; and they may sometimes be observed floating in a reversed position, the sole of the foot being on a level with the sur	-	Jeffreys, 1865
	Mitra saltata	Regularly	Drifting threads	When disturbed, the animal would skip 5 or 6 inches in a horizontal line, from one side of the cavity to the other, at the same time spinning out a very fine web. When held in the hand, it would jump off, suspending itself by a thread to a distance of 2 o	-	Pease, 1865
	Rissoa striatula [=Alvania carinata], R. [=A.] cancellata, R. abyssicola [=A. testae], R. parva	Regularly	Drifting threads	… sole grooved down the middle for about half its length towards the tail, whence it emits a glutinous thread by which the animal suspends itself to foreign bodies or to the surface of the water: ...	-	Jeffreys, 1867 Alder in Jeffreys, 1867 *(Pleurotoma nebula)*
	R. membranacea, R. [=Zebina] vitrea, R. [=Setia] pulcherrima, R. [=Eatonina] fulgida					
	Barleeia rubra [=unifasciata], Jeffreysia [=Rissoella] diaphana			[all these species are able to suspend themselves from the surface of the water by a viscous thread]		
	Skenea [=Skeneopsis] planorbis, Homalogyra [=Omalogyra] atomus, Pleurotoma [=Bela] nebula					
	Eulima intermedia [=Melanella polita], Cerithium [=Bittium] reticulatum					

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Odostomia Warreni [=Ondina warreni]*	1	Drifting threads	One individual spun a fine glutinous thread from the middle of the sole of the foot, and kept itself suspended for some time from the surface of the water, with the point of the shell downwards.	St. Magnus Bay and near Fetlar (Shetland Islands, UK)	Jeffreys, 1868
	Lima elliptica	1	Drifting threads	One of my largest specimens moored itself to the side of a glass vessel in which it was kept, by two threads as fine as any that spiders spin; and it was thus held suspended in the water.	In an aquarium	Jeffreys, 1869
	Physa [=Aplexa] hypnorum, Physa fontinalis, Limnæa [=Omphiscola] glabra *L. [=Lymnaea] stagnalis, L. [=Stagnicola] palustris, L. [=Radix] peregra, L. [=Mixas] glutinosa*	Regularly	Drifting threads	The method of anchoring these threads to the surface of water is singular: a minute concavity at the upper end acts like a small boat—of air, and thus sustains the thread.	-	Tye, 1874
	Pectinibranchs, nudibranchs	Regularly	Drifting threads	The pectinibranchs, … both fluviatile and marine, often suspend themselves from the surface of the water or from a floating object, by a thread, but do not ascend by it again. The same remarks apply to the nudibranchs.		
	Bythinia tentaculata	Regularly	Drifting threads	This snail suspends itself by a thread, after floating, which is usually attached to the surface of the water.		
	Physa [=Aplexa] hypnorum	Regularly	Drifting threads	When in deep water (though it naturally prefers shallow, and loves to crawl, foot upwards, on the surface) it will frequently spin a web of slime (byssus) and so rise perpendicularly to the surface, and having taken the required supply of air, turn leisur	In an aquarium	Jeffery, 1882
	Ancylus lacustris [=Acroloxus lacustris]	1	Drifting threads	"I have just been watching a young specimen of *Ancylus lacustris* spinning a downward thread."	-	Cockerell in Taylor, 1883
	Rissoa	Regularly	Drifting threads	*Rissoa* is active and bold, floats like its congeners, and spins a byssal thread instantaneously on being detached from a crawling position.	-	Tryon, 1883
	Lymnæidæ	Occasionally	Drifting threads	… and sometimes may be observed gliding, shell downwards, on the surface of the water, anchoring or letting themselves down occasionally by means of a glutinous thread.	-	Tryon, 1884
	Segmentina lineata [=nitida]	1	Drifting threads	… he has observed a specimen spinning a downward thread from the surface of the water to the bottom of the bell-jar.	In a ditch at Barnes (Greater London, UK); in an aquarium	L. M. C. Cockerell in Cockerell, 1885
	Litiopa	Regularly	Drifting threads	[These small molluscs live in abundance on *Sargassum* to which they adhere by one or more filaments up to one meter in length. Once suspended, if their anchoring breaks, they emit an air bubble surrounded by a glutinous secretion, which rises to the water	-	Fischer, 1887
	Lepton	Regularly	Drifting threads	[... they can also move along the surface of the water in an inverted position. Sometimes they are found hanging by a few hyaline filaments.]		
	Mya arenaria	1	Drifting threads	… young clams adhering in great numbers to the surface of floating timbers … a few individuals were found from which a single byssal thread was found to proceed, invariably from the point where the tip of the foot is thrust through the median opening in t	New Bedford (Massachusetts, USA)	Ryder, 1889 (reported an event observed in 1888)
	Limnæa [=Myxas] glutinosa	Regularly	Drifting threads	It seems extremely light in the water, and often floats about at random and if disturbed instead of quickly sinking like *L. peregra* I have seen it gently rise to the top. … Mucous threads are seen in the jar connecting weed to weed, and sometimes even dec	Skidby Drain, about a mile from Hull (Yorkshire, UK); in an aquarium	Fierke, 1890
	Sphærium corneum	Regularly	Drifting threads	As the animals seek higher levels they come to the surface film of the water and there anchor, depressions in the film due to their suspension being easily seen even without a lens.	In an aquarium	Crowther, 1894 (reported an observation made in 1893)
	Eolis [=Facelina] coronata	Frequently	Drifting threads	… frequently observed in *Eolis,* —this is its suspension by means of a thread of mucus, from a globule of the same, which, entangled with air, floats on the surface; …	-	Sinel, 1894
	Valvata piscinalis	1	Drifting threads	... to crawl up the side of a glass vessel nearly to the surface of the water; they then gave one or two twisting motions, and crawled out on the under surface of the water, leaving a thread joining them to their point of departure. They then either sank	The Grange neighbourhood, Hereford (Herefordshire, UK)	Boycott, 1895
	Limnaea [=Lymnaea], Physa, Planorbis, Bithynia tentaculata, Cycladidae [=Sphaeriidae]	Periodically	Drifting threads	The threads are 'spun' by several species of *Limnaea, Physa,* and *Planorbis,* by *Bithynia tentaculata,* and several of the Cycladidae. They are anchored to the surface by a minute concavity at the upper end, which appears to act like a small boat in keeping	-	Cooke, 1895
	Cyclas cornea [=Sphaerium corneum]	Frequently	Drifting threads	This species, which is particularly fond of crawling along the under surface of the water, has been noticed to spin a thread half an inch in length while on the surface, and to hang suspended from it for a considerable time.		
	Limnæa [=Lymnaea] stagnalis	1	Drifting threads	The tracks of the *Limæa* were quite distinct on the lower surface of the water-film, and were visible to us as straight paths, six to eight feel long, and half-an-inch wide, of whitish iridescent slime.	Tag Lock, Calder Vale (Lancashire, UK)	Crowther, 1896
	Mya arenaria	Regularly	Drifting threads	… the free-swimming embryos attach themselves to foreign objects, such as the seaweeds *(Enteromorpha* and *Ulva),* eelgrass, stones, and other bodies, …	Narragansett, Woods Hole and Buzzards bays (Rhode Island, USA)	Kellogg, 1899 (reported observations made in 1898)
	Runcina hancocki [=coronata], Limapontia nigra [=capitata], Doto coronata *Eolis [=Eubranchus] farrani, E. drummondi [=Facelina bostoniensis]* *Skenea [=Skeneopsis] planorbis, Rissoa striata [=Onoba semicostata], R. parva* *R. cingillus [=Cingula trifasciata], Modiolaria [=Musculus] discors*	Regularly	Drifting threads	Of the 18 County Dublin species placed under observation by me last year no less than 10 were seen to climb up along their suspensory slime-threads to the water surface from which they had descended; …	Dublin county (Ireland); in an aquarium	Colgan, 1909 (reported results of a study performed in 1908)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Hydrochory - 169 references	*Mercenaria mercenaria*	Regularly	Drifting threads	... the byssal stage, in which the animal alternates byssal fixation with crawling on a still highly effective motile foot. Thus in the presence of adverse localized environmental factors the clam can move a short distance and possibly avoid the negative	New Jersey, New York, and North Carolina; Institute of Fisheries Research Laboratory, Morehead City (USA)	Carriker, 1961 (reported results of a study performed during 1947-56)
	Corbicula	Regularly	Drifting threads	The byssal holdfast thread of juvenile *Corbicula* (Fig. 5), allows the animals to populate a shifting, sandy river bottom …	Arkansas River from mile 283 near Fort Smith to mile 43 near Mud Lake (Arkansas, USA)	Kraemer, 1979 (reported results of a study performed during 1974-75)
	Macoma balthica	Regularly	Drifting threads	Floating behaviour among responding mussels began with burrowing displacements as their foot was directed towards the sediment surface. ... In many specimens thin threads were observed that originated from the posterior side of the base of the foot where	Wadden Sea mudflats (52° 55' N, 40° 50' E), the Netherlands; Netherlands Institute for Sea Research laboratory, Texel	Sörlin, 1988 (reported results of a study performed in 1982)
	Transennella tantilla	Regularly	Drifting threads	*Transennella tantilla* initially resubmerged more rapidly in containers with eel grass, and a higher proportion of juveniles than of adults remained suspended for a longer period of time ... *Transennella tantilla* is capable of attaching to objects with bys	False Bay, San Juan Island; Friday Harbor Laboratories, San Juan Island, Washington (USA)	Highsmith, 1985 (reported results of a study performed during 1982-84)
	Mytilus edulis	Regularly	Drifting threads	Preliminary laboratory drifting trials with *Mytilus edulis* have confirmed the existence of the post-larval drifting phenomenon observed by Sigurdsson *et al.* (1976). … Terminal drifting velocities for 500 to 700 μm and 1000 to 1100 μm post-larvae are of th	Marine Science Laboratories, Menai Bridge, Anglesey (UK)	Lane *et al.,* 1985
	Corbicula fluminea	Regularly	Drifting threads	Within 10 minutes, several of the clams produced long mucous threads which extended from their exhalent siphons; these clams then floated out of the pan.	Black River near Brooklyn (Mississippi, USA)	Prezant & Chalermwat, 1985
	Musculus sp., *Lasaea* sp., *Transennella tantilla*	Regularly	Drifting threads	The mechanism(s) that enables the brooding bivalve *Musculus* sp., *Lasaea* sp. and *Transennella tantiila* to drift in the water column was not determined, although preliminary experiments suggest that drifting in these taxa involves the use of long microscopi	Prasiola Point, Bamfield Marine Station (48° 50' N, 125° 08' W), Barkley Sound, Vancouver (British Columbia, Canada)	Martel & Chia, 1991a (reported results of a study performed during 1988-89)
	Barleeia spp., *Tricolia pulloides, Nucella emarginata* juv., *Littorina sitkana* juv.	Regularly	Drifting threads	Experiments conducted in a flow tank and in a wave tank revealed that mucous threads are involved in the drifting of the gastropod *Barleeia* spp., *Tricolia pulloides,* as well as in the early juvenile stages of *Nucella emarginata* and *Littorina sitkana* Phili		
	Macoma balthica	Regularly	Drifting threads and tidal ebb drifting	Thread drifting in juvenile *Macoma balthica* results in massive displacements in winter when the turbulent tidal currents serve as the transporting agent.	Wadden Sea and North Sea off the West-Frisian island Terschelling (the Netherlands); Sea Research laboratory	Beukema & de Vlas, 1989
	Zebra mussel (*Dreissena polymorpha*)	Regularly	Drifting threads	*Dreissena polymorpha* may also use thin threads, which originate from the siphon or foot, to contact the surface and float from these (Kirpichenko 1971; J. D. Ackerman, personal observation in August 1990).	-	Ackerman in Ackerman *et al.,* 1994 (reported observations performed in 1990)
	Planorbis [=Planorbarius] corneus	Regularly	Drifting threads	Then it unfastened itself from the leaf and started floating, leaving an ever longer thread behind the tail, the distal end of the thread being fastened to the top of the leaf (Fig. 6C, 2,3).	Laboratory	Deliagina & Orlovsky, 1990
	Zebra mussel (*Dreissena polymorpha*)	1	Drifting threads	Enhanced transport by thread drifting has been demonstrated in several marine bivalve species … Although similar behaviour has been observed in *D. polymorpha* held in laboratory aquaria (Ron Griffiths, pers . comm.), …	In laboratory aquaria	Griffiths in Mackie, 1991
	Lacuna variegata, Lacuna vincta	Regularly	Drifting threads	The mucus produced and accumulated at the posterior of the sole of the foot is then taken away with the water current, and stretched up to 160 times the length of the gastropod. The mucous thread pulled by water currents then transports the gastropod, ena	Barkley Sound (48' 50' N, 125' 08' W), Vancouver Island, British Columbia (Canada); Bamfield Marine Station laboratory	Martel & Chia, 1991b
	Cerastoderma edule	Regularly	Drifting threads	During the sorting of cockles at the beginning of experiments and sometimes during flume experiments, byssal threads could be observed protruding out of the shell.	Arcachon Bay (France); Laboratory	de Mountaudouin, 1997 (reported results of a study performed during 1993-94)
	Ruditapes [=Venerupis] philippinarum			Clam juveniles, however, also produced byssal filaments which were tightly entangled when stored at high densities.		
	Corbicula fluminea	Regularly	Drifting threads on recreational boats	[… the strong dispersal observed in August is related to passive transportation through recreational boats to which they attach via mucous threads …]	Lateral canal of the Garonne River (France)	Dubois, 1995
	Corbicula fluminea	-	Drifting threads	The results show that changes in water temperature, at least at high ranges (above 20°C), affect the production of the mucous drogue line by *C. fluminea* and its drifting behavior, thus possibly influencing dispersal patterns with consequences on populatio	Six Mile Run creek, (N40°28.166', W74°32.620'), New Jersey; Montclair State University Laboratory (USA)	Rosa *et al.,* 2012
Ectozoochory: Mollusca - 2 ref.	*Pupa umbilicata [=Lauria cylindracea]*	1	*Helix virgata [=Cernuella virgata]*	… he saw a full-grown chrysalis-shell *(Pupa umbilicata),* not yet aroused from torpor, securely fastened to a specimen of *Helix virgata*—the zoned-snail—which was crawling out after a shower; …	Clifton, Bristol (England, UK)	Musson in Kew, 1893
	Neritina asperulata [=Neripteron asperulatum], Neritina petitii, N. sp. 3	Regularly, 71 *N. a.* juv. attached on 11 *N. p.* subadults	*Neritina pulligera*	Small juveniles of *N. asperulata* (< 5 mm in maximum shell length, MSL) were found almost exclusively (98.6%) on the shells of *N. pulligera,* an abundant, large-sized congeneric species with upstream migration behaviour (figure 1b,c; Kano 2006).	Five streams and rivers on Guadalcanal (Solomon Islands) and Santo (Republic of Vanuatu)	Kano, 2009
Ectozoochory: Insecta - 108 references	*Ancylus*	1	*Dyticus* [sic *Dytiscus*]	… a *Dyticus* has been caught with an *Ancylus* (a fresh-water shell like a limpet) firmly adhering to it; …	-	Lyell in Darwin, 1859
	Pisidium	1	Water bug (Nepomorpha)	[A water bug collected in a water body in Mexico was found with a *Pisidium* fixed to one of its appendices,]	Mexico	Heynemann in Kobelt, 1871
	Small mussel	1	*Dytiscus**	I saw on the bank a few inches from the water a *Dytiscus* beetle, which to my surprise made no effort to escape. On closer inspection, I found that a small mussel, about half an inch across, had attached itself to one of the beetle's antennae, and held on	-	Wood Green, 1874
	Ancylus fluviatilis	More than once	*Acilius sulcatus*	… I have found young specimens of this slow mollusk adhering to an active flying water-beetle, the *Acilius sulcatus.*	On the coast of Jersey, between tide-marks	Duprey, 1876
	Sphaerium corneum	1	Water scorpion *(Nepa)*	A specimen with a small *Sphærium corneum* on one of its legs, …	Mere Mere, Cheshire now in the Manchester Museum (England, UK)	Walken in Kew, 1893 (reported an event observed in 1879)
	Cyclas cornea [=Sphaerium corneum]	1	*Dytiscus marginalis*	Shortly after the shell had detached itself, the beetle dived to the bottom of the vessel, was again caught for a few minutes.	In an aquarium	Darwin, 1882
	Cyclas cornea [=Sphaerium corneum]	1	*Dytiscus marginalis*	… he caught a female *Dytiscus marginalis,* with a shell of *Cyclas cornea* clinging to the tarsus of its middle leg.	In a pond	Crick in Darwin, 1882

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Insecta - 108 references	*Cyclas cornea?* *[=Sphaerium corneum?]*	Frequently	Water beetle	… informs me that the larger water-beetles and newts in his aquarium "frequently have one foot caught by a small freshwater bivalve *(Cyclas cornea ?)*, …	In an aquarium in Sparham, near Norwich (England, UK)	Norgate in Darwin, 1882
	Sphaerium corneum	1	*Dytiscus marginalis**	… the first specimen, netted in 1883 with a full-grown shell clinging to one of its legs, was slowly flying along in Mill Lane, Goosnargh, about five hundred yards from the nearest pond, …	Mill Lane Goosnargh, Lancashire (England, UK)	Standen (1883) in Kew, 1893; also in Standen, 1885
	Pomatias elegans	1	Humble-bee [=bumblebee]*	… a humble-bee has been seen with an operculate land-shell holding on to one of its legs in a similar manner.	-	F. W. T. (1885) in Kew, 1893; also in Rees, 1965
	Small mussels	-	*Dytiscus*	Some frogs, and a *Dytiscus,* with small mussels clinging to their legs, …	-	Some boys writing to Darwin in Standen, 1885
	Sphaerium corneum	1	*Dytiscus marginalis*	… with a shell of good size firmly clasping the extremity of one of the front legs, …	In a pond at Woodford, Essex (England, UK)	Oldham in Kew, 1893 (reported an event observed in 1886)
	Molluscs	A number	*Notonecta*	Mr. Whitelegge exhibited a number of water insects *(Notonecta),* with small mollusks attached to their legs, …	-	Whitelegge, 1886
	Vitrina	1	Coleoptera	… a Coleopterous insect, carrying on one of its elytra a specimen of a land-snail *(Vitrina).*	Mount Archer near Rockhampton, Queensland (Australia)	Musson, 1890 (reported an event observed in 1887)
	Sphaerium corneum	1	*Dytiscus marginalis*	I procured a female *Dytiscus marginalis* with a *Sphærium corneum attached* to its right front tarsus.	In a pond at West Barkwith, Lincolnshire (England, UK)	Kew, 1888
	Sphaerium corneum	1 with 2 shells	*Dytiscus marginalis**	… on the wing, a specimen which was carrying two shells, one being of good size and the other small; the nearest pond, he thinks, was about one hundred and fifty yards distant.	Moor Side, Swinton near Manchester (England, UK)	Standen in Kew, 1893 (reported an event observed in 1888)
	Pisidium fontinale *[=Pisidium casertanum?]*	2, each one with 1 shell	Water scorpion *(Nepa)*	… two others, collected by Mr. Hardy in 1889, each carrying a shell of *Pisidium fontinale* upon a leg of the hind pair, are also possessed by the Museum.	In the Manchester Museum (England, UK)	Hardy in Kew, 1893 (reported an event observed in 1889)
	Ancylus fluviatilis	1	*Dytiscus marginalis**	Mr. Standen, who was fortunate enough to detect a shell of *A. fluviatilis* upon one of the wing-cases of a *Dytiscus* caught on the wing after dusk on the evening of May 8th, 1890, at Birch, near Manchester, about fifty yards from the nearest water.	At Birch, near Manchester (England, UK)	Standen in Kew, 1893 (reported an event observed in 1890)
	Shell *[Sphaerium corneum?]*	1	Beetle *[Dytiscus]*	… and a further case, in which a small shell was attached to one of the hind legs of the beetle, was observed by Mr. Standen, in June, 1890, …	In a pond at Birch, Manchester (England, UK)	
	Sphærium [=Musculium] lacustre	1	*Dytiscus marginalis*	A specimen of *Dytiscus marginalis* with a shell of *Sphærium lacustre* clinging to one of the front legs was caught by Mr. Standen, in a pond at Gorton, in 1890.	In a pond at Gorton (England, UK)	
	Sphaerium corneum	1	Dragonfly larva	The larva of a dragon-fly with a shell of *Sphærium corneum* clinging to one of its legs was once caught at Twenty Pits, near Manchester, …	Twenty Pits near Manchester (England, UK)	Kew, 1893
			Water scorpion *(Nepa)*	… another specimen (preserved in spirit) having attached to it a much larger shell of the same species;	In the Manchester Museum (England, UK)	
	Ancylus [=Acroloxus] lacustris	1 with 3 shells	*Dytiscus marginalis*	… that Mr. Hardy once found a specimen of *Dytiscus marginalis* with three shells of *A. lacustris* adhering to the wingcases, one on the left and two on the right side.	-	Hardy in Kew, 1893
	Bythinia [=Bithynia] tentaculata	1	Aquatic larva of a dragonfly	… with one foot firmly held between the operculum and lip of a specimen of *Bythinia tentaculata,* …	-	
	Bivalve	1	Water beetle	… clinging of bivalves to the antennae of water-beetles ...	-	
	Pisidium fontinale *[=Pisidium casertanum?]*	1	*Acilius*	A beetle belonging to the allied genus *Acilius* with a shell of *Pisidium fontinale* on one of the legs of the second pair has been presented to the Manchester Museum by Mr. Hardy.	Presented to the Manchester Museum (England, UK)	
	Sphaerium corneum	1	Water beetle *Dytiscus*	I had the good fortune to catch a specimen with a shell upon the right front leg in a pond at West Barkwith, Lincolnshire, in August, 1888 (Fig. 3). Mr. W. H. Heathcote found another specimen with a shell similarly attached …	Farington, Lancashire (England, UK)	Heathcote in Kew, 1893
	Ancylus fluviatilis egg-capsule	1	*Acilius*	Mr. Standen informs me that he once saw, in the Hollinwood canal, an egg-capsule of the river-limpet *(Ancylus fluviatilis)* attached to one of the wing-cases of an *Acilius,* a strong flying water-beetle.	Hollinwood Canal, Greater Manchester (England, UK)	Standen in Kew, 1893
	Pisidium fontinale *[=Pisidium casertanum?]*	1	Water scorpion *(Nepa)*	… a specimen with *P. fontinale* attached, …	In a pond near Birch Hall, Manchester (England, UK)	
	Pisidia	2, 1 with 2 shells	Water beetle	… two water-beetles with Pisidia attached were obtained by Mr. Whitelegge (now of the Australian Museum) when collecting, years ago, in Lancashire; in one of the cases two shells were clinging to the same insect, one on each side.	Lancashire (UK)	Whitelegge in Kew, 1893
	Pisidium etheridgei	Frequently, 1 with 3 shells	*Notonecta* and *Corixa*	Mr. Whitelegge has frequently noticed hemipterous insects, both *Notonecta* and *Corixa,* laden with bivalves: three specimens of *Pisidium etheridgei* have been seen attached to one insect, one on each fore-leg and one on the snout.	In the vicinity of Sydney (Australia)	
	Ancylus parallelus *[=Ferrissia parallela]*	1	*Dytiscus*	The other, a *Dytiscus,* collected in October, 1898, carried an *Ancylus parallelus* Hald., 5 x 2.5 mm., near the end of the left elytron.	Wellesley (Massachusetts, USA)	Morse in Johnson, 1904 (reported an event observed in 1898)
	Ancylus [=Laevapex] fuscus	1	*Dinutes* [sic *Dineutus*] (whirligig beetle)	One a *Dinutes* (whirligig beetle), collected April 26, 1900, has an *Ancylus fuscus* Adams, 4 x 2.5 mm., situated dorsally and extending about equally over each elytron;	Wellesley (Massachusetts, USA)	Morse in Johnson, 1904 (reported an event observed in 1900)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Insecta - 108 references	*Cyclostoma [=Pomatias] elegans*	1	Bumblebee*	… it was a huge bumble-bee with one of its hind legs held firmly between the shell and the operculum of a fine specimen of *Cyclostoma elegans,* …	In a lane near Upper Beeding, West Sussex (England, UK)	Stalley, 1911 (reported an event observed in 1907)
	Cyclostoma [=Pomatias] elegans	1	Bumblebee*	… the bee proved to have one of its hind tarsi firmly wedged between the shell and operculum of a full grown *Cyclostoma elegans.*	At the foot of Lord's Wood on the Great Doward Hill, a little below Symond's Yat, Herefordshire (England, UK)	le Brockton Tomlin, 1910
	Pisidium pusillum [Pisidium spp.]	A large number, some with 2 shells	*Corixa*	The *Corixa* were very lively and were nearly all furnished with a shell holding by the grip of its valves to the hind leg, and usually to the trasi [sic tarsi] of the insect; in several instances there were two shells, being one to each hind leg.	In a small reservoir situated at an elevation of nearly 1,000 feet at Crag Vale, West Halifax, Yorkshire (England, UK)	Walsh in Cash, 1912
	Pisidium	-	Water beetles	… water beetles carrying *Pisidium* …	-	Peacock (1917) in Fernando, 1954
	Ancylus sp. (*Ancylus [=Ferrissia] baconi?)*	1 with a considerable numbers of shells	Dytiscid beetle	… a large dysticid [sic dytiscid] beetle the elytra of which were covered with a species of *Ancylus* in considerable numbers.	In the canal at Cuttack in Orissa (India)	Annandale *et al.,* 1921
	Helicodiscus parallelus, Gastrocopta pentodon, Vertigo gouldii, Striatura milium, Striatura ferrea *Punctum pygmaeum minutissimum, Paravitrea multidentata, Hawaiia minuscula* *Zonitoides arboreus, Zonitoides nitidus, Retinella burringtoni [=Glyphyalinia wheatleyi]* *Retinella [=Glyphyalinia] rhoadsi*	6 with numerous shells attached	Larvae of Hemerobiidae	The larvae of certain *Neuropterous* insects of the family Hemerobiidae have the peculiar habit of covering themselves with a protective mat of ... At first it appeared that the shells were just massed together but when I went to pick them up the shell mass	In woods near Weston, Lewis; French Creek, Upshur and Parsons, Tucker (West Virginia, USA)	MacMillan, 1939
	Small clams	Often	Nymphs of Corixidae	Nymphs are often seen in awkward association with small clams, with the minute shells clamped on the long abdominal fringes or flipping along on the tip of a leg;	In an aquarium	Griffith, 1945
	Renea moutoni	1	Large bee*	I have already experienced another case of such a passive dispersal, that of the southwest European acmid shell *Renea moutoni* Dupuy sticking to a leg of a large bee caught while flying in the air.	-	Haas, 1947
	Ancylus fluviatilis	Several, 1 with 21 shells	*Dytiscus marginalis*	[… transport of 21 *Ancylus fluviatilis* Müller by a female *Dytiscus marginalis* L. …]	Richelieu, Indre-et-Loire (France)	Buttner (1953) in Rees, 1965
	Pisidium nitidum	6	Corixidae	… six Corixidae were captured, four on 23 January and two on 7 March, 1954, each with a small bivalve attached to one leg.	In a pond at Radley, Oxfordshire (England, UK)	Fernando, 1954
		20 out 50 during a week; 25 out 50, 1 carried 2 shells	*Corixa punctata, Sigara distincta, S. striata, S. fossarum, S. lateralis*	In the course of a week 20 Corixidae acquired bivalves on their legs *[Corixa punctata* (Illig.), *Sigara distincta* (Fieb.), *S. striata* (L.), *S. fossarum* (Leach) and *S. lateralis* (Leach) (nomenclature of Macan (1939)]. 25 of the water bugs carried a single *P*	In an aquarium	
	Pisidium spp.	1	*Corixa puntata* [sic *punctata]*	Records of small bivalves of the family Sphaeriidae found nipped on the legs of aquatic beetles	Hadley Green, Hertfordshire (England, UK)	Lansbury (1955) in Rees, 1965
	Ancylastrum vitraceum [sic *vitraceus, =Ancylus fluviatilis]*	1	*Melodema coriaceum [=Meladema coriacea]*	-	Banyuls (France)	Theodorides (1961) in Rees, 1965
	Pisidium sp.	1	*Laccobius biguttatus*	[… gave me a *Laccobius biguttatus* Gerh. which had attached to his right hind leg a pea clam *(Pisidium* sp.) …]	Zell-Pfarre, Carinthia (Germany)	Schaeflein in Stöckel, 1987 (reported an event observed in 1963)
	Lævapex [=Laevapex] fuscus	1 with 2 shells	*Cybister occidentalis**	Two living specimens of *Lævapex fuscus* (C. B. Adams) (nomenclature of Basch, 1959 and 1963) were found attached to the outer surface of the elytra of a large (33 mm) dytiscid water beetle, *Cybister occidentalis* Aubé, taken in a light-trap …	At the Archbold Biological Station, Highlands County (Florida, USA)	Rosewater, 1970 (reported an event observed in 1967)
	Ancylidae	-	Water beetle	Transport of Ancylidae by a water-beetle	Surinam	van Regteren Altena, 1968
	Pisidium milium, P. nitidum	ca. 20% of thousands of specimens with 1 or 2 shells	*Sigara lateralis*	Both adult and nymphal bugs carried these small bivalves which were invariably attached to the slender claws borne by the tarsi of the second pair of legs.	Village pond at Huggate (Yorkshire, UK)	Fryer, 1974 (reported an event observed in 1973)
	Sphaerium corneum	1	*Colymbetes fuscus*	[... in which the left middle leg was in a shell.]	In a pond in Liebenberg, Kreis Gransee (Germany)	Stöckel, 1987 (reported an event observed in 1973)
	Sphaerium corneum	1	*Cybister lateralimarginalis*	[… a female of *Cybister lateralimarginalis* whose left front leg was stuck in a shell.]	In a pond in Liebenberg, Kreis Gransee (Germany)	Stöckel, 1987 (reported an event observed in 1974)
	Musculium lacustre	1	Dragonfly nymph	*M. lacustre* was found clamped onto the tarsal claws of a dragonfly nymph (Fig. 2).	Guelph, Ontario (Canada)	Mackie, 1979
	Dreissena polymorpha	1	*Onychogomphus forcipatus* exuviae	[… *Onychogomphus forcipatus* exuviae stuck to a few mm in size zebra mussel *(Dreissena polymorpha* Pall.).]	Müritzufer (Germany)	Schaeflein in Stöckel, 1987 (reported an event observed in 1982)
	Dreissena polymorpha	1	*Gomphus vulgatissimus* exuviae	[… wrote to me (letter 1984) that he noticed the same phenomenon on *Gomphus vulgatissimus* L., exuviae which he had collected in the Spree.]	In the Spree (Germany)	Beutler in Stöckel, 1987 (reported an event observed in 1984)
	Acroloxus lacustris	1 with 3 shells	*Dytiscus dimidiatus*	[… on its right elytra were found attached 3 specimens of *Acroloxus lacustris* L. …]	-	Donath (1986) in Stöckel, 1987

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Insecta - 108 references	Little bivalve	1 with 3 shells	*Dytiscus dimidiatus*	[… once caught a *Dytiscus* in Altenkirchen, whose left leg was stuck in a little bivalve …]	Altenkirchen (Germany)	Fichtner in Donath (1986) in Stöckel, 1987
	Sphaerium (Musculinum) tasmanicum [=Musculium (Sphaerinova) tasmanicum]	21 out of 152 adults (13.82%); 1 out of 57 nymphs (1.75%)	*Sigara (Tropocorixa) truncatipala*	… 152 adults of both sexes and 57 nymphs of the ultimate (last, 5th) instar were found. Of the adults, 21 specimens were found to carry one or two mussels on their leg, ... On the other hand, nymphs seem to be free of infestation. Only a single specimen (	Pool located at the end of Marysville golf course near Buxton Raad about 3.5 km from Marysville (Australia)	Soldán *et al.,* 1989 (reported events observed in 1987)
		1	*Austrolestes cingulatus* nymph	We found a single nymph of the last instar carrying one mussel on the claws of metathoracic leg …		
		1 out of 52 specimens (1.92%)	*Sigara (Tropocorixa) truncatipala*	… among the aquatic weeds only a single case of phoresis between adult female of *Tropocorixa* and immature *Sphaerium* was found …	Dam reservoir near the junction of the Steavenson and Taggerty river about 4 km N of Marysville (Australia)	
	Sphaerium	-	*Sigara*	… that he had observed cases of *Sigara-Sphaerium* assotiation [sic association] only in rock-pools near Tvärmine, …	Tvärmine, South Finland	Jansson in Soldán *et al.,* 1989 (reported events observed before 1989)
	Dreissena polymorpha	1	*Gomphus pulchellus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Kuhgrien gravel pit lake (Baden-Württemberg, Germany)	Foidl (1990) in Weihrauch & Borcherding, 2002
	Dreissena polymorpha	-	*Gomphus vulgatissimus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	River Spree? (Germany)	Beutler (1991) in Weihrauch & Borcherding, 2002
	Dreissena polymorpha	2	*Gomphus vulgatissimus* exuviae	… a zebra mussel attached to the vertex of the head ...	Lake Wuckersee, Schorfheide, Brandenburg (Germany)	Mauersberger in Weihrauch & Borcherding, 2002 (observed in 1992)
	Dreissena polymorpha	1 larva with 2 shells attached	*Gomphus vastus* larva	This larva identified as *Gomphus vastus* Walsh (Huggins & Brigham, 1982) was firmly attached to the twig and the encrusting zebra mussels by byssal threads of the mussels.	Mississippi River, 0.8 km E of Grafton (NW'/4 Sec 145 T6N, RI2W), Jersey County, Illinois (USA)	Tucker & Camerer, 1994 (reported an event observed in 1993)
	Dreissena polymorpha	1	*Orthetrum cancellatum* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Lake Jezioro Białe near Okunince, Central Poland	Tonczyk (1995) in Weihrauch & Borcherding, 2002
	Dreissena polymorpha	1	*Orthetrum cancellatum* exuviae	… an exuviae of *Orthetrum cancellatum* from Lac d'Annecy, an oligotrophic alpine lake, in mid-June carrying a mussel with 10 mm side length …	Lake Annecy (Haute Savoie, France)	Bal *et al.* in Weihrauch & Borcherding, 2002 (observed in 1996)
	Dreissena polymorpha	1	*Orthetrum cancellatum* exuviae	The exuviae, which was found in the bank vegetation at a height of about 30 cm and 80 cm from the shore, carried one specimen of *D. polymorpha* attached to the dorsal side of the abdomen, covering segments 6-10.	Lower Rhine River ox-bow channel south-east of Rees (6° 30' E, 51° 42' N), North Rhine-Westphalia (Germany)	Klostermann in Weihrauch & Borcherding, 2002 (observed in 1997)
	Dreissena polymorpha	3	*Onychogomphus* f. *forcipatus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Lake Krummer, Köllnsee, Schorfheide, Brandenburg (Germany)	Mauersberger in Weihrauch & Borcherding, 2002 (observed in 1997)
	Dreissena polymorpha	1	*Gomphus vulgatissimus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	River Oder near Lebus, Brandenburg (Germany)	Müller in Weihrauch & Borcherding, 2002 (observed in 1997)
	Dreissena polymorpha	1	*Epitheca princeps* exuviae	… he spotted the dragonfly exuvia illustrated in the accompanying photograph. What made him take a second look was the zebra mussel *Dreissena polymorpha* attached to its side!	Clear Lake, Peterborough County, Ontario (Canada)	Ness in Anonymous, 1998 (reported an event observed in 1997)
	Pisidia	-	Rove beetle (Staphylinidae)	[… pea clams (pisidia) clipped to the maxilla of a rove beetle (Staphylinidae) …]	-	Gittenberger *et al.* (1998) in Mildner & Happ, 2007
	Dreissena polymorpha	3	*Gomphus vulgatissimus* exuviae	… three exuviae of *G. vulgatissimus,* each carrying a specimen of *D. polymorpha* tightly attached to the dorsum of the abdomen, were collected at a small gravel pit lake …	A small gravel pit lake near Geisenfeld, Upper Bavaria (Germany)	Weihrauch, 1999 (reported an event observed in 1998)
	Pisidium nitidum	1	*Sigara falleni*	I was surprised to find a specimen of *Pisidium nitidum* clamped to the mid tarsal claw of a female corixid bug *Sigara falleni.*	A pond on great Bookham Common, Surrey (map reference TQ 1256) (England, UK)	Carr, 1999
	Dreissena polymorpha	1	*Oxygastra curtisii* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Lake Annecy (Haute Savoie, France)	Bal in Weihrauch & Borcherding, 2002 (reported an event observed in 2000)
	Dreissena polymorpha	1	cf. *Hagenius brevistylus* larva	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	St. Croix National Scenic River, mile 7.5 (Wisconsin, USA)	Kams & Rowse in Weihrauch & Borcherding, 2002 (observed in 2000)
	Dreissena polymorpha	1	Onychogomphus f. *forcipatus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Lake Helenesee near Frankfurt (Oder), Brandenburg (Germany)	Müller in Weihrauch & Borcherding, 2002 (observed in 2000)
	Dreissena polymorpha	4	*Epitheca princeps* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Clear Lake, Peterborough County, Ontario (Canada)	Ness in Weihrauch & Borcherding, 2002 (reported events observed in 2000)
	Dreissena polymorpha	1	*Gomphus vulgatissimus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Datteln-Hamm-Kanal near Hamm, North Rhine-Westphalia (Germany)	Postler & Postler (2000) in Weihrauch & Borcherding, 2002
	Dreissena polymorpha	1	*Cordulia aenea* exuviae	The exuviae, which clung to the lower side of a leaf of *Carex* sp. at a height of 80 cm, 20 cm from the shore, carried one specimen of *D. polymorpha* attached to the ventral side of the abdomen, covering segments 6-8.	Gravel pit lake near Geisenfeld (11° 37' E, 48° 43' N), Brandenburg (Germany)	Weihrauch in Weihrauch & Borcherding, 2002 (observed in 2000)
	Dreissena polymorpha	Half dozen with a few shells, 1 larva with 13 shells attached	*Didymops transversa* larvae	… he found a half dozen larvae that had more than a few zebra mussels attached.	Otter Lake (Michigan, USA)	Chriscinscke, 2001
		1	*Dromogomphus spinosus* not a final instar	… have found one dragonfly larva *(Dromogomphus spinosus* - not a final instar) bearing one zebra mussel.		

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Insecta - 108 references	*Dreissena polymorpha*	1	*Dromogomphus spinosus* exuviae	I saw a *Dromogomphus spinosus* exuviae with a zebra mussel on the shore of Burt lake, …	Burt Lake (Cheboygan County, Michigan, USA)	O'Brien, 2005 (reported an event observed in 2001)
	Dreissena polymorpha	1	*Gomphus vulgatissimus* exuviae	… dragonfly larvae or exuviae with attached zebra mussels *Dreissena polymorpha* ...	Datteln-Hamm-Kanal NSG Beversee, North Rhine-Westphalia (Germany)	Postler & Postler in Weihrauch & Borcherding, 2002 (observed in 2001)
	Dreissena polymorpha	1 out of 40 exuviae with 1 shell attached	*Epitheca princeps* exuviae	... one of 40 exuviae of *Epitheca princeps* found 30 cm above the water level along the wall of a marina at Presqu'ile Bay (44.0188 N, 77.7276 W, Northumberland county) had a zebra mussel firmly attached near the lateral edge of the dorsal surface of abdom	Presqu'ile Bay (44.0188 N, 77.7276 W), Northumberland Co., Ontario (Canada)	Catling, 2003 (reported an event observed in 2002)
	Dreissena polymorpha	1	*C.* [sic *Epitheca*] *cynosura* (common baskettail)	Zebra mussel attached to an exuvium of *C. cynosura* (common baskettail) was sent by K. Dewey.	Downstream from the Outlet River bridge in Sandbanks Provincial Park (43.89198 N, -77.21731 W), Ontario (Canada)	Dewey in Catling, 2004 (reported an event observed in 2003)
	Dreissena polymorpha	-	Dragonfly larvae	At this site, zebra mussels were first observed on dragonfly larvae in the lake in 2003 (B. Scholtens, pers. comm.).	Douglas Lake (Michigan, USA)	Scholtens in Fincke *et al.,* 2009 (reported observations performed in 2003)
	Dreissena polymorpha	*Didymops* (89 out of 149: 60%), *Hagenius* (116 out of 157: 74%)	*Didymops transversa, Hagenius brevistylus* sprawlers	The highest percentage of colonization by zebra mussels in the 2005 sample were on the sprawlers *Hagenius* (74%) and *Didymops* (60%), …	Douglas Lake at the University of Michigan Biological Station (UMBS, 45"350N, 84"420W) near Pellston (Michigan, USA)	Fincke *et al.,* 2009 (reported results of a study performed in 2005)
		P. o. (2% of 458), *D. s.* (3% of 581), *E. p.* (10% of 17)	*Progomphus obscurus, Dromogomphus spinosus, Epitheca princeps* exuviae	… all of the *Progomphus* and *Epitheca,* and 97% *Dromogomphus* that were colonized carried only a single zebra mussel;		
	Acroloxus lacustris	1	*Aeshna cyanea* exuviae	[… I saw a small bump over the epiproct of an *Aeshna cyanea* specimen, which revaled to be an *Acroloxus lacustris* shell attached to the exuvia ...]	Ljmuiden (the Netherlands)	Kuijper, 2005; also in Kuijper, 2013
	Dreissena polymorpha	Many instances	*Hagenius brevistylus* (dragonhunter) instars	… there were many *Hagenius brevistylus* (dragonhunter) trying to emerge and dying at the water's edge, when they could not break free from the coating of zebra mussels *(Dreissena polymorpha)* from the final larval instar.	Douglas Lake, Michigan (USA)	Myers in O'Brien, 2005
	Dreissena polymorpha	1	*Epitheca princeps* exuviae	The attached photo shows a skin of *Epitheca princeps* with zebra mussels attached.	Keuka Lake, New York (USA)	Sibley reported to Donnelly in O'Brien, 2005
	Laevapex fuscus	2, 1 with 3 shells	Water bugs *(Belostoma flumineum)*	… we captured two water bugs *(Belostoma flumineum)* with freshwater limpets *(Laevapex fuscus,* a type of snail) attached to their backs.	Southeastern Michigan (USA)	Bernard, 2006
	Dreissena polymorpha	*H. brevistylus:* 2 out of 11 (18%) *D. transversa:* 1 out of 48 (2%)	*Hagenius brevistylus, Didymops transversa* exuviae	The frequency of *H. brevistylus* with mussels was 18% (N=11) and the frequency of *D. transversa* with mussels was found to be 2% (N=48).	Douglas Lake in Pellston (Michigan, USA)	Bienek & Hickner, 2007
	Dreissena polymorpha	63% of the 51 larvae had 1 to 8 shells attached	Odonata larvae	Fifty-one larvae were collected and the majority (63%) had been colonized by one or more zebra mussels. Some dragonfly larvae were heavily infested, carrying up to 8 zebra mussels and more than their own mass in attached zebra mussels.	North America	McCauley & Wehrly, 2007
	Dreissena polymorpha	*E. princeps,* 1 to 7 shells attached, *E. cynosura* 1 shell attached	*Epitheca princeps, E. cynosura* exuviae	Only the *E. princeps,* 35 exuviae or 30%, and *E. cynosura,* 1 exuviae or 5%, had zebra mussels attached. Most individuals had only 1 mussel but 12 had more with 5 and 7 being the maximum counts. … The one *E. cynosura* with an attached mussel had it on the pr	Keuka Lake approximately 6 miles south of Penn Yan, Yates County, New York (USA)	Sibley, 2007
	Dreissena polymorpha	1	*Leucorrhinia caudalis* exuviae	… an exuvia of *Leucorrhinia caudalis* with a zebra mussel *(Dreissena polymorpha)* attached to the ventral side of its metathorax was found ...	In a gravel pit near Karlsruhe (south-west Germany)	Schiel, 2009 (reported an event observed in 2008)
	Dreissena polymorpha	2 out of 23	*Macromia illinoiensis* larvae	… two of the 23 studied dragonfly larvae (9%) were each colonized by one zebra mussel.	Douglas Lake at the University of Michigan Biological Station (43° 35' N, 84° 42' W) near Pellston (Michigan, USA)	Hughes, 2010 (reported results of a study performed in 2009)
		21 out of 23	*Macromia illinoiensis* larvae	During the five-day colonization experiment, 21 of the 23 studied larvae (91%) were colonized by at least one mussel.	In an aquarium	
	Dreissena polymorpha	-	*Macromia illinoiensis* larva	Larval members of *Macromia illinoiensis,* a sprawling odonate, are known to suffer from direct colonization by *Dreissena polymorpha,* ...	-	Tylczak & Fincke, 2009
	Ferrissia fragilis	1	*Aeshna cyanea* larva	[Southern hawker *Aeshna cyanea* larva with *Ferrissia fragilis]*	Fuveau, Bouches-du-Rhône (France)	Adriaens, 2012 (reported an event observed in 2011)
	Ancylus fluviatilis, Acroloxus lacustris	1 with 19 *A. fluviatilis* and 1 *A. lacustris* specimens	*Dytiscus semisulcatus* or *D. dimidiatus [=Dytiscus marginalis]**	Also of note on the night, was a spectacular looking diving beetle attracted to one of the MV traps. ... Twenty freshwater limpets can be seen in the photograph. Most are *Ancylus fluviatilis,* with a single specimen of *Acroloxus lacustris* near the outer ma	Lynford Hall, Norfolk (NGR TL8293, England UK)	Wheeler, 2009; also in Driscoll, 2011
	Zebra mussel *(Dreissena polymorpha)*	Regularly	Dragonfly nymphs	Even larval insects, like these dragonfly nymphs, may fall victim to zebra mussels.	Great Lakes, region, North America (USA)	Sternberg, 2011
	Dreissena polymorpha	1 with one shell, the second with several shells attached	*Hagenius brevistylus* larvae	Dragonfly larvae *(Hagenius brevistylus)* with attached zebra mussels	-	jjneal, 2012
	Dreissena polymorpha	1	Dragonfly exuviae	… on another exuvium from Sfantu Gheorghe, Rumania a specimen of *Dreissena polymorpha* was found.	Sfantu Gheorghe (Romania)	Kuijper, 2013 (reported an event observed in 2012)
	Dreissena rostriformis bugensis	*2 G. vulgatissimus* exuviae, 1 *O. cancellatum* exuvia	*Gomphus vulgatissimus* exuviae *Orthetrum cancellatum* exuviae	Individuals of *Dreissena rostriformis bugensis,* ... were reported from two exuviae of *Gomphus vulgatissimus* … and from an exuvia of *Orthetrum cancellatum* …	Datteln-Hamm-Kanal near Bergkamen, North Rhine-Westphalia (Germany)	Postler *et al.,* 2012
	Dreissena polymorpha	1 with several attached shells	*Neurocordulia* exuviae	Dragonfly larvae with attached zebra mussels	Ohio River near Owensboro (Kentucky, USA)	Society for Freshwater Science, 2012
	Sphaerium [=Musculium] lauricochae	7, 1 with 2 shells	*Ectemnostega quechua*	Seven specimens of *Ectemnostega (Ectemnostegella) quechua* Bachmann, 1961 (Heteropta: Corixidae) were found carrying fingernail clams (Fig. 2).	A small reservoir located at 16° 59' 33.43" S, 68° 04' 30.83" W, 3,993 m AMSL (Bolivia)	Zelaya & Marinone, 2012

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Crustacea - 28 references	*Cyclas fontinalis [=Pisidium casertanum?]*	Several	*Astacus fluviatilis [=Astacus astacus]*	[… crayfishes that I withdrew through nets were all hanging small molluscs belonging to the genus *Cyclas* and to the species *Cyclas fontinalis* at the ends of their deambulatory legs ...]	In ponds in the environs of Brie-Comte-Robert (Seine-et-Marne, France)	Girard, 1859
	Dreissena polymorpha	Frequently	Crayfish	[… the animal is able to detach the filaments by which it fixes itself to other objects, and that it is frequently found attached to the tail of crayfishes.]	Germany	Rossmäessler, 1864
	Pisidium	1	Shrimp	… in a large bell-glass, which he used as a sort of aquarium, a *Pisidium* on one occasion fastened its valves tightly upon one of the maxillipedes of a shrimp.	In an aquarium	Jenkins in Kew, 1893
	Helix rotundata [=Discus rotundatus]	1	Woodlouse	… the same observer saw one of our common little snails, *Helix rotundata,* riding about on the back of a woodlouse, …	Lambley Dumbles, near Nottingham, Nottinghamshire (England, UK)	Musson in Kew, 1893
	Dreissena polymorpha	-	*Astacus astacus*	-	Poland	Kulmatycki (1932) in Ďuriš *et al.,* 2007
	Dreissena polymorpha	-	*Potamobius [=Astacus] leptodactylus*	Organisms whose bodies served as suitable substrates for *Dreissena* appeared to be negatively affected. These included the crawfish, *Potamobius leptodactylus,* and unionid mussels.	Lake Balaton (Hungary)	Sebestyén, 1938
	Dreissena polymorpha	1	*Orconectus limosus*	… from a single specimen, a male (TL 95 mm) of *O. limosus* caught in the Maine Departement, France.	Maine (France)	Laurent & Suscillon (1962) in Laurent, 1994
	Dreissena polymorpha	-	*Astacus leptodactylus cubanicus*	The zebra mussel had attached itself to a variety of areas of the chitinized covering of the crayfish: to the rear surface of the claw; to the surface of the carapace; to the dorsal and ventral surfaces of the abdomen; and to the surface of the eye.	Rostov Province (Russia)	Lamanova (1971) in Ďuriš *et al.,* 2006
	Sphaeriidae	1	*Orconectus* sp.	Williams (1981) [sic 1982] found pea mussels (Sphaeriidae) which where glued to the legs of a crayfish *(Orconectus* sp.).	-	Williams (1982) in Nijboer & Verdonschot, 2006
	Freshwater pearl mussels glochidia Amblemidae	-	Palaemonid shrimp	… but glochidia are also found infected tadpoles (Seshaiya, 1941; Walker, 1981), a salamander (Howard, 1951) and a palemonid shrimp (Panha, unpublished), as well.	-	Panha, 1990
	Dreissena polymorpha	30 specimens ca.	Crayfish	-	Lake Erie (North America)	Carlton (1993) in Ďuriš *et al.,* 2007
	Dreissena polymorpha	Limited number	*Orconectus limosus*	I observed again a limited number of *Orconectus limosus* with *Dreissena polymorpha* in the Lake of Geneva.	Lake of Geneva (Switzerland)	Laurent, 1994
	Dreissena polymorpha	6 out of 25-50 crayfishs (12-24%) with 16 to 431 shells	*Orconectes rusticus*	… six rusty crayfish *(Orconectes rusticus)* colonized with zebra mussels *(Dreissena polymorpha)* were captured … Colonization ranged from 16 to 431 zebra mussels per crayfish, …	Peter's Marsh and Long-Tail Point Wetland in lower Green Bay (Wisconsin, USA)	Brazner & Jensen, 2000 (reported an event observed in 1995)
	Dreissena polymorpha	-	*Orconectes limosus*	… *Dreissena polymorpha* epibiotic on *Orconectes limosus* …	-	Anwand, 1996
	Dreissena polymorpha	6 out 600 (1%)	*Orconectus limosus*	… recorded the occurrence of zebra mussels attached to *O. limosus* from the Dąbie Lake, Poland …	Dąbie Lake (Poland)	Śmietana (1996) in Ďuriš *et al.,* 2006
	Dreissena polymorpha	1	*Procambarus clarkii*	[... a crayfish *(Procambarus clarki* [sic *clarkii])* was found, an alien species as well, that recently colonised the Lake Trasimeno, with a juvenile zebra mussel attached to an abdomen sternite;]	Polvese Island jetty, Trasimeno Lake (Italy)	Spilinga *et al.,* 2000
	Golden mussel *(Limnoperna fortunei)*	1 specimen with 1? shell attached	*Aegla platensis*	... the settlement of the golden mussel on native species, such as specimens of ... the crab *Aegla platensis* Schmitt (Anomura, Aeglidae) …	Argentina	Darrigran, 2002
	Dreissena polymorpha	-	Crayfish	Although the mussel has been observed on UK crayfish (senior authors unpublished studies) it was not found during the present study.	United Kingdom	Rogers *et al.,* 2003
	Dreissena polymorpha	1	*Orconectes pardalotus*	Zebra mussels *(Dreissena polymorpha)* were found attached to the left ventral surface of pleuron 3 of a form I female *O. pardalotus* (CL = 36.0 mm) collected at the Joppa site on 12 October 2003.	Ohio River at Joppa (Illinois, USA)	Wetzel *et al.,* 2005 (reported an event observed in 2003)
	Dreissena polymorpha	1 out 274 specimens with 1-4 shells attached	*Orconectes luteus*	Sites INHS 7256 [1 with a zebra mussel, *Dreissena polymorpha,* attached when collected], INHS 9104 [1 with 4 zebra mussel, *Dreissena polymorpha,* attached when collected], MCZ 47131 [1 with a zebra mussel, *Dreissena polymorpha,* attached when collected]	Mississippi River (Illinois, USA)	Wetzel *et al.,* 2004
	Dreissena polymorpha	4 out 4 carried shells in summer 2004; 15 out of 16 in spring 2005	*Orconectes limosus*	... 42 crayfish specimens collected ... in 2004, and 16 specimens in April 2005. Each of the four crayfish caught at the beginning of summer 2004 carried the mussels. ... small juvenile mussels were observed in autumn... In spring 2005, almost all crayfis	In the flooded sandpit Lhota near Brandýs nad Labem (Czech Republic)	Ďuriš *et al.,* 2006; also in Ďuriš *et al.,* 2007; (events during 2004-05)
	Gastropod eggs	-				
	Dreissena polymorpha	1	Crayfish	Crayfish overcome by zebra mussels	Great Lakes region, North America	Hager, 2005
	Dreissena polymorpha	1	*Orconectus limosus*	… *D. polymorpha* specimens attached to the dorsal carapace of *O. limosus* from Croatia.	Croatia	Lajtner *et al.* (2005) in Ďuriš *et al.,* 2006
	Dreissena polymorpha	1	Crayfish	Adult mussels secrete durable elastic strands, called byssal fibers, which attach to almost anything that floats, such as boat hulls, crayfish, or turtles. … crayfish covered with zebra mussels …	North America	Finley, 2006
	Golden mussel *(Limnoperna fortunei)*	1 specimen with 62 shells attached	*Aegla platensis*	One live individual of *A. platensis* (25.5 mm tail to head; 2.8 g) was colleted [sic collected] carrying 62 individuals (30.4 g) of *L. fortunei,* ...	São Gonçalo channel, Mirim Lagoon (Brazil)	Lopes *et al*., 2009 (reported results of a study performed in 2008)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Crustacea 28 references	*Dreissena polymorpha*	End members: 0 out of 200 and 7 out of 168 (4.17%) *specimens*	*Procambarus clarkii*	Despite the rarity of the phenomenon (0 to 4.17% of crayfish with attached mussels; Table 1), 32% of crayfish colonized had more than one mussel.	Trasimeno Lake (Italy)	Gonçalves *et al.*, 2013 (reported events observed during 2011-2012)
		1	*Procambarus clarkii*	In the laboratory, after a period of 5 days, only one mussel was found attached to a male crayfish measuring 30.7 mm, in the proximity of the antennules (Figure 1A).	In an aquarium	
	Limnoperna fortunei	2 specimens with 1 and 2 shells attached respectively	*Trichodactylus borellianus*	… we collected two specimens of *Trichodactylus borellianus* with one and two live individuals of *L. fortunei* attached to their dorsal carapaces, respectively ...	Alejandra lake, Coronda River (31° 43' 21" S, 60° 47' 43" W, Argentina)	Molina & Williner, 2013
Ectozoochory: Amphibia Anura & Caudata - 65 references	*Tellina cornea [=Sphaerium corneum]*	1	Common newt *(Lacertus aquaticus) [=Lissotriton vulgaris]*	… having a small shell-fish *(tellina cornea)* attached to one or all of its feet;	-	Knapp, 1829
	Cyclas cornea [=Sphaerium corneum]	1	Toad	… the middle toe of one of the hind feet was firmly held between the valves of a mollusk about half an inch in diameter, …	In a fish-pond near Forebridge?, Stafford (England, UK)	Douglas, 1851b
	Cyclas cornea [=Sphaerium corneum]	A number, some with 3 shells	Toads	Some of the toads had as many as three shells on each of the hind feet, …	In a pond near Warrington?, Cheshire (England, UK)	Peers, 1865
	Pisidium	1	Newt	[I caught a newt whose jaw was grasped by pisidiums]	-	Heynemann, 1870
	Cyclas cornea [=Sphaerium corneum]	1	Frog*	A few days since, a living frog was brought to me with a full-sized specimen of this shell-fish attached to one of its toes, …	Upon a bank by the side of a canal	Riches, 1877
	Cyclas cornea [=Sphaerium corneum]	1	Frog*	… and found on the bank a frog which appeared to have been lately killed; and to the outer toe of one of its hind legs a living shell of the same species was attached.	In a pond	Crick in Darwin, 1882
	Cyclas cornea? [=Sphaerium corneum?]	Frequently	Newts	… informs me that the larger water-beetles and newts in his aquarium "frequently have one foot caught by a small freshwater bivalve *(Cyclas cornea?)*, ...	In an aquarium in Sparham, near Norwich (England, UK)	Norgate in Darwin, 1882
	Cyclas lacustris (?) [=Musculium lacustre (?)]	1	Newt, frog	One of these cockles, I observed, had attached itself to the foot of a newt, and another was enclosing the toe of a frog.	In ponds in the neighbourhood of Louth, Lincolnshire (England, UK)	Goulding, 1885
	Sphaerium	1	Frog	… and another, having an immature *Sphærium* upon one of its toes, was seen by the Rev. S. Spencer Pearce, in 1885, …	At low water on the south bank of the Thames between Putney and Hammersmith bridges (England, UK)	Pearce in Kew, 1893 (reported an event observed in 1885)
	Sphaerium corneum	1	Frog	Mr. Standen, in a letter published in 1885, mentioned that he had often found these amphibians with shells of *S. corneum* attached, and he has favoured me with a note of a case observed subsequently in a lake at Drinkwater Park, near Prestwich.	In a lake at Drinkwater Park, near Prestwich (England, UK)	Standen in Kew, 1893 (reported events observed in 1885)
	Limnæa peregra [=Radix balthica]	1	Toad*	I once captured a toad that was tramping leisurely along the roadside, in the dusk of evening, with a full-grown *Limnæa peregra* on its back. ['about twenty yards from the water' as quoted by Kew, 1893]	-	Standen, 1885 also in Kew, 1893
	Sphaerium corneum	Often	Newts, frogs, toads	I have often seen the toes of newts, frogs, and toads firmly grasped by small bivalves *(Sphærium corneum).*	-	Standen, 1885
	Sphaerium corneum	1 with 4 shells	Warty newt *(Triton cristatus) [=Triturus cristatus]*	I caught a fine warty newt *(Triton cristatus),* with four Sphæriums firmly attached to its toes, …	In a ditch at Goosnargh, Lancashire (England, UK)	Standen, 1885; also in Kew, 1893
	Small mussels	-	Frogs	Some frogs, and a *Dytiscus,* with small mussels clinging to their legs, …	-	Some boys writing to Darwin in Standen, 1885
	Sphaerium corneum	1	Newt*	In 1886, a newt, with a shell of *Sphærium corneum* upon its right fore foot, was discovered by Mr. Hardy at the base of a wall at Dunham Massey, Cheshire, between the grass and the wall, and about ten yards from the water of a small pond, which it appeared	Dunham Massey, Cheshire (England, UK)	Hardy in Kew, 1893 (reported an event observed in 1886)
	Sphaerium corneum	2	Newts	… and Mr. Heathcote on two occasions in 1889 found shells of *S. corneum* attached to the toes of newts at Farington, Lancashire.	Farington, Lancashire (England, UK)	Heathcote in Kew, 1893 (reported an event observed in 1889)
	Sphaerium corneum	Many instances	*Molge vulgaris, [=Lissotriton vulgaris] Molge cristata [=Triturus cristatus]*	… as also has Mr. Standen, who informed me in 1890 that for many years he had not missed taking either smooth or great warty newts *(Molge vulgaris* or *M. cristata)* with shells of this species upon their feet.	-	Standen in Kew, 1893 (reported events observed prior 1890)
	Sphaerium corneum	4, 1 with 4 shells	*Molge vulgaris, [=Lissotriton vulgaris] Molge cristata [=Triturus cristatus]*	In 1890, in ponds in the neighbourhood of Manchester, he met with four instances, three with *M. vulgaris* and one with *M. cristata:* in one case, in a pond at Birch, a newt had four shells clinging to it, two on one hind foot, and one on each of the fore fe	In ponds in the neighbourhood of Manchester (England, UK)	Standen in Kew, 1893 (reported an event observed in 1890)
	Sphaerium corneum	1 with 2 shells	Newt*	… upon the toes of a newt which was making its way across a field, and apparently proceeding from one pond to another; when discovered it was nearly mid-way between two ponds, which are about one hundred and fifty paces [1 pace = 0.75 m] apart.	-	Henshall in Kew, 1893 (reported an event observed in 1891)
	Sphaerium corneum	1	Toad	… when a number of toads were spawning in the " leg-of-mutton " pond on Hampstead Heath, I fished out an individual with a fine shell of the same kind on a toe of one of the hind legs (Fig. 5).	"Leg-of-mutton" pond on Hampstead Heath, London (England, UK)	Kew, 1893
	Sphaerium corneum	Frequently	Newts	… he was a boy dabbling with aquaria he had occasionally met with this bivalve clinging to newts; the same has been frequently observed by Mr. L. E. Adams in ponds in the South of England, …	In ponds in the South England (UK)	Adams in Kew, 1893
	Sphaerium corneum	Many instances	Newts	… he was a boy dabbling with aquaria he had occasionally met with this bivalve clinging to newts; the same has been frequently observed by Mr. L. E. Adams in ponds in the South of England, and Mr. Hardy, during his long experience as a collector, has obse	Preserved in the Manchester Museum (England, UK)	Hardy in Kew, 1893
	Sphaerium corneum?	Several	Common frog *(Rana temporaria temporaria ?)*	Mr. Hardy in the course of his collecting has observed several similar instances.	-	

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Amphibia Anura & Caudata - 65 references	*Ancylus [=Acroloxus] lacustris*	1	Frog*	A small living shell of *Ancylus lacustris* was detected by Mr. Baker Hudson adhering to one of the legs of a frog caught, hopping through the grass by the side of a footpath, in Cowpen Marsh, County Durham, perhaps thirty yards from the nearest water, the	Cowpen Marsh, Durham (England, UK)	Hudson in Kew, 1893
	Sphaerium corneum	1 with 2 shells	Frog	Mr. Hudson tells me that he once saw one, swimming in a pond at Redcar, with two shells (which were found to be those of *S. corneum)* upon the toes of its left hind foot;	In a pond at Redcar, North Yorkshire (England, UK)	
	Sphaerium corneum	Occasionally	Newts	The late Mr. W. Jeffery told me that ever since he was a boy dabbling with aquaria he had occasionally met with this bivalve clinging to newts;	In an aquarium	Jeffery in Kew, 1893
	Sphaerium corneum?	-	Newts	Mr. Jenkins states that he also has seen newts caught in this way in aquaria.	In aquaria	Jenkins in Kew, 1893
	Molluscs	From time to time	Frogs, toads and newts	Mr. Jenkins has seen molluscs of various kinds, both young and adult, crawling upon the bodies of frogs, toads, and newts kept by him from time to time.	-	
	Sphaerium corneum	1	Frog*	… a frog, with a shell of the same kind upon one of its toes, was once found by Mr. Standen under a log in a damp ditch about thirty yards from the nearest water, a pond in which Sphæria were abundant:	-	Standen in Kew, 1893
	Sphaerium corneum	6-7	Frogs	… a batch of frogs which were spawning in a ditch in that parish; five or six other frogs similarly encumbered had been seen in the ditch, all the shells being attached to toes of the hind legs.	In a ditch in the parish of Alford, Lincolnshire (England, UK)	Woodthorpe in Kew, 1893
	Anodonta glochidia	Frequently	Axolotl, *Proteus* and tadpoles of *Rana* and *Pelobates*	[Some artificial infections of *Anodonta* mature larvae were realized with fishes (perch, bleak, lamprey, etc.) as well as with amphibians (axolotl, *Proteus* and tadpoles of *Rana* and *Pelobates).*]	Neva River (Russia) and in an aquarium	Faussek, 1901
	Sphaerium corneum	5, 1 with 2 shells	Toads	... toads were plentiful in the drains at Tetney; and we secured five, to the toes of the hind feet of which individuals of *Sphærium corneum* were firmly affixed. Four carried one shell each, while the fifth, a small toad, had two full-sized shells on the	In the drains at Tetney, Lincolnshire (England, UK)	Kew, 1903
	Pisidium	Frequently	Salamander	[… the small mussels were clinging to the toes of the salamander …]	In an aquarium	Schreitmüller (1909?) in Anonymous, 1909
	Hemilastena [=Simpsonaias] ambigua	12 infected out of 15 specimens (80%) (great majority *S. ambigua)*	*Necturus maculosus* (common mudpuppy)	The great majority of infections were by a glochidium unknown to me. They were deeply imbedded in the external gills of the *Necturus* and by keeping the animals alive all winter I succeeded in carrying the young mussels through to the juvenile stage, … a f	Moline, Illinois (USA)	Howard, 1914; also in Howard, 1915 (reported results of a study performed in 1912)
	Quadrula heros [=Megalonaias nervosa]	12 infected out of 15 specimens (80%) (a few *M. nervosa* not imbedded *)*				
	Sphaerium	1	Frog	Thus the writer has found a frog carrying a fresh-water bivalve *(Sphærium)* attached to its hind leg, …	-	Elton, 1927
	Hemilastena [=Simpsonaias] ambigua	Regularly	*Necturus*	Again, in 17 cysts of *Hemilastena ambigua* on the gills of *Necturus* only one mitotic figure occurred during the period of encystment.	-	Arey, 1932
	Lamellidens glochidia	Regularly	*Rhachophorus* and *Rana* tadpoles	I infected the tadpoles of *Rhachophorus* and *Rana* with the glochidia of *Lamellidens* and observed the metamorphosis of the encysted glochidia into juvenile mussels.	Annamalai University laboratory (India)	Seshaiya,1941
	Sphaerium corneum	12	*Bufo vulgaris [=Bufo bufo]*	… with common orb mussles *(Sphaerium corneum* (L., 1758)), clamped to the phalanges of the toads.	-	Sixl (1968) in Gutleb *et al.,* 2000
	Lamellidens marginalis, L. consobrinus, L. corrianus, Parreysia corrugata, P. rugosa glochidia	Regularly	*Rana [=Euphlyctis] hexadactyla, Rhacophorus [=Polypedates] maculatus* tadpoles	Glochidial infection was successfully carried out on a dozen species of freshwater fish and also on the tadpoles of the frogs, *Rana hexadactyla* and *Rhacophorus maculatus.*	South Indian ponds and streams, aquaria in the Porto Novo Marine Biological Station laboratory (India)	Seshaiya,1969
	Pisidium	2	*Triturus vulgaris [=Lissotriton vulgaris]*	I captured two male smooth newts *Triturus vulgaris* both with a *Pisidium* so attached to their flanks.	An isolated farm pond near Nuneaton, Warwickshire (England, UK)	Wisniewski, 1999 (reported an event observed some 30 years before)
	Velesunio ambiguus [=ambiguous]	Regularly	Common froglet *(Ranidella [=Crinia] signifera),* marsh frog *(Limnodynastes tasmaniensis)*	… the glochidia completed metamorphosis on tadpoles of the common froglet, *Ranidella signifera* (Girard). Glochidia readily attached to tadpoles of the marsh frog, *Limnodynastes tasmaniensis* Günther, but were absorbed within 24 hr of encystment.	Point Sturt, Lake Alexandrina and Overland Corner, Murray River (South Australia); University of Adelaide Laboratory	Walker, 1981 (reported results of a study performed during 1977-79)
	Pisidium adamsi	2 out of 16	*Ambystoma laterale* (blue-spotted salamander)	… two of these were found to have one individual each of the pea clam, *Pisidium adamsi,* (family Sphaeriidae) attached to a toe of a hind foot (Figure 1).	Cattail ponds along Beecham Road, (45° 55' N, 64° 00' W), 10 km south of Tidnish, Cumberland County, (Canada)	Davis & Gilhen, 1982
	Pisidium adamsi	6 shells found among 500 salamanders	Blue-spotted salamander *(Ambystoma laterale-jeffersonianum* complex)	... we encountered several salamanders (genus *Ambystoma)* and a single wood frog *(Rana sylvatica)* which carried pea clams attached to the digits of their feet, ... and encountered elsewhere (New Brunswick, Quebec and Ontario; personal observation).	Beaver pond located near Kashagawigamog Lake (45° 00' N, 78° 35' W, 340 m amsl), Dysart township, Ontario; New Brunswick, Quebec and Ontario (Canada)	Lowcock & Murphy, 1990 (reported results of a study performed in 1988)
		A. m. : 4 shells among 799; *R. s.* : 1 shell among 78	Yellow-spotted salamander *(Ambystoma maculatum)* wood frog *(Rana sylvatica)*			
	Sphaerium corneum	2 specimens with 1 shell each attached	Common toads *(Bufo bufo)*	Two males of the common toad *(Bufo bufo)* served as vector hosts of the bivalve *Sphaerium corneum.* The bivalve adhered to the tip of the toe of the toad. The importance of this interspecific relationship is discussed.	In a small (20 cm ca. depth) drainage ditch of the Federsee (Baden-Württemberg, Germany)	Kwet, 1995 (reported an event observed in 1992)
	Sphaerium corneum?	1	Alpine newt	[… an alpine newt with a sphaeriid, presumably a *Sphaerium corneum* as well, attached on the hind leg …]	-	Sättele & Pieh in Kwet, 1995

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Amphibia Anura & Caudata - 65 references	*Lampsilis cardium*	Regularly	*Ambystoma tigrinum* ssp. 11% attached glochidia successfully methamorphosed	*Lampsilis cardium* successfully metamorphosed on six species of exotic fishes, as well as on larval tiger salamanders. *Utterbackia imbecillis* successfully metamorphosed on 30 species of exotic fishes and all four amphibian species tested	Conneaut Creek, northeastern Ohio (USA) plus traded amphibians. Ohio State University laboratory	Watters, 1997; also in Watters & O'Dee, 1998 (reported results of a study performed in 1995)
	Utterbackia imbecillis	Regularly	*Rana [=Lithobates] pipiens, R. [=L.] catesbeiana:* 8.8% and 29.1% metham. glochidia *Xenopus laevis, Ambystoma tigrinum* ssp.: 75% and 6.6% methamorphosed glochidia	*Lampsilis cardium* successfully metamorphosed on six species of exotic fishes, as well as on larval tiger salamanders. *Utterbackia imbecillis* successfully metamorphosed on 30 species of exotic fishes and all four amphibian species tested	Lake Erie and Raccoon Creek (Ohio), Lake Monticello (South Carolina) plus traded amphibians. Laboratory	
	Sphaerium corneum	1	*Bombina bombina*	[A specimen of *Bombina bombina* was met with *Sphaerium corneum* attached to its finger.]	Markthof (Southern Austria)	Gutleb *et al.,* 2000 (reported an event observed in 1996-97)
	Salamander mussel *(Simpsonaias ambigua)*	Regularly	Mudpuppy *(Necturus maculus)*	The percent transformation success on *Necturus* was rather low; 13% of initially attached glochidia survived and transformed.	Meramec River, Missouri (USA), Laboratory of the Southwest Missouri State University, Springfield (USA)	Barnhart *et al.,* 1998 (reported results of a study performed in 1997)
	Pisidium sp.	2 out of 303 (0.7%) specimens, each one with 1 shell attached	*Bufo [=Anaxyrus] boreas* (boreal toad)	Both toadlets were on a muddy surface and had the clam attached to the distal end of a toe on the rear foot.	Lost Lake, Boulder County, Colorado (USA)	Scherff-Norris & Livo, 1999 (reported events observed in 1997)
	Sphaerium corneum	3, 1 with 6 shells	*Rana dalmatina*	[… three specimens of *Rana dalmatina* were met with up to 6 shells of *Sphaerium corneum* attached to their fingers and toes.]	St. Kathrein, Carinthia (Austria)	Gutleb *et al.,* 2000 (reported an event observed in 1998)
	Strophitus undulatus	Regularly	Northern two-lined salamander larvae *(Eurycea bislineata)*	In addition the larvae (but not adults) of the northern two-lined salamander *(Eurycea bislineata)* served as a suitable host species for *S. undulatus;* ...	Piscataquog River watershed, New Hampshire (USA), Laboratory of the Saint Anselm College, Manchester (USA)	Wicklow & Beisheim, 1998
	Strophitus undulatus	6 specimens exposed, 1 juvenile metamorphosed (20%)	Red-spotted newt adults *(Notophthalmus viridescens viridescens)*	*Strophitus undulatus* successfully metamorphosed on 15 of 22 potential hosts, including five cyprinid species, two salmonids, two centrarchids and two percids, as well as *Acipenser oxyrhynchus, Ameiurus natalis, Cottus cognatus* and *Notophthalmus viridescen*	Pine Creek, Tioga County, (41°44.099'N, 077°25.857'W) Pennsylvania (USA), USGS Laboratory in Wellsboro (USA)	van Snik Gray *et al.,* 2002 (reported results of a study performed in 1999)
	Sphaerium	1	Newt	… *Sphaerium* attached to a newt …	United Kingdom	Millar, 2001
	Sphaerium corneum	3 (5.4% of the cluster)	*Lissotriton helveticus*	[Three adult specimens of *Lissotriton helveticus* (5.4% of those observed at the time) were carrying a bivalve mollusc *Sphaerium corneum* grabbed to one of his fingers.]	Maular (sierra de Andía, Navarra; 580562 E; 4741094 N; 1,019 m amsl, Spain)	Laza-Martínez *et al.,* 2012 (reported an event observed in 2004)
		5 out of several tens	*Lissotriton helveticus*	[Tens of newts extracted from the pond were temporarily stored along with numerous molluscs into two 5 l containers arranged on the banks of the pond and found that in less than two hours five newts were carrying molluscs on their fingers ...]	In 5 l tanks temporarily filled in Maular (Sierra de Andía, Navarra; 580562 E; 4741094 N; 1,019 m amsl, Spain)	
	Sphaerium ovale	1	Common newt *(Triturus vulgaris) [=Lissotriton vulgaris]*	[… a common newt *(Triturus vulgaris)* was caught with a net, it had a *Sphaerium ovale* specimen attached to the fourth toe of its right hind leg.]	Grafenstein, Carinthia (Austria)	Mildner & Happ, 2007 (reported an event observed in 2004)
	Mussels	1 with 2 shells	Newt	[… a small male newt with two mussels that had hung on his hind leg …]	The Netherlands	Kelderman in Anonymous, 2008 (reported an event observed in 2007)
	Sphaerium nucleus, Pisidium subtruncatum	37 out of 161 in Dréisch, 1 out 28 in Laaschtert-3 and 4 out 57 in Laa.-4	*Ichthyosaura alpestris, Triturus cristatus, Lissotriton helveticus, L. vulgaris*	Individuals of all four newt species present in Luxembourg were observed with mussels attached to their toes: *Mesotriton [=Ichthyosaura] alpestris* (n = 23), *Triturus cristatus* (n = 10), *Lissotriton helveticus* (n = 2) and *L. vulgaris* (n = 7).	In three ponds: Dréisch (Gauss-Luxembourg grid ref.: LC 708 636), Laaschtert 3 & 4 (LC 725 934 & LC 727 935, Luxemburg)	Wood *et al.,* 2007; also in Wood *et al.,* 2008
		22 newts with a mussel for 3 days; 9 of them retained mussels for longer	*Ichthyosaura alpestris, Triturus cristatus, Lissotriton vulgaris*	Twenty-two newts with attached mussels were observed in aquaria for up to 3 days: 13 mussels detached when the newt's toe fell off and nine remained attached.	In an aquarium	
	Sphaerium	Some specimens, 1 with 2 shells	Newts *[Lissotriton vulgaris]*	[Whilst taking some photographs of newts, we noticed that some of them were 'attacked' by fingernail clams of the genus *Sphaerium.]*	Carinthia (Austria)	Böhm, 2012 (reported an event observed in 2009)
	Corbicula	Sometime	Toads *(Bufo bufo)*	All toads had fingers clamped by alive tiny bivalves of genus *Corbicula.* Every toad had 2 or 3 shells on its fingers.	In a lake	Volkov in Naish, 2010b
	Pomatias elegans	10 out of 768 plus other 9 specimens	*Bufo calamita [=Epidalea calamita]*	[In transects for monitoring toad population, 768 individuals were counted, of which 10 (1.3%) had snails. The other 9 cases of toads carrying snails, were observed outside the transects. 9 snails (45%) were attached to the rear toes, 8 (40%) to the womb	Playa de Gorrondatxe (Getxo, Vizcaya; 499021 E; 4803072 N; 53 m amsl, Spain)	Laza-Martínez *et al.,* 2012
	Clam	1 with 2 shells attached	Common toad	… my son and I came across a breeding pair and the female had 2 small yellowish white clam like biovalve's [sic bivalves] on each back flipper attached to the toe …	Swamp area next to Balgavies and Rescobie Loch near Forfar (Scotland, UK)	lowarth, 2013
	Clam	1	Smooth newt?	Spotty newt- male smooth newt? With clam-like creature attached to back foot.	Bethnal Green Nature Reserve, in a pond (England, UK)	Columbia Family, 2015
Ectozoochory: Reptilia - 15 references	*Limneus pereger [=Radix balthica]*	1	Turtles	I have seen the *L. pereger* attached in numbers to the backs of turtles, …	In a pond at Fort William, near Belfast (Ireland)	Thompson, 1841
	Æolis [=Aeolidia]	1	*Chelone [=Eretmochelys] imbricata*	Tizard caught a turtle *(Chelone imbricata)* covered with *Lepas anatifera,* and with some specimens of *Æolis* on it, as seen on a log some time ago.	Station 70, Bermuda to Azores, Lat. 38° 25' N., Long. 35° 50' W	Moseley in Murray, 1895 (reported an observation made in 1873)
	Unio complanatus? [=Mya complanata?]	1	*Chelydra** (snapping turtle)	There was clinging to its lower jaw a clam, which, though they were several rods from the river, was still apparently alive.	Rock River, near Beloit (Wisconsin, USA)	Todd, 1883; also in Kew, 1893 (reported an event observed in 1882)
	Oyster	1 with a patch of oysters at the back	Diamondback terrapin	Recently, however, the Institute received a terrapin heavy growth of oysters.	-	Allen & Neill, 1952
	Crassostrea virginica, Crepidula plana	7 *C. v.* + 1 *C. p.* specimens	Ornate diamondback terrapin *(Malaclemys terrapin macrospilota)*	Herein we report the only specifically identified record of both an oyster, *Crassostrea virginica* (Gmelin), and a slipper shell, *Crepidula plana* Say, fouling the carapace of an ornate diamondback terrapin, *Malaclemys terrapin macrospilota* Hay	In shallows near Shired Island, in the California Swamp, Dixie County (29° 23' 36" N, 83° 12' 12" W), Florida (USA)	Jackson & Ross, 1971 (reported an event observed in 1962)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Reptilia - 15 references	*Brachidontes exustus*	6 *B. e.* specimens in a *Balanus [=Amphibalanus] eburneus* shell	Ornate diamondback terrapin *(Malaclemys terrapin macrospilota)*	We record here a unique occurrence of a bivalve mollusk, *Brachidontes exustus* (Linnaeus), in the vacant shell of a barnacle, *Balanus eburneus* Gould, attached to the carapace of a turtle, *Malaclemys terrapin macrospilota* Hay (Fig. 1A).	Cedar Island in the coastal swamp of Taylor Co., approximately 29° 48' 57" N, 83° 35' 15" W (Florida, USA)	Jackson *et al.*, 1973 (reported an event observed in 1967)
	Septifer bilocularis juv.	1 *E. i.* specimen with 1 *S. b.* juvenile individual attached	*Eretmochelys imbricata*		Maziwi Island (Tanzania)	
	Crassostrea cf. *gigas*	3 *L. o.* specimens with 2, 3 and 2 *C.* cf. *g.* individuals attached	*Lepidochelys olivacea*		Gahirmatha, Orissa (India)	
	Anadara transversa, A. sp., *Brachidontes exustus, B. modiolus, Chama macerophylla*	6 *C. c.* specimens with several bivalves attached			Cumberland Island, Georgia, Hutchinson Island, Florida (USA)	
	Hiatella arctica, Musculus lateralis, Mytilus edulis, M. sp., mytilid spat, *Ostrea edulis, O. equestris*	10 *C. c.* specimens with several bivalves attached		At least 15 species of bivalves and 5 species of gastropods were found on turtles. ... Mollusks have been collected on only three species of marine turtles: *Eretmochelys imbricata, Caretta caretta,* and *Lepidochelys olivacea;* the numbers of each species in	Zakynthos Island, Peloponnesus (Greece), Cumberland Island, Georgia (USA)	Frazier *et al.*, 1985 (reported results of a study performed during 1974-84)
	Petricola lithophaga, cf. *Rupellaria typica, Sphenia antillensis [=fragilis],* venerid	6 *C. c.* specimens with several shells attached	*Caretta caretta*		Zakynthos Island, Peloponnesus (Greece), Cumberland Island, Georgia (USA)	
	Costoanachis avara, C. cf. *a., C. floridana, Crepidula fornicata, C. plana*	9 *C. c.* specimens with several shells attached			Cumberland Island, Georgia, Hutchinson Island, Florida (USA)	
	Thais haemastoma floridana [=Stramonita floridana]	2 *C. c.* specimens with several shells attached			Hutchinson Island, Florida (USA)	
	Laevapex sp.	-	Freshwater turtles	[… specimens of *Laevapex* sp. were found adherents to the carapace of freshwater turtles, ...]	Serra da Mesa hydroelectric power plant, Goiás (Brazil)	Barbosa dos Santos, 2003 (reported an event observed in 1999)
	Pomatias elegans	1	*Podarcis liolepis**	[An adult male of *Podarcis liolepis* was captured on Monte Urgull, San Sebastián (Guipúzcoa, 581786 E, 4797194 N, 26 m) with a specimen of *Pomatias elegans* attached to two fingers of the right front leg (Figure 2).]	Monte Urgull, San Sebastián, Guipúzcoa; 581786 E; 4797194 N; 26 m amsl (Spain)	Laza-Martínez *et al.*, 2012 (reported an event observed in 2005)
	Zebra mussel *(Dreissena polymorpha)*	Regularly	Turtles	Zebra mussels attach themselves to living things, like turtles, crayfish and native clams. In some infested waters, native clams have been nearly eliminated by encrusting of their shells.	Great Lakes, region, North America (USA)	Sternberg, 2011
Ectozoochory: Osteichthyes - 5 references	Gravette oyster	1	Fish *(Blennius pholis) [=Lipophrys pholis]* (shanny)	[The fish (Figure 5, Plate II) was found early last February, living & rolled on itself in an oyster shell, coming from Marennes (i).]	Marennes (France)	de Saint-Amans, 1787; also in de Lacépède, 1831
	Mussel	1	Shanny	The fish was alive when taken, and its head firmly fixed in the mussel.	In the harbour at Looe, Cornwall (England, UK)	Clogg in Wilson, 1880
	Anodonta glochidia	Frequently	Perch, bleak, lamprey, etc.	[Some artificial infections of *Anodonta* mature larvae were realized with fishes (perch, bleak, lamprey, etc.) as well as with amphibians (axolotl, *Proteus* and tadpoles of *Rana* and *Pelobates).*]	Neva River (Russia) and in an aquarium	Faussek, 1901
	Musculium securis	3	Northern pike fingerling *Esox lucius*	One of the two clam-bearing pike caught had both jaws clamped together; the other bore the mollusc on the upper jaw.	In drainage ditches that flow into the Houghton Lake at Peterson's Resort (Michigan, USA)	Carbine, 1942
	Pisidia	-	Trout	[… pea clams (pisidia) attached to the lips and fins of trout …]	-	Gittenberger *et al.* (1998) in Mildner & Happ, 2007
Endozoochory: Osteichthyes - 15 references	*Unio [=Velesunio] angasi*	1	Cod	Mr. Hedley exhibited the shell of a mussel, *Unio angasi,* Lea, taken alive from the stomach of a 10 lb. cod caught in the Barwon River near Brewarrina by Mr. William Davies.	Barwon River near Brewarrina, New South Wales (Australia)	Davies in Hedley, 1894
	Paludestrina jenkinsi [=Potamopyrgus antipodarum]	Occasionally	Perch	If starved a little the perch will take this mollusc, but I noticed that the shells appeared again in the excreta unbroken.	In an aquarium	Dean, 1904
	Hydrobiids	-	European plaice *(Pleuronectes platessa)*	The youngs of flat-fishes (especially the plaice *(Pleuronectes platessa* L.)) to a great extent feed on hydrobiids, which passes uninjured through the fishes ...	-	Hertling (1928) in Bondesen & Kaiser, 1949
	Hydrobiids	-	European plaice *(Pleuronectes platessa)*	The youngs of flat-fishes (especially the plaice *(Pleuronectes platessa* L.)) to a great extent feed on hydrobiids, which passes uninjured through the fishes ...	-	Ankel (1929) in Bondesen & Kaiser, 1949
	Hydrobia jenkinsi [=Potamopyrgus antipodarum]	-	Trout *(Salmo trutta)*	*H. jenkinsi* passes through trout *(Salmo trutta* L.) alive ...	Danmarks Akvarium, Charlottenlund (Denmark)	Mandahl-Barth in Bondesen & Kaiser, 1949
	Potamopyrgus jenkinsi [=Potamopyrgus antipodarum]	35 snails survived after 3 hours feeding experiment	Rainbow trout *(Oncorhynchus mykiss)*	The trout were then transferred to another aquarium where on one occasion, 35 snails survived passage through the fish gastrointestinal tract and within 24h produced 10 live neonates, ... after 6h of being ingested two live snails were recovered and withi	In aquaria	Haynes *et al.* (1985) in Bruce, 2006
	Alvinia spp., *Lacuna* spp., *Margarites* spp., *Transennella tantilla*	Regularly	*Asemichthys taylori* (spinynose sculpin)	... more than 75% of the gastropod shells were punched, and more than 40% of the unpunched gastropods survived passage through the digestive tract. ... Number of survivors: *Alvinia* spp. 13 out of 101, *Lacuna* spp. 7 out of 72, *Margarites* spp. 3 out of 31,	North America	Norton, 1988
	Hydrobia spp.	46% of survivors at 15°C; 92% of survivors at 20°C	*Platichthys flesus*	The survival of ostracods and *Hydrobia* spp. differed significantly at the two temperatures: the survival of ostracods was 53% at 15 °C and 75% at 20 °C (p<0.05) and the survival of *Hydrobia* spp. was 46% at 15 °C and 92% at 20 °C (p<0.001; Table 1).	Experiment in 4-liter aquaria, *P. flesus* and *H.* spp. from southwestern coast of Åland (Finland)	Aarnio & Bonsdorff, 1997
	Mysella charcoti	1,970 out of 3,742 viable specimens recovered from 6 fishes	*Notothenia coriiceps* (black rockcod)	Surprisingly, healthy specimens of *Mysella* were also recovered from feces of all examined fishes, during 5 days following their capture. These live bivalves remained healthy for the next 5 days, when the authors had to interrupt their scientific activitie	Admiralty Bay, King George Island (62° 10.168' S; 58° 26.959' W), South Shetland Islands (Antarctica)	Domaneschi *et al.*, 2002
	Corbula [=Potamocorbula] amurensis	39 survivors out of 43 unopened overbite clams (91%)	White sturgeon *(Acipenser transmontanus)*	In the feces, I found 43 unopened overbite clams (7 to 14 mm total width), ... By the end of the observation period, 34 (79%) had actively burrowed, and 5 (12%) had extended their siphons or the foot without burrowing. The other 4 clams (9%) showed no sig	Broad Slough (38° 02' 20" N, 121° 50' 33" W, California, USA)	Kogut, 2008 (reported an event observed in 2002)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Endozoochory: Osteichthyes - 15 references	*Potamopyrgus antipodarum*	54% of the ingested snails were alive	Rainbow trout *(Oncorhynchus mykiss)*	We found that nearly 54% of the snails recovered from fish feces passed through the digestive system alive and would probably be able to reproduce.	Green River, downstream from Flaming Gorge Dam and downstream from Little Hole (Utah, USA) and in an aquarium	Vinson, 2004; also in Vinson & Baker, 2008
	Corbicula fluminea	Considerable amount	*Pterodoras granulosus*	... a considerable amount of *C. fluminea* shells were still closed and intact at the final section of its digestive tract.	Paraná River (22° 43' S, 53° 11' W), Baía River (22° 43' S, 53° 18' W), and Ivinheima River (22° 49' S, 53° 33' W) Brazil	Cantanhêde *et al.*, 2008 (reported observations during 2004-05)
	Potamopyrgus antipodarum	5 fishes in 8 tanks; max alive snails: 30% after 12h, 35% after 24h	Rainbow trout *(Oncorhynchus mykiss)*	Adult snails that were recovered were also examined for the expulsion of live neonates. Snails were still contained in the gastrointestinal tract at 48 h. No live adult or neonate snails were recovered in the posterior intestine or fecal material of fish	University of Idaho, College of Natural Resources Fisheries Wet Laboratory (Idaho, USA)	Bruce, 2006
	Pea clam *(Pisidium idahoensis)*	Regularly	Humpback whitefish *(Coregonus pidschian)*, broad whitefish *(Coregonus nasus)*	Mean number (range) of live mollusks observed per fish by species: pea clams 442 (312-769), in humpback whitefish (n=6), 604 (558-650) in broad whitefish (n=2)	Kanuti River drainage (66° 10.5' N, 151° 45.0' W) and in the Selawik River delta (66° 26.5' N, 159° 59.9' W, Alaska, USA)	Brown, 2007
	Valve snail *Valvata sincera*, pond snail *Lymnaea atkaensis*	Regularly	Humpback whitefish *(Coregonus pidschian)*, broad whitefish *(Coregonus nasus)*	Mean number (range) of live mollusks observed per fish by species: valve snails 873 (432-1,212), pond snails 0 in humpback whitefish (n=6), valve snails 712 (591-833), pond snails 0.5 (0-1) in broad whitefish (n=2) …		
	Corbicula fluminea, Driessena [sic *Dreissena*] *polymorpha*	Survivors: 161 *C. fluminea* out of 756; 114 *D. polymorpha* out of 1,012	Blue catfish *(Ictalurus furcatus)*	We collected 62 blue catfish from which we recovered 756 Asian clams (161 alive) and 1,012 zebra mussels (114 alive; Table 1).	Sooner Lake, Pawnee County (Oklahoma, USA)	Gatlin *et al.*, 2013
Ectozoochory: Aves - 121 references	Just hatched fresh-water shells	1	Duck	... I suspended a duck's feet, which might represent those of a bird sleeping in a natural pond, in an aquarium, where many ova of fresh-water shells were hatching; and I found that numbers of the extremely minute and just hatched shells crawled on the fe	In an aquarium	Darwin, 1859
	Otter's-shell *(Lutraria maxima)*	1	Shoveller duck*	I'll be dog gone, if a big clam hadn't nailed him fast by the beak.	North America	Lord, 1866
	Cockle	1	Snipe*	… when I picked him up (after shooting him) I found he had a large cockle attached to his foot.	-	J. B., 1867 (reported an event observed in 1866)
	Mussel	1	Tern	… a tern, caught by the foot by a mussel, was found some twenty-five years ago …	Hunstanton beach, Norfolk (England, UK)	Cresswell fide Gurney in Kew, 1893 (reported an event observed in 1868 ca.)
	Oyster	1	Rail	… —a common rail—quite dead, with its beak held firmly by the oyster, which was still alive.	Helford River at Helston near Falmouth, Cornwall (England, UK)	Buckland (1870) in Houghton, 1870
	Cockle-shell	1	Sanderling*	… my brother shot a sanderling having a cockle-shell attached to the middle toe; …	-	Leach, 1872
	Cockle	1	*Sterna paradisea [=Sterna paradisaea]* (arctic tern)	… a cockle firmly fixed on the upper mandible, …	On the sands at Morecambe Bay (England, UK)	Hancock, 1874
	Cockle	1	Peewit	… a cockle was found firmly grasping the bill, …	Fenham Flats, Newcastle upon Tyne (England, UK)	Crawshay in Hancock, 1874
	Succinea?	1	Mallard*	I once shot a mallard a hundred miles away from water, in the Sahara, and noticed the ova of some mollusk—probably *Succinea*—adhering to one of its feet.	Sahara	Tristram, 1877
	Unio	Frequently	Ducks	… for at low water the ducklings were liable to be caught by the mussels and held until drowned by the rising tide.	On the Pamunky [=Pamunkey] river, near White-house landing (Virginia, USA)	Mather, 1878
	Unio complanatus [=Mya complanata]	1	Blue-winged teal *(Querquedula discors) [=Anas discors]**	… a living *Unio,* which had caught one of the toes of a duck's foot between its valves, …	Near the Artichoke river at West Newbury (Massachusetts, USA)	Newcomb fide Gray in Darwin, 1878
	Oyster-shell	1	Water rail	Mr. Norgate tells me that he saw a stuffed water-rail, with its bill in an oyster-shell, at the National Fisheries Exhibition, at Norwich, in 1881.	-	Norgate in Kew, 1893 (reported an event observed in 1881)
	Freshwater clam	1	Duck*	This he shot, and on picking it up found a common 'fresh-water clam attached to the penultimate joint of the 'middle toe.	Sebec River (Maine, USA)	Barry in Fewkes, 1884
	Sphaerium corneum	1	Snipe*	… a snipe being shot which had a small *Sphærium* clinging to its toe.	Near Rye, Sussex (England, UK)	Chapman (1884) in Standen, 1885; also in Kew, 1893
	Cockle	1	Dunlin	A bird of the same kind [dunlin] with a cockle similarly attached, which had been picked up dead on the Yorkshire coast, …	Yorkshire coast (England, UK)	Payne-Gallwey (1884) in Kew, 1893
	Small cockle	1	Dunlin	A dunlin with a small cockle about the size of a hazel-nut clinging to its bill was once found, …	Near the estuary of Moy (Ireland)	Warren (1884) in Kew, 1893
	Cockle	1	Wader	… a wader being caught by a cockle, …	-	Anonymous (1885) in Standen, 1885
	Freshwater mussel	1	Some species of *Turdus,* perhaps a blackbird	… a large fresh-water mussel was found, having between the valves the toe of a small bird, apparently that of some species of *Turdus,* perhaps a blackbird; …	In a pond at Hole Park, at Rolvenden, Kent (England, UK)	Tweedie fide Godwin-Austen (1885) in Standen, 1885; also in Kew, 1893
	Anodonta	1	*Totanus calidris [=Tringa totanus,* common sandpiper]	[The bird was walking in shallow water and its feet was caught by a mussel after having introduced it between the half-open valves of the mollusc ...]	Germany	Schäff, 1888
	Mussel	1	Grey crow	… a grey crow with a mussel upon its bill was caught by Mr. C. Springall, in 1888, …	On the beach at Brancaster, Norfolk (England, UK)	Springall fide Gurney in Kew, 1893 (reported an event observed in 1888)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Aves - 121 references	Oyster	1	Golden plover	The closure of an oyster upon one of the toes of a golden plover was recorded …	-	Anonymous (1889) in Kew, 1893
	Large cockle	1	Sandpiper	I found that one claw of one foot was firmly held by a large cockle (about 1 ½ in. by 2 in.).	On the coast of Queensland (Australia)	McNabb, 1890 (reported an event observed in 1889)
	Cockle	1	Dunlin*	Another dunlin with a cockle upon its bill, which got up from the observer's feet and flew heavily away, was shot in 1891.	-	Anonymous (1891) in Kew, 1893
	Oyster	1	Cormorant	… the taking of a cormorant with an oyster upon its bill was reported, in 1892, …	-	Anonymous (1892b) in Kew, 1893
	A big horse mussel	1	Heron*	… the bird, flying near the ground, was endeavouring to shake off the shell—" a big horse-mussel "—which dangled from its foot, …	Claughton, Lancashire (England, UK)	Kew, 1893
	[Gastropods?] molluscs	1	Wild duck*	Mr. Cordeaux once noticed minute molluscs among duckweed within the bill of a wild duck shot by him, …	-	Cordeaux in Kew, 1893
	Anodonta or *Unio*	1	Common sandpiper *(Totanus hypoleucos)* *[=Actitis hypoleucos]**	… have been caught, some time previously, on a stream in that neighbourhood, with a mussel *(Anodonta* or *Unio)* firmly clinging to one of its feet; …	In the Redhill neighbourhood (England, UK)	Ford in Kew, 1893
	Cockle	1	Curlew sandpiper	… a curlew sandpiper with a cockle hanging to one of its toes was shot, a few years ago, …	At Cley, in Norfolk (England, UK)	Hoare fide Gurney in Kew, 1893
	Snail	1	Thrush*	… and Mr. Roberts, I hear, has actually seen a thrush drop a snail while flying.	-	Roberts in Kew, 1893
	Anodonta	1	Duck*	… which was found, about half way home, with a big *Anodonta* attached to one of its feet; it was slowly and painfully dragging the shell along, and had already crossed two large fields.	Goosnargh, Lancashire (England, UK)	Standen in Kew, 1893
	Freshwater clam	1	Sora *(Porzana carolina)*	It had a " freshwater clam " attached to one toe, being firmly caught by the bivalve.	In the vicinity of Portland (Connecticut, USA)	Clarke in Sage, 1895 (reported an event observed in 1894)
	Pinna muricata	1	Killdeer plover	I observed a killdeer plover that seemed very tame, but on a closer examination I found that it was caught by a *Pinna.*	New Pass, Sarasota Key, (Florida, USA)	Post, 1896
	Freshwater mussel	1	Female duck	[In 1897 I saw on the Dender canal near Isières (Hainaut), a duck badly swimming because it had a large freshwater mussel attached to one of its interdigital membranes.]	On the Dendre canal near Isières (Hainaut, Belgium)	Mansion, 1901 (reported an event observed in 1897)
	Unio	2	Wild ducks*	Twice I have killed wild ducks with unios attached to their toes, and have seen what I believed to be unios hanging from the feet of others flying overhead.	Lake Kissimee? (Florida, USA)	Frierson, 1899
	Anodonte *[=Anodonta* sp.]	1	Duckling	[… a duckling emerging from the Blaton canal water with the beak closed by an enormous anodonte.]	Blaton canal, Ath (Belgium)	Mansion, 1901 (reported an event observed in 1899)
	Scallop	1	Sheldrake (shelduck)	… he had driven his bill through both shells of a scallop, which slipped or worked its way up to his nostrils, muzzling the bird perfectly with a hard shell ring.	North America western coast	Long, 1901
	Anodonta cygnea	1	Peewit	… a peewit had been found on Gatton Park estate with a freshwater mussel attached to its foot, …	Gatton Park, Surrey (England, UK)	Anonymous (1904) in Adams, 1905
	Common mussel	1	Merganser *(Mergus serrator)**	[After being shot turned out to be essentially a merganser, probably a young specimen of the middle type *(Mergus serrator),* who had landed with his jaw between the valves of a large specimen of a common mussel.]	Westpolder, Groningen (the Netherlands)	Manshalt, 1904
	Mussel	Occasionally	Eider duck	[The only anomaly that I could find on it, was a living mussel, a species that occurs on the rocks at sea that held the eider mussel tongue firmly clamped between its valves]	Canada	Long in Heimans, 1905
	Mussel	1	Kingfisher	It had swooped down and poked its bill into the open shell of a mussel, which suddenly closed on the bill of the bird.	Salem? (Massachusetts, USA)	Anonymous, 1908a
	Clam or freshwater mussel	1	Blue heron	… he discovered that a clam or fresh water mussel had closed tightly about one of the bird's toes ...	Along the river at Beach Haven, Bloomsburg (Pennsylvania, USA)	Anonymous, 1908b
	Physa	Numerous, each one with 20-40 snails	Upland plover *(Bartramia longicauda)**	… has collected numerous upland plover *(Bartramia longicauda)* soon after their arrival upon the Gulf Coast, which bore beneath their wings from 20 to 40 small snails of the Genus *Physa.* … I found as many as forty-one, oftener between twenty and thirty, ne	Gulf Coast (USA)	Beyer in McAtee, 1914 (reported an event observed in 1911)
	Succinea riisei	3-4	Bobolink *[=Dolichonyx oryzivorous]**	I shot three or four birds, all males, and was very much surprised to find live Mollusca among their feathers; …	San Carlos Estate, Guantanamo (Cuba)	Ramsden, 1913; also in Ramsden, 1914
	Vitrina pellucida	1	Lark	*Vitrina pellucida* (Müller) found on the plumage of migrant birds in Europe	Juist, East Frisian Islands (Germany)	Leege (1914) in Rees, 1965
	Vitrina pellucida	3	Meadow pipit*	… three small examples (average greatest diameter 4 mm.) of *Vitrina pellucida* which he found adhering by their own slime to the abdominal feathers of a meadow pipit caught at the lantern on the night of 4th/5th October.	Butt of Lewis Lighthouse, Isle of Lewis (Scotland, UK)	Clyne in Evans, 1915

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Aves - 121 references	*Paludestrina jenkinsi [=Potamopyrgus antipodarum]* *Pisidium casertanum, P. subtruncatum*	1	Scaup duck *(Nyroca marila) [=Aythya marila]**	*Paludestrina jenkinsi, Pisidium casertanum,* and *P. subtruncatum,* taken from bill of a scaup duck *(Nyroca marila)* shot in the Old Harbour, Perth (Perth Mid.), on Feb. 15th, 1922. Some of the shells were adhering to the outside of the bill; others were enta	In the Old Harbour, Perth (Perthshire, Scotland, UK)	Coates, 1922a
	Clam	1	Sandpiper	He discovered that the bird had rashly placed its bill into the open jaw of a clam, which had to be killed before the sandpiper could be released.	Cooper (Texas, USA)	Baker in Anonymous, 1925
	Hydridella australis (=Velesunio evansi) [=Velesunio ambiguous]	1	Black duck *(Anas superciliosa)**	… carried on the feet of birds shot on the wing …	Naracoorte (South Australia)	Cotton (1934) in Rees, 1965
	Succinea	1	Western vesper sparrow *[=Pooecetes gramineus]**	A unique capture was that of a tiny fresh-water mollusk, *Succinea,* found "hitch-hiking" in the back feathers of a western vesper sparrow.	Ten miles south of Gila Bend (Arizona, USA)	Huey in Anonymous, 1936
	Clam	1	Arctic tern *(Sterna paradisaea)*	… was caught by a clam …	Orleans, Massachusetts (USA)	Cooke, 1938 (reported an event observed in 1937)
	Mercenaria mercenaria	1	American oystercatcher *(Haematopus palliatus)*	… an adult American oyster-catcher *(Haematopus palliatus palliatus)* was found that had its bill caught by a hard-shell clam *(Mercenaria mercenaria).*	Cape Romain National Wildlife Refuge, Charleston County, (South Carolina, USA)	Baldwin, 1946 (reported an event observed in 1939)
	Mytilus edulis	1	American eider *(Somateria mollissima dresseri)*	Occasionally the tongue of a bird is caught between the valves of an open mussel, which usually results in the bird's death (pl. 7, B). The mussel tightly clamps the tongue, causing strangulation or starvation.	-	Cottam, 1939
	Bivalves	A few cases	Oystercatcher	… they have heard of a few oyster-catchers being found with their toes caught by bivalves, …	Cape Romain National Wildlife Refuge, Charleston County, (South Carolina, USA)	Local residents in Baldwin, 1946
	Vitrina pellucida	1 with 7 shells	Robin	In the plumage of a robin were detected seven specimens of *Vitrina pellucida* (Vitrinidae).	-	Brandes (1951) in Tenzer, 2003
	Plananiscus [=Gyraulus] isingi *Simlimnea subaequatilis [=Austropeplea tomentosa]* *Peplimnea [=Austropeplea] lessoni* juv.	1 *A. superciliosa* with a shell, 1 *B. lobata* with a shell	Black duck *(Anas superciliosa)* Musk duck *(Bizura* [sic *Biziura] lobata)*	Records of Mollusca carried on the feet of birds	S. Australia	Cotton in Rees, 1965 (reported events observed in 1953)
	Corbiculina angasi [=Corbicula australis]	-	Black duck *(Anas superciliosa)* Musk duck *(Bizura* [sic *Biziura] lobata)*	… Mr B. C. Cotton *(in litt.* 1953) has found the small Australian freshwater cockle *(Corbiculina angasi* Prime) attached to the underside feathers of ducks *(Anas superciliosa* and *Bizura lobata).*	-	
	Physa, Lymnaea, Helisoma	1 with several adhering shells	White-faced ibis *(Plegadis mexicana) [=Plegadis chihi]*	Several aquatic gastropods were discovered adhering to the feathers of a white-faced glossy ibis *(Plegadis mexicana),* …	Two miles south of Orr's Ranch, Skull Valley, Tooele County (Utah, USA)	Davidoff in Roscoe, 1955 (reported an event observed in 1954)
	Vitrina pellucida	10	Meadow pipit *(Anthus pratensis)*	Records of *Vitrina pellucida* (Müller) found on the plumage of migrant birds in Europe	Amager, Copenaghen (Denmark)	Lemche in Rees, 1965 (reported an event observed in 1954)
	A medium-sized clam	1	Green heron *(Butorides virescens)*	A medium-sized clam was attached to one of the toes, weighting the whole leg down.	In the salt marsh at Fox Point, Nassau County, New York, (USA)	Post, 1973 (reported an event observed in 1954)
	Cardium [=Cerastoderma] edule	1	Red knot *(Calidris canutus)*	[… a red knot, who was killed because his beak became stuck between the valves of a clam ...]	On the mudflats in a polder in the Eierlandse (Texel Island, the Netherlands)	van Sasse van Ysselt, 1958 (reported an event observed in 1957)
	Vitrina pellucida	1	Northern waterthrush *(Seiurus noveboracensis) [=Parkesia noveboracensis]*	A small snail which was removed from its flank feathers was identified by S. P. Dance at the British Museum (Natural History) as *Vitrina pellucida.*	St. Agnes Bird Observatory, Isles of Scilly (England, UK)	Williamson *et al.* (1959) in Harris *et al.,* 1960
	Vitrina pellucida	1	Hooded crow *(Corvus corane cornix)*	Records of *Vitrina pellucida* (Müller) found on the plumage of migrant birds in Europe	St. Agnes Bird Observatory, Isles of Scilly (England, UK)	Williamson *et al.* (1959) in Rees, 1965
		1 *F. coelebs* with 1 shell, 1 *O. o. leucorhoa* with 4 shells	Chaffinch *(Fringilla coelebs),* Greenland wheatear *(Oenanthe o. leucorrhoa)* [sic *leucorhoa]*		Fair Isle Observatory (Scotland, UK)	
	Snails	-	Birds	… of finding dead snails on the surfaces of birds …	-	Cotton (1960) in Malone, 1965
	Mytilus edulis	*1*	Grey plover *(Charadrius [=Pluvialis] squatarola)* Oystercatcher *(Haematopus ostralegus)*	… another oystercatcher and a grey plover *(Charadrius squatarola)* with mussels on their bills.	Shellness, Isle of Sheppey (Kent, UK)	Hori, 1962 (reported events observed before 1961)
	Mytilus edulis	1	Redshank *(Tringa totanus)*	… a redshank *(Tringa totanus),* … The whole of its bill, right to the base, was enclosed by a live mussel …	Shellness, Isle of Sheppey (Kent, UK)	Hori, 1962 (reported an event observed in 1961)

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Aves - 121 references	*Mytilus edulis*	2	Oystercatcher *(Haematopus ostralegus)**	… I noted two separate oystercatchers *(Haematopus ostralegus)* with mussels on their bills.	Shellness, Isle of Sheppey (Kent, UK)	Hori, 1962 (reported events observed in 1962)
	Cardium [=Cerastoderma] edule	1	Knot *(Calidris canutus)*	… a knot *(Calidris canutus)* which I watched on the same day had considerable difficulty in flying with a cockle on its bill.		
	Cardium [=Cerastoderma] edule	2	Redshank *(Tringa totanus)*	Twice I saw a cockle close on the bill of a redshank.	Shellness, Isle of Sheppey (Kent, UK)	Hori, 1962
	Mussel	1	Oystercatcher	… who found an oystercatcher near Southport with half an ounce of mussel securely clamped on to the end of its bill, ...	Near Southport, Merseyside (England, UK)	Bennett in Anonymous, 1964
	Mussel	1	Oystercatcher	A dead oystercatcher found with a mussel clamped to the beak	Dawlish Warren (Devon, UK)	Ginn (1971) in van Gemert & Schipper, 2013 (event observed in 1965)
	Anodonta	1	Water bird	[… a small pond mussel *(Anodonta)* clamped at the foot of a water bird …]	-	Kühnelt (1965) in Gutleb *et al.,* 2000
	Promentus [sic *Promenetus*] *exacuous, Lymnaea [=Galba] obrussa*	-	Killdeer *(Charadrius vociferus)*	Juveniles and adults of both species of snails crawled onto the killdeer feet. … Adult *Lymnea* usually clung to the feet no longer than 5 minutes before dropping; juveniles remained attached at least 48 hours. All *Promentus* [sic *Promenetus*] remained attach	Shallow water in ponds in Andrews County (Texas, USA)	Malone, 1965
	Succinea unicolor	11.4% of woodcocks had 3 shells in average	Woodcock *Philohola minor [=Scolopax minor]*	Various birds were caught during these operations but snails were found on only 3 species: woodcock *(Philohola minor),* common snipe *(Cappella gallinago),* and whippoorwill *(Caprimulgus vociferous).* ... The first season the number of snails per bird ranged	In the Atchafalaya River Basin area (Louisiana, USA)	Dundee *et al.,* 1967
		-	Common snipe *(Cappella* [sic *Capella*] *gallinago), [=Gallinago gallinago]*			
		-	Whippoorwill *(Caprimulgus vociferus) [=Antrostomus vociferus]*			
	Venus [=Mercenaria] mercenaria	1	Common tern *(Sterna hirundo)*	Its bill tip was gripped tightly by the shell of a *Venus mercenaria* (the clam measured 6 x 8 cm).	Oak Beach, Suffolk County, New York, (USA)	Enders & Post in Post, 1973 (reported an event observed in 1967)
	Modiolus demissus? [=Geukensia demissa?]	1	American bittern *(Botaurus lentiginosus)*	… its leg was weighted down by a mollusc, in this case a large mussel, probably *Modiolus demissus.*	Oak Beach salt marsh, New York, (USA)	Post, 1973 (reported an event observed in 1967)
	Tridacna clams	-	Sanderling *(Calidris alba)*	*Tridacna* clams attached to sanderling feet	-	Cooper (1969) in Melville & Choi, 2013
	Mussel	1	Oystercatcher	A dead oystercatcher found with a mussel clamped to the beak	Heacham (Norfolk, UK)	Ginn (1971) in van Gemert & Schipper, 2013 (event observed in 1970)
			Red knot	A red knot found with a mussel clamped to the beak	Gorlee [=Goeree?] (the Netherlands)	
	Cockle	2 out 1,500 specimens	Red knot	Two of the 1,500 captured red knots had their leg clamped in a cockle	The Wash (England, UK)	Anonymous (1974) in van Gemert & Schipper, 2013 (event observed in 1973)
	Bivalve	-	Sanderling *(Calidris alba)*	Bivalve attached to a sanderling foot	-	Quickelberge (1974) in Melville & Choi, 2013
	Mussel *(Mytilus edulis)*	1	Oystercatcher *(Haematopus ostralegus)*	Adult oystercatcher found dead with a mussel pinched onto its bill.	Rottumeroog (the Netherlands)	Witteveen in Hulscher, 1988 (reported an event observed in 1976)
	Cockle	1	Golden plover *(Pluvialis apricaria)*	Golden plover *(Pluvialis apricaria)* with the foot clamped among the valves of a cockle	Winsum, Friesland (the Netherlands)	Jukema (1979a) in van Gemert & Schipper, 2013 (event observed in 1977)
	Choromytilus sp.	1	Curlew sandpiper *(Calidris ferruginea)*	Curlew sandpiper caught by a mussel	Walvis Bay to Swakopmund (Namibia)	Summers & Whitelaw (1978) in Gemert & Schipper, 2013 (event observed in 1977)
	Mytilus edulis	1	*Somateria mollissima*	[A large mussel *Mytilus edulis* was clamped to the bird's lower beak, so that it could not close its mouth and probably it could not take food any more for itself (Fig. 1).]	Wadden Sea coast at the pumping station Roptazijl near Harlingen (the Netherlands)	Jukema, 1979b (reported an event observed in 1978)
	Sphaerium fabale, S. occidentale, Musculium lacustre, M. securis *Pisidium casertanum, P. variabile*	Regularly	Mallards *(Anas platyrhynchos platyrhynchos)*	Number of parents (out of 10) that contained viable extra-marsupial larvae after 60 min suspension in air with a 0.20 mm diam wire clamped between the valves: *S. fabale:* 3, *S. occidentale:* 2, *M. lacustre:* 6, *M. securis:* 10, *P. casertanum:* 4, *P. variabile:*	Laboratory	Mackie, 1979
	Mussels	1	Eider duck	[… we took on Vlieland an eider with a group of mussels attached to the toes.]	Vlieland (the Netherlands)	Swennen & Duiven, 1989 (reported an event observed in 1979)
	Lymnaea stagnalis, Stagnicola elodes, Helisoma [=Planorbella] trivolvis	1	Whistling swan *[=Cygnus colombianus]*	The snails clinging to the feathers were then placed in an air stream to simulate flight conditions. ... The number of individuals who remained clinging to feathers decreased rapidly with time, and after 15 minutes of exposure, only 6% of *L. stagnalis,* 18	Laboratory	Boag, 1986

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Aves - 121 references	Quahog *(Mercenaria* sp.)	1	Great egret *(Casmerodius albus)* *[=Ardea alba]*	The bird was pulled from the mud with some difficulty. An average-sized quahog *(Mercenaria* sp.) was firmly clamped on its bill.	On the shore of City Island on the south side of the New Pass (Florida, USA)	DeLynn *et al.,* 1989 (reported an event observed in 1988)
			Brown pelican	… a brown pelican was brought to the laboratory with a quahog firmly clamped to its bill.		
	Mussel	1	Oystercatcher	An oystercatcher found with a mussel clamped to the beak	-	Hulscher in van Zomeren (1988) in van Gemert & Schipper, 2013
	Cerastoderma edule	1	Chick	[… we saw a chick with a cockle *Cerastoderma edule* at his feet, ...]	Vlieland (the Netherlands)	Swennen & Duiven, 1989 (reported an event observed in 1988)
	Zebra mussel *(Dreissena polymorpha)*	<0.5 mussel per duck per trip	Mallard ducks *(Anas platyrhynchos)*	Zebra mussels were transported under all situations, but at very low numbers, usually <0.5 mussel per duck per trip.	Lake St. Clair or 2-m-diameter wading pools (laboratory), Michigan (USA)	Johnson & Carlton, 1996
	Spisula solidissima	39 out of 3,000	Dunlin *(Calidris alpina)*	We proceeded to survey the beach and found a total of 39 dunlin with trapped bills, out of a total 3,000 dunlin ...	Cape May County beaches (New Jersey, USA)	Tsipoura & Burger, 1999 (reported events observed in 1996)
		4 dunlins and 1 sanderling	Dunlin *(Calidris alpina),* sanderling *(Calidris alba)*	We also found four dunlin and one sanderling with feet that were trapped in the surf clams, but they were able to fly off or free themselves before we could approach them.		
	Pipi? *(Donax deltoides)*	1	Australian pied oystercatcher *[Haematopus longirostris]*	A 3-4 cm bivalve presumably a pipi *Donax deltoides* had clamped around one of its toes.	On a beach at Ballina (New South Wales, Australia)	Carter, 1999
	Large bivalve	1	Terek sandpiper *(Xenus cinereus)*	It was trailing a large bivalve of some sort from its left foot.	Yalu Jiang National Nature Reserve (northem China)	Riegen, 2000
	Bivalve	1	Greenshank *(Tringa nebularia)*	I saw a greenshank *Tringa nebularia* fly across the water with a bivalve locked onto a toe.		
	Deroceras reticulatum	1	Common yellowthroat* *(Geothlypis trichas)*	The slug on the common yellowthroat was *Deroceras reticulatum* (Müller, 1774) (CM 66603) and was found among the bird's body feathers.	Powdermill Nature Reserve (Rector, PA; 40.1636° N, 79.2668° W), Pennsylvania (USA)	Pearce *et al.,* 2012 (reported an event observed in 2003)
	Arion subfuscus	1	Northern saw-whet owl *(Aegolius acadicus)**	The slug on the northern saw-whet owl was *Arion subfuscus* (Draparnaud, 1805) (CM103313), and it also was found among the bird's body feathers.		Pearce *et al.,* 2012 (reported an event observed in 2004)
	Bivalve	-	Wrybill *(Anarhynchus frontalis)*	Bivalve attached to a bill of a wrybill	-	Battley (2005) in Melville & Choi, 2013
			Red knot *(Calidris canutus)*	Bivalve attached to a red knot bill		
	Bivalves	-	Bar-tailed godwit *(Limosa lapponica)*	Bivalves attached to bar-tailed godwit foot and bill	-	Vaughan (2005) in Melville & Choi, 2013
	Cerastoderma edule	2 *Calidris alba,* 1 *C. alpina,* 1 *C. ferruginea* out of 17,000 specimens	Sanderling *(Calidris alba),* dunlin *(C. alpina),* curlew sandpiper *(C. ferruginea)*	… four individuals (two sanderling *Calidris alba,* one dunlin *Calidris alpina* (Fig. 3), one curlew sandpiper *Calidris ferruginea)* were found to have a live cockle *Cerastoderma edule* attached to one of their digits.	Odiel Marshes (southwest Spain)	Sayago in Green & Figuerola, 2005
	Clam	1	Double-crested cormorant	[Double-crested cormorant with a clam clamped to its bill]	-	Hanisek, 2008a
	Large clam	1	Double-crested cormorant	Cormorants dive after fish, and this one apparently made inadvertent contact with a large clam on one of its underwater forays.	Norwalk Islands, Connecticut (USA)	Hanisek, 2008b
	Shellfish	1	Wilson's plover	… we realized that a shellfish, I think it was an oyster, had clamped down on the bird's foot or toe, …	An uninhabited barrier island called Shackleford Banks, near Cape Lookout, North Carolina (USA)	Scottybgood, 2008
	Clam	Sometime	Dunlins	I saw photos of dunlins parading with a tiny clam attached to their bills.	-	Jerzy in Naish, 2010a
	Swan mussel? *[=Anodonta cygnea]*	1	Black-headed gull *(Chroicocephalus ridibundus)*	… a black-headed gull *Chroicocephalus ridibundus* – appears to have been captured (and killed?) by what I think is a freshwater swan mussel *Anodonta cygnea*	Hørsholm Museum, (Denmark)	Bühler in Naish, 2010b
	Ostrea	1	Cormorant	The cormorant, while diving for food, had obviously poked his beak into the oysters shell, which the oyster promptly closed, trapping them both in a death grip.	Westport, Washington (USA)	CoyotePrime, 2011
	Cochlicopa lubrica	1	Lesser spotted eagle *Aquila pomarina*	During our field research we found a fresh, fully developed shell of *Cochlicopa lubrica* (O. F. Müller, 1774) in a nest of the lesser spotted eagle *(Aquila pomarina).*	In a forest in the Rajgród Forest Inspectorate (Podlaskie province, 53° 58' 53'' N, 22° 61' 57'' E, Poland)	Maciorowski *et al.,* 2012
	Japanese oyster	1	Gull	[The animal had a leg pinched between the oyster valves and could not fly away.]	Cocksdorp, Texel (the Netherlands)	Westbroek & Hottentot, 2012

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Aves - 121 references	Clam?	1	Bar-tailed godwit *(Limosa lapponica menzbieri)*	The bird was foraging normally and probed into the mud every few steps until it abruptly stopped walking and stretched its wings, with head pointing downwards. … In both instances, the most likely explanation of what we observed was that the bird's toe/fo	Dandong Yalu Jiang Estuarine Wetland National Nature Reserve, Liaoning Province, China	Melville & Choi, 2013
			Bar-tailed godwit *(Limosa lapponica)*	After 21 seconds of observation the bird appeared to get a fright as it stumbled and flapped its wings briefly. … In both instances, the most likely explanation of what we observed was that the bird's toe/foot had been caught by a clam …		
	Bivalve	-	*Great knot (Calidris tenuirostris)*	Bivalve attached to a great knot foot	-	
	Fruticicola fruticum, Zonitoides nitidus	1	Blackcap *(Sylvia atricapilla)**	We observed a blackcap *Sylvia atricapilla* L. (Sylviidae) which carried terrestrial gastropods *Fruticicola fruticum* (O. F. Müller) (Bradybaenidae) and *Zonitoides nitidus* (O. F. Müller) (Zonitidae) in a deciduous forest. ... *Z. nitidus* was transported over	Deciduous forest	Shikov & Vinogradov, 2013
	Arion subfuscus	1	Blackbird *(Turdus merula)**	… a blackbird *Turdus merula* L. (Turdidae) was observed carrying a slug, *Arion subfuscus* s. l. (Arionidae), in a dry pine forest. … while *A. subfuscus,* no less than 25 m.	Dry pine forest	
	Alinda biplicata, Cochlodina laminata	20-100% snails stuck to the bird legs in a simulated medium flight	Dried legs of chicken *(Gallus gallus* f. *domestica)*	… our experiments, though artificial, suggest that a snail that accidentally crawled onto a resting bird's leg has considerable powers of adhesion, allowing it to travel some distance.	Laboratory of the ČSOP ParaZOO, Vlašim (Czech Republic)	Simonová *et al.,* 2016 (reported results of a study performed in 2013)
	Cormorant	1	Clam	A cormorant was fishing in Lake Montauk early this morning … He stuck his beak in for a bite and the clam was faster and clamped down.	Lake Montauk, New York (USA)	Simons, 2014
Endozoochory: Aves - 16 references	*Helix caperata [=Candidula gigaxii]*	1	Wood pigeon*	... took thirteen wrinkled-snails *(Helix caperata),* together with a quantity of tares, from the stomach of a wood pigeon which had been shot three days previously. Most of the snails were alive, and "began creeping about on being placed in a dish containi	-	Ward in Kew, 1893
	Chloritis [=Badistes] jervisensis	1	*Rallus pectoralis [=Lewinia pectoralis]**	From the throat of a *Rallus pectoralis* Mr. J. A. Thorpe of the Australian Museum extracted the snail I now exhibit. … When found by Mr. Thorpe, to whom I am indebted for both facts and specimen, the snail was quite dead: …	Randwick, near Sydney (Australia)	Hedley, 1895
	Assiminea grayana	1	Oystercatcher? *(Haematopus ostralegus)*	A similar experience by myself was made somewhere during the 19sixtees: an observation of numerous living specimens of *Assiminea grayana* (also an operculate species) in a pellet of most probably an oyster-catcher *(Haematopus ostralegus).*	-	Janssen, 2011 (reported an event observed during the 1960s)
	Physa anatina [=Physella virgata]	4 out of 7 eggs hatched	Mallard ducks *(Anas platyrhynchos)*	Five ducks were used for 47 trials with *Physa.* Only 2 intact egg masses were recovered from the feces. The first of these contained 17 embryos, none of which developed further. Seven eggs were contained in the second; 4 developed normally and hatched on t	Cages placed in ponds in Andrews County (Texas, USA)	Malone, 1965
		17 out of 26 eggs hatched	Killdeer *(Charadrius vociferus)*	A total of 45 *Physa* egg masses were recovered from the feces of killdeer. Only 3 of these contained viable embryos. Seventeen of 26 embryos contained in the 3 egg masses hatched. Embryos contained in the remaining 42 egg masses were killed during passage.		
	Succinea putris	1	Pigeon	… recovery of a living *Succinea putris* from the crop of a pigeon at least 8 hours after the bird had died.	-	Biggs (1968) in Vagvolgy, 1975
	Sphaerium fabale, S. occidentale, Musculium lacustre, M. securis, Pisidium casertanum, P. variabile	4 out of 4,252 (=0.1%)	Mallards *(Anas platyrhynchos platyrhynchos)*	Thus if sphaeriids contained in the crop were regurgitated, the present study indicates that some would be viable, especially the extra-marsupial larvae which are protected by the parent's shell.	Laboratory	Mackie, 1979
	Hydrobia [=Peringia] ulva [sic *ulvae*]	36 out of 1,100 specimens	Shelduck *(Tadorna tadorna)*	[... I collected 3 droppings of shelduck ... These contained in total 1,100 *Hydrobia* specimens of which 44% were completely crushed ... 31% showed less damaged empty shells and 25% were completely intact (13% of the latter were still living.]	Mokbaai in Texel, Wadden Sea (the Netherlands)	Cadée, 1988; also in Cadée, 1994b (reported an event observed in 1987)
	Cerastoderma edule	1	Herring gull	I observed a regurgitated *Cerastoderma* burrowing again in the sediment.	Wadden Sea (the Netherlands)	Cadée, 1995
	Spisula subtruncata	1	Herring gull	… living *Spisula subtruncata* clams from regurgitates of herring gulls …	North Sea beach of Texel (the Netherlands)	de Wolf in Wesselingh *et al.,* 1999
	Tornatellides tryoni, Ogasawarana microtheca, Lamellidea ogasawarana	4 faeces sample of *Z. japonicus* in total	Japanese white-eye *(Zosterops japonicus)*	Number of molluscs specimens with body preservation > 75% in *Zosterops japonicus* faeces: 3 *Tornatellides tryoni* from 2 samples, 1 *Ogasawarana microtheca* and 2 *Lamellidea ogasawarana* from 1 sample	Hahajima and Anejima, oceanic Bonin Islands (Japan)	Kawakami *et al.,* 2008
	Nodilittorina trochoides, Littoraria pintado	2 faeces sample of *M. solitarius* in total	Blue rockthrush *(Monticola solitarius)*	Number of molluscs specimens with body preservation > 75% in *Monticola solitarius* faeces: 6 *Nodilittorina trochoides* from 2 samples, 2 *Littoraria pintado* from 1 sample		
	Hydrobia [=Peringia] ulvae	37 droppings contained an average of 2.57 ± 3.62 survivors	Shelduck *(Tadorna tadorna)*	In the 37 shelduck droppings examined, the remains of 168 *H. ulvae* shells were recovered. Nine of the droppings examined contained no *H. ulvae* . ... On average, a dropping contained 2.57 ± 3.62 *H. ulvae* which had not been digested and survived passage thro	Traeth Melynog (TM, 53° 08' N, 4° 19' W), southern tip of Anglesey (Wales, UK)	Anders *et al.,* 2009
	Hydrobia [=Peringia] ulvae	0-12 h survivors out of 3,600: 9 from isolation, 5 wading, 1 swimming	Mallard *(Anas platyrhynchos)*	The number of snails viably retrieved was too low to compare between treatments, but viable snails were retrieved from all three treatment groups (Appendix Table 4.S1). The last viable snail was retrieved after 7 h.	In aquaria located in the outdoor aviary of the Netherlands Institute of Ecology in Heteren (the Netherlands)	van Leeuwen, 2010; also in van Leeuwen *et al.,* 2012
	Tornatellides boeningi	Survivors: 17 out of 119 in *Z. japonicus;* 9 out of 55 in *H. amaurotis*	Japanese white-eye *(Zosterops japonicus),* brown-eared bulbul *(Hypsipetes amaurotis)*	Of the 119 snails fed to Japanese white-eyes and 55 snails fed to browneared bulbuls, 14.3% and 16.4% of the snails, respectively, passed through the gut alive. Additionally, one snail gave birth to juveniles after emerging from a bird's gut.	Hahajima Island of the Ogasawara Islands in the Western Pacific (Japan)	Wada *et al.,* 2012
	Alinda biplicata, Cochlodina laminata, Discus rotundatus	A. b. + C. l., 1.8 % alive of 440 snails, D. r. 0.7 % alive of 140 snails	*Turdus merula, Sturnus vulgaris, Corvus frugilegus, C. corone, Columba palumbus, C. livia domestica*	Of 720 snails offered, 14 passed intact through the birds, of which nine were alive (eight clausiliids and one *D. rotundatus);* thus more than 1% of all snails offered survived ingestion.	A beech forest and a mesic garden in Bohemia; In aviaries, ČSOP ParaZOO, Vlašim (Czech Republic)	Simonová *et al.,* 2016 (reported results of a study performed in 2013)
Ectozoochory: Mammalia 8 ref.	*Anodonta*	1	Water vole	A dead water vole with one of its feet firmly held between the valves of an *Anodonta* four inches in length, was once found …	Mere Mere, Cheshire (England, UK)	Hardy in Kew, 1893
	Bythinella dunkeri	-	Wild boar *(Sus scrofa)*	Transport in mud on European wild boar *(Sus scrofa)* has been proposed as a dispersal mechanism for the spring snail *Bythinella dunkeri* (Frauenfeld) (Hydrobiidae) …	-	Groh & Fuchs (1988) in Kappes & Haase, 2012

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Ectozoochory: Mammalia 8 ref.	Slugs	Occasionally	Mammals*	Mammals as vectors of slugs	-	Eversham, 1989
	Slugs	Occasionally	Cat*	Cat carrying a slug	-	McMillan, 1989
	Slugs	1	Pallid bat* *(Antrozous pallidus)*	Pallid bats *(Antrozous pallidus)* caught grey slugs in grasslands in central coastal California and dropped them either in flight or at the feeding roost.	Central California (USA)	Johnston, 1992 (reported a survey performed in 1991)
	Pupilla muscorum, Helicella itala, Trichia cf. *plebeia [=Trochulus plebeius],* cf. *Aegopinella* sp.	Occasionally	Sheep*	It is possible that snails and spiders are transported by sheep equally often as grasshoppers but, because of their small size, they could be seen only during the intensive investigations of the two tame sheep.	In the vicinity of Münsingen on the Schwäbische Alb (south-west of Germany)	Fischer *et al.,* 1996 (reported results of a study performed in 1993)
	Helicella itala, Pupilla muscorum	Occasionally	Sheep*	Land snails, for example, *Helicella itala* and *Pupilla muscorum,* have been found attached to the fur of sheep.	-	Dörge *et al.,* (1999) in Örstan, 2006
	Arion distinctus	Commonly	Cat*	This species is still in the garden, but I think it is by no means as common as it once was. It is the slug most commonly brought into the house stuck in the cats' fur.	35 Bartlemy Road, Newbury, West Berkshire (England, UK)	Weideli, 2008
Anthropochory - 33 references	*Viviparus ater*	1	Deliberate introduction	In 1882 a few individuals of *Viviparus ater* (Cristofori and Jan) originating from Lake Maggiore, Italy were released at a single location near the northern end of Lake Zürich, Switzerland (Roth 1906). … Today, *V. ater* is present in shallow water all aroun	Northern end of Lake Zürich (Switzerland)	Roth (1906) in Ribi, 1986 (reported an event observed in 1882)
	22 species of molluscs and 1 crustacean	Regularly	Seed oysters *(Ostrea gigas)* from Japan	On March 26, 1930, a shipment of 150 boxes of Japanese seed was sampled at Elkhorn Slough, California. … There were 22 species of molluscs and one crustacean.	Elkhorn Slough (California, USA)	Bonnot, 1935 (reported an event observed in 1930)
	Succinea sp.	Regularly	Knapsacks, clothing and shoes	I also found when working on the Galápagos Islands that species of *Succinea* invariably attached to our knapsacks, clothing and shoes when we were passing through dense brush, and sometimes dozens crawled onto our tent overnight.	Galápagos Islands	Vagvolgyi, 1975
	Cepaea nemoralis	1	Deliberate introduction	Proschwitz (1980) introduced twelve individuals of *Cepaea nemoralis* in a habitat judged to be suitable for this species in Dalsland, Sweden, in 1977. Nine years later, a small population has been established (Proschwitz, personal communication).	Dalsland, Sweden	Proschwitz (1980) in Baur & Bengtsson, 1987
	Dreissena polymorpha	-	Overgrowing of ships	[The following 10 animal spp. and 3 algae spp. were found in the overgrowing of ships in the Caspian Sea: … *Dreissena polymorpha* …]	Caspian Sea	Alibekova *et al.* (1985)
	1 Bivalvia, 10 Gastropoda species	1	Boat hull fouling	All common fouling species survived the open sea voyages between the harbors, with largely no ecologically significant changes in abundance nor significant losses in overall diversity detected.	Golden Hinde II (replica of a 16th century vessel), Yaquina Bay, Coos Bay, Humboldt Bay San Francisco (California, USA)	Carlton & Hodder, 1995 (reported an event observed in 1987)
	Dreissena polymorpha	10^6 individuals of diverse exotic organisms per tank	Ship ballast water	There is little doubt that *Dreissena* entered the Great lakes via ballast water discharge. The likelihood of such an introduction was predicted by an EPS (1981) study ... Moreover, the number of individuals of single taxa were large - in some cases greater	Great Lakes region (North America)	Hebert *et al.,* 1989
	Zebra mussel *(Dreissena polymorpha)*	1	Boat hull fouling	In fact, the hull of a fishing vessel that had travelled from Lake Erie to Lake Michigan was observed to have been infested with zebra mussels when it was dry-docked at Green Bay, Lake Michigan in September 1989 (Pers . Comm., D. W. Schloesser, U.S. Fish	Green Bay, Lake Michigan (USA)	Schloesser in Mackie, 1991 (reported an event observed in 1989)
	Zebra mussel *(Dreissena polymorpha)*	1	Aquarium release	... a woman who admitted dumping her pet turtle (and the contents of its aquarium) into the reservoir after the turtle appeared sick. ... Unfortunately, the critters turned out to be zebra mussels.	Laurel Creek Reservoir (Pennsylvania, USA)	O'Neill, 1991
	Zebra mussel *(Dreissena polymorpha)*	1 out of 275 trailers inspected	Recreational boats trailers	On the receiving end (i.e., ramps at uninfested inland lakes), zebra mussels were observed entangled in macrophytes on 1 of 275 trailers inspected.	North American inland lakes	Johnson & Carlton, 1996 (reported observations performed in 1992)
		43 out 52 live wells sampled (83%)	Recreational boats live wells	Larvae were found in all places that lake water was stored or accumulated in boats. ... Larvae were found in 43 of the 52 live wells sampled (83%) and the densities of larvae in a subset of these samples ranged from 0.5 to 157 larvae/L [sic l] (111 ± 222		
	Dreissena polymorpha	1 with more than 1,000 adult zebra mussel transported for 15,884 km ca.	Boat hull fouling	In April 1992 more than 1,000 adult zebra mussels *(Dreissena polymorpha)* were found on the hull of a commercial barge in dry-dock in Hartford, IL.	Hartford (Illinois, USA)	Keevin *et al.,* 1992
	Mollusca Bivalvia, Gastropoda	Regularly	Ship ballast water	We sampled ballast water from 159 cargo ships in Coos Bay, Oregon. The ships and their ballast water originated from 25 Japanese ports (9). Plankton from these vessels included 16 animal and 3 protist phyla, and 3 plant divisions (Table 1).	Coos Bay (Oregon, USA)	Carlton & Geller, 1993
	Dreissena polymorpha	0 to 514 specimens per wetsuit	Wetsuits	From a total of eight dives, calculated numbers of veligers collected from suits ranged from 0 to 514 per suit.	Illinois River (Illinois, USA)	Blodgett *et al.,* 1995
	Gastropoda, Bivalvia	A miminum of 50 live plankton taxa after 16 days	Ship ballast water	The rate of copepod decline, including nauplii, juveniles, and adults, was significantly greater than that of all other larval taxa together (Gastropoda, Bivalvia, Cirripedia, Polychaeta, Platyhelminthes) …	Coal-carrier MV 'Leon' ballasted in Hadera (Israel), and deballasted in Baltimore (USA)	Wonham *et al.,* 2001 (reported results of a study performed in 1995)
	Xerocrassa cretica, Eobania vermiculata	1	Accidental introduction	In 1996 I saw a farmer near Sitía in eastern Crete accidentally transporting *Xerocrassa cretica* and *Eobania vermiculata* in his pickup truck together with agricultural products.	Crete Island (Greece)	Welter-Schultes, 1998 (reported an event observed in 1996)
	Mytilus galloprovincialis	1	Boat hull fouling	The smooth shelled blue mussel, *Mytilus galloprovincialis* Lmk (Bivalvia: Mollusca) arrived in Pearl Harbor, Oahu, Hawai'i on 22 June 1998 as a member of the fouling community of the USS Missouri, and mussel spawning activity was observed within 2 h of the	Pearl Harbor, Oahu (Hawai'i, USA)	Apte *et al.,* 2000 (reported an event observed in 1998)
	Helix cincta	1	Deliberate introduction	… he successfully initiated a *Helix cincta* population, originally from Alíkambos, on his real estate in Attikí.	Crete Island to Attica (Greece)	Servoudakis in Welter-Schultes, 1998
	Land snails	Occasionally	Seed stocks delivery	… land snails were commonly transported mixed with seeds across country borders …	-	Dörge *et al.,* (1999) in Örstan, 2006
	Dreissena polymorpha	170 dispersal events during a summer season	Recreational boats live wells	Larvae were found in all forms of water carried by boats (i.e., in live wells, bilges, bait buckets, and engines) but were estimated to be 40-100X more abundant in live wells than other locations.	Public boat launches on Lake St. Clair (Michigan, USA)	Johnson *et al.,* 2001

Type	Species	Frequency	Host species/vector	Original observation	Locality	Observer and reference
Anthropochory - 33 references	Golden mussel *(Limnoperna fortunei)*	Regularly	Boat hull fouling	… the boats after three months only of permanence in water, showed a *L. fortunei* fouling encrusted around the hull and the propeller ...	Praia do Veludo, Lago Guaíba, Rio Grande do Sul (Brazil)	Mansur *et al.,* 2003 (reported results of a study performed in 2001)
	Potamopyrgus antipodarum	1 to 227 (mean 33) specimens per sample (52 wading boots in total)	Wading boots	NZMS were observed on the tongue area of wading boots, associated with the laces or the area of the tongue that was tucked beneath the lacing eyelets. Large numbers of small NZMS were present inside of the boots, having worked down between the boot and th	Putah Creek in Yolo County (California, USA)	Hosea & Finlayson, 2005
	Xeropicta derbentina	Regularly	11 vehicles out of 1247 hosted 21 individuals	The speed with which they react allows the snails to climb onto the vehicle or object that disturbed them and to be transported kilometres away. … *X. derbentina* was found on 0.88% of the searched vehicles for a total of 21 individuals on 11 cars (Table 4)	Seven different car parks in Provence (France)	Aubry *et al.,* 2006
	Valvata macrostoma, Stagnicola palustris, Stagnicola corvus, Planorbis planorbis *Bathyomphalus contortus, Anisus spirorbis, A. septemgyratus, Segmentina nitida*	1	Coir rollers and matting	These molluscs were transported on coir rollers and matting which were used for stabilisation of the reservoir banks during restoration.	Water reservoir N1 – Stodůlky, Elbe River Basin (Prague, Czech Republic)	Beran, 2006
	Dreissena polymorpha	Frequently	Boat hull fouling	"we only have found zebra mussels on boats being trailered into California. These boats are quarantined and cleaned before launching," …	North America	Veldhuizen in Finley, 2006
	Potamopyrgus antipodarum	Regularly	Recreational watercraft and trailers	When directly exposed to NZ mudsnails boats, canoes, kayaks and associated gear and trailers may become fouled, providing a contamination source when moved to uninfested waters.	North America	NZMS, 2007
	Quagga mussel *(Dreissena rostriformis bugensis),* zebra mussel *(Dreissena polymorpha)*	Regularly	Recreational watercraft and trailers	Quagga and zebra mussels found overgrowing hulls, marine engines, cooling systems and trailers	Norh America (USA)	Pacific States Marine Fisheries Commission, 2008
	Mytilus spp.	Detected presence in 59.3% of the 491 boats surveyed	Boat hull fouling	Cryptogenic mussels *(Mytilus* species complex) were found on a majority of boats examined, even those travelling frequently and/or long distances.	24 marinas in British Columbia (Canada)	Murray *et al.,* 2011 (reported results of a study performed in 2008-2009)
	Quagga mussel *(Dreissena rostriformis bugensis),* zebra mussel *(Dreissena polymorpha)*	Regularly	Boat hull fouling	Colonize on both hard and soft surfaces, from the water's surface to more than 400 feet down, including boat hulls, propellers, anchors, docks, and boat trailers.	California (USA)	California Department of Fish and Game, 2009
	Dreissena polymorpha, D. bugensis [=D. rostriformis bugensis]	Regularly	Ships	A drydock survey revealed that a large proportion of the ships that reach the upper Rhine River from distant locations such as the Danube basin carry both attached *D. polymorpha* and the recent invader *D. bugensis* …	Upper Rhine River (Germany)	Mayer *et al.* (2009) in Kappes & Haase, 2012
	Littorina Littorea, Hyotissa numisma, Mya arenaria, Mytilus galloprovincialis, Scapharca sp.	Median number of total molluscs (6.75) per tank (9 occurrences)	Ship ballast water	One hundred and forty-two sediment samples from 135 ships were collected ... *L. littorea* (2 specimens, 1 occurrence), *H. numisma* (1.5 specimens, 2 occurrences), *M. arenaria* (1 specimen, 4 occurrences), *M. galloprovincialis* (1 specimen, 1 occurrence), *Scap*	Pacific region, Great Lakes, Atlantic region	Briski *et al.,* 2011
	Quagga mussel *(Dreissena rostriformis bugensis),* zebra mussel *(Dreissena polymorpha)*	Regularly	Boat hull fouling	Byssal threads secrete a powerful glue, enabling the mussels to form dense colonies on rocks, metal, plastic, concrete, pipes, ropes, boats, motors and practically any other submerged object.	Great Lakes region, North America (USA)	Sternberg, 2011
	Potamopyrgus antipodarum	Regularly	Wading boots	Mudsnails can attach to the seam of a stream boot. Unintentional transport from one stream location to another by hitchhiking on waders or wading boots is one of the primary vectors for spreading New Zealand mudsnails.	North America	Newhall Land and Farming Company, 2012

Appendix V. Passive dispersal literature records. The host species marked with an asterisk refer to captures outside the aquatic environment. Square brackets in the 'Original observation' column either include a personal translation from the original non-English text or a clarification comment. The year of the references reported between brackets in the 'Observer and reference' column means that the article has not been accessed directly, only as a summary quoted in a later work. References preceded by the adverb also, quote extra information with respect to the original observation.

GLOSSARY

From:
Wikipedia the free encyclopaedia (modified)
Encyclopaedia Britannica (modified)

Adapical: near or toward the apex or tip of a shell

Alien: an introduced, alien, exotic, non-indigenous, or non-native species, or simply an introduction, is a species living outside its native distributional range

Anemochory: dispersal of plants, seeds or living organisms by wind

Anoxic waters: anoxic waters are areas of sea water or fresh water that are depleted of dissolved oxygen. This condition is generally found in areas that have restricted water exchange

Anthropochory: dispersal of plants, seeds or living organisms by humans or human-related activities

Anura: an order of tailless amphibians that comprises the frogs and toads

Arctic: the Arctic consists of the Arctic Ocean and all or parts of Canada, Russia, Greenland, the United States, Norway, Sweden, Finland, and Iceland. The Arctic region consists of a vast, ice-covered ocean, surrounded by treeless permafrost. The area can be defined as north of the Arctic Circle (66° 33'N), the approximate limit of the midnight sun and the polar night

Augen: augen are large, lenticular eye-shaped mineral grains or mineral aggregates visible in some foliated metamorphic rocks. In cross section they have the shape of an eye

Biocoenosis: a biocoenosis describes the interacting organisms living together in a habitat (biotope)

Biotope: a biotope is a region uniform in environmental conditions providing a living place for a specific assemblage of plants and animals

Biplot: biplots are a type of graph used in statistics. A biplot allows information on both samples and variables of a data matrix to be displayed graphically. Samples are displayed as points while variables are displayed either as vectors, linear axes or nonlinear trajectories

Bivalvia: Bivalvia or bivalves are a class of marine and freshwater molluscs characterised by two hinged shells also known as Lamellibranchia

Bog: a bog is a wetland type that accumulates acidic peat, a deposit of dead plant material often represented by mosses or, in Arctic climates, by lichens

Calcifuge: a calcifuge is an animal (or plant) that does not tolerate alkaline (basic) soil

Calciphile: a calciphile is an animal (or plant) that does not tolerate acidic soil

Callus: in Sphaeriidae a callus is a small rounded bulge located in front of the posterior cardinal teeth P_1 and P_3 of the right valve of the genus *Pisidium.* In *Pisidium personatum* it can be also present on the left valve, in front of the cardinal teeth P_2

Centroid: a centroid is the multivariate equivalent of the mean. Just like the mean, the centroid of a cloud of points minimizes the sum of the squared distances from the points of the cloud to a point in the space

Chorological: relating to chorology, the study of the spatial distribution of organisms

Cirque: a cirque (French for "circus") or corrie (from Scottish Gaelic coire meaning a "kettle") is an amphitheatre-like valley head, formed at the head of a valley glacier by erosion. The concave amphitheatre shape is open on the downhill side corresponding to the flatter area of the stage, while the cupped seating section is generally steep cliff-like slopes down which ice and glaciated debris combine and converge from the three or more higher sides

Cluster analysis: cluster analysis considers the assignment of a set of observations into subsets (called clusters) so that observations in the same cluster are similar in some sense

Columella: the columella is the central structural feature of a coiled gastropod shell

Crenon: the crenon is the uppermost zone of river, characterised by low temperatures, reduced oxygen content, slow-moving water and gravelly-sandy bottoms

Diphyoidy: diphyoidy is a morphological character affecting the mollusc's shell. The diphyoidic shell shows a transversal furrow in the ventral side of the valve

Drainage basin: a drainage basin (or catchment basin) is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point, usually the exit of the basin, where the waters join another waterbody, such as a river, lake, reservoir, estuary, wetland, sea, or ocean

Dystrophic: dystrophic is one of the classes (oligotrophic, dystrophic, mesotrophic and eutrophic) of the trophic classification. A dystrophic waterbody refers to lakes with brown- or tea-coloured waters, the colour being the result of high concentrations of humic substances and organic acids suspended in the water. They are common in the taiga of North America and Eurasia

Ecosystem: an ecosystem is a biological environment consisting of all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, water and sunlight

Ecotope: ecotopes are the smallest ecologically-distinct landscape features in a landscape mapping and classification system. As such, they represent relatively homogeneous, spatially-explicit landscape functional units that are useful for stratifying landscapes into ecologically distinct features for the measurement and mapping of landscape structure, function and change

Ecozone: an ecozone is the largest scale biogeographic division of the Earth's land surfaces, based on the historic and evolutionary distribution patterns of terrestrial plants and animals

Ectozoochory: dispersal of plants, seeds or living organisms attached to the surface or to the extremities of living animal vectors

Endozoochory: dispersal of plants, seeds or living organisms which passed unarmed the intestine of an animal (mostly birds fishes and mammals)

Elytron: (plural elytra) is a modified, hardened forewing of certain insect orders, notably beetles (Coleoptera) and a few of the true bugs (Heteroptera)

Ephemeral waterbody: an ephemeral waterbody is a wetland, spring, stream, river, pond or lake that only exists for a short period following precipitation or snowmelt. They are not the same as intermittent or seasonal waterbodies, which exist for longer periods, but not all year round

Euryhaline: euryhaline organisms are able to adapt to a wide range of salinities. Euryhaline organisms are commonly found in habitats such as estuaries and tide pools where the salinity changes regularly

Eutrophic: eutrophic is one of the classes (oligotrophic, dystrophic, mesotrophic and eutrophic) of the trophic classification. An eutrophic body of water, commonly a lake or pond has high primary productivity due to excessive nutrients and is subject to algal blooms resulting in poor water quality. The bottom waters of such bodies are commonly deficient in oxygen, ranging from hypoxic to anoxic

Felsite: felsite is a very fine grained volcanic rock that may or may not contain larger crystals. The mass of the rock consists of a fine-grained matrix of felsic materials, particularly quartz, sodium and potassium feldspar, and may be termed a quartz felsite or quartz porphyry if the quartz phenocrystals are present

Gabbro: a gabbro is a rock-type that refers to a large group of dark, coarse-grained, intrusive mafic igneous rocks chemically equivalent to basalt. The rocks are plutonic, formed when molten magma is trapped beneath the Earth's surface and cooled into a crystalline mass

Gastropoda: Gastropoda or gastropods are a large taxonomic class within the molluscs, a group of animals that are more commonly known as snails and slugs

Generalist species: a generalist species is able to thrive in a wide variety of environmental conditions and can make use of a variety of different resources

Granite: a granite is a common and widely occurring type of intrusive, felsic, igneous rock with at least 20% quartz by volume. Granites usually have a medium- to coarse-grained texture

Granitoid: a granitoid or granitic rock is a variety of coarse grained plutonic rock similar to granite which mineralogically is composed predominately of feldspar and quartz. Examples of granitoid rocks include granite, quartz monzonite, quartz diorite, syenite, granodiorite and trondhjemite

Habitat: an habitat is an ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism. It is the natural environment in which an organism lives, or the physical environment that surrounds (influences and is utilized by) a species population

Halophile: halophiles are extremophile organisms that thrive in environments with very high concentrations of salt

Holarctic: the Holarctic region includes the habitats found throughout the northern continents of the world as a whole. This region is divided into the Palaearctic subregion (or ecozone), consisting of Northern Africa and all of Eurasia, with the exception of Southeast Asia and the Indian subcontinent, and the Nearctic, consisting of North America and north of southern Mexico

Hydrochory: dispersal of plants, seeds or living organisms by water

Kettle-hole: a kettle-hole is a fluvioglacial landforms occurring as the result of blocks of ice calving from the front of a receding glacier and becoming partially to wholly buried by glacial outwash

Lacustrine: relating to a lake

Lagg fen: lagg fen is a natural feature of a raised bog. It is created around the edges of the peat domes where seepage from the peat body meets mineral soils

Lanceolate: narrow and tapering like the head of a lance

Lentic: lentic is an ecosystem of a lake, pond or swamp. Included in the environment are the biotic interactions (amongst plants, animals and micro-organisms) and the abiotic interactions (physical and chemical)

Leucocratic rock: a leucocratic rock is an igneous rock in which the quantity of light-coloured minerals (feldspars, quartz, and feldspathoids) is greater than in the normal average type of rock

Limnocrene spring: limnocrene springs occur where discharge from confined or unconfined aquifers emerges as one or more lentic pools

Limnophile: an animal thriving in lakes or ponds

Lotic: an ecosystem of a river, stream or spring. Included in the environment are the biotic (amongst plants, animals and micro-organisms) as well as the abiotic (physical and chemical) interactions

Mafic: is an adjective describing a silicate mineral or rock that is rich in magnesium and iron

Malacofauna: the molluscs inhabiting an area

Mesotrophic: mesotrophic is one of the classes (oligotrophic, dystrophic, mesotrophic and eutrophic) of the trophic classification. Mesotrophic lakes are lakes with an intermediate level of productivity, greater than oligotrophic lakes, but less than eutrophic lakes. These lakes are commonly clear water lakes and ponds with beds of submerged aquatic plants and medium levels of nutrients

Migmatite: migmatite is a rock at the frontier between igneous and metamorphic rocks. Migmatites form under extreme temperature conditions during prograde metamorphism, where partial melting occurs in pre-existing rocks. Migmatites are not crystallized from a totally molten material, and are not generally the result of solid-state reactions. Migmatites are composed of a leucosome, new material crystallized from incipient melting, and a mesosome, old material that resisted melting

Minerotrophic waterbody: a minerotrophic waterbody is mainly supplied from streams or springs. This water has flowed over or through rocks or other minerals, often acquiring dissolved chemicals which raise the nutrient levels and reduce the acidity

Moorland: moorland or moor is a type of habitat, in the temperate grasslands, savannas, and shrublands biome, found in upland areas, characterised by low growing vegetation on acidic soils and heavy fog

Multivariate analysis: multivariate analysis is based on the statistical principle of multivariate statistics, which involves observation and analysis of more than one statistical variable at a time

Native: a term to describe endemic species (indigenous) or naturalized to a given area in geologic time

Nearctic ecozone: the Nearctic is one of the eight terrestrial ecozones dividing the Earth's land surface. The Nearctic ecozone covers most of North America, including Greenland and the highlands of Mexico

Oligotrophic: oligotrophic is one of the classes (oligotrophic, dystrophic, mesotrophic and eutrophic) of the trophic classification. An oligotrophic lake is a lake with low primary productivity, the result of low nutrient content. These lakes have low algal production, and consequently, often have very clear waters, with high drinking-water quality. The bottom waters of such lakes typically have ample oxygen contents

Ombrotrophic waterbody: a waterbody that receives all of its water and nutrients from precipitation, rather than from streams or springs. Such environments are hydrologically isolated from the surrounding landscape, and since rain is generally acidic and very low in nutrients, they are home to organisms tolerant of acidic, low-nutrient environments

Palaearctic ecozone: the Palaearctic is the largest among the eight terrestrial ecozones dividing the Earth's land surface. It includes the terrestrial ecoregions of Europe, Asia north of the Himalaya foothills, northern Africa, and the northern and central parts of the Arabian Peninsula

Palustrine: relating to a marsh. Palustrine is also a wetlands category of inland marshes and swamps as well as bogs, fens, tundra and floodplains. Palustrine systems include any inland wetland which lacks flowing water, contains ocean-derived salts in concentrations of less than 0.05%, and is non-tidal

Parthenogenesis: parthenogenesis is a form of asexual reproduction found in females, where growth and development of embryos occurs without fertilization by a male

Patelliform shell: or limpet-like shell shows a more or less conical shape and either is not spirally coiled, or appears not to be coiled in adult specimens

Pelite: pelite is old and currently not widely used field terminology for a clayey fine-grained clastic sediment or sedimentary rock, i.e. mud or mudstone. Pelite is more commonly used for metamorphosed sediments (which should technically be called a metapelite)

Periostracum: the periostracum is a thin organic coating or "skin" which is the outermost layer of the shell of many shelled animals, including molluscs and brachiopods

Periphyton: the periphyton is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems

Peristome: the peristome (or lip) is the margin of the aperture in a gastropod shell

Pharyngeal mill: grooved grinding apparatus occurring on the upper and lower elements of the gill arches of certain fish families such as Cichlidae and Scaridae

Phyllite: phyllite is a type of foliated metamorphic rock primarily composed of quartz, sericite, mica, and chlorite; the rock represents a gradation in the degree of metamorphism between slate and mica schist

Planispiral: a planispiral shell is coiled in a single horizontal plane and the diameter increases away from the axis of coiling

Porphyritic: porphyritic is an adjective used in geology, specifically for igneous rocks, for a rock that has a distinct difference in the size of the crystals, with at least one group of crystals obviously larger than another group

Potamon: the potamon is the downstream zone of river that follows the rhithron, characterised by relatively warm temperatures, low oxygen contents, slow-moving water and sandy bottoms

Principal Component Analysis: a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components

Prodissoconch: a prodissoconch is an embryonic or larval shell of bivalves; it corresponds to the initial growing stage of the valves sometimes called umbone or umbo

Prosocline growth lines: lean forward (adapically) with respect to the direction of the shell cone

Protoconch: a protoconch is an embryonic or larval shell of some classes of molluscs such as gastropods, corresponding to its initial development stage

Psammite: psammite is a general term for a sandstone, most often used to describe a metamorphosed rock unit with a dominantly sandstone protolith

Pseudocallus: an irregular thickening of the posterior cardinal tooth P_3 similar to the 'callus' found in *Pisidium personatum;* it is only found on the right valve of *Pisidium obtusale*

Pseudospecies: the pseudospecies concept is based on species relative abundances, which assignment is given through threshold percentage values of the original populations' counts

Redox potential: (also known as oxidation / reduction potential, ORP or E_h) is a measure of the tendency of a chemical species to acquire electrons and thereby be reduced. Reduction potential is measured in volts (V), or millivolts (mV). In well-oxidized waters the redox potential tends to be significantly positive, whilst in reduced environments it decreases possibly reaching negative values

Rheophile: a rheophile is an organism that prefers to live in running water

Rhithron: the rhithron is the upstream zone of river that follows the crenon, characterised by relatively cool temperatures, high oxygen contents, fast turbulent flow and gravelly-sandy bottoms

Riverine: relating to a river

Schist: the schists constitute a group of medium-grade metamorphic rocks, chiefly notable for the preponderance of lamellar minerals such as micas, chlorite, talc, hornblende, graphite and others. Quartz often occurs in drawn-out grains to such an extent that a particular form called quartz schist is produced. By definition, schist contains more than 50% platy and elongated minerals, often finely interleaved with quartz and feldspar

Seston: any drifting organisms (bioseston) and non-living matter (abioseston) swimming or floating in a water body

Sialic: derived from the sial, the upper layer of the Earth's crust made of rocks rich in silicates and aluminium minerals

Silicophile: a plant preferring silica-rich soils

Specialist species: a specialist species can only thrive in a narrow range of environmental conditions or has a limited diet

Stadial: a stadial is a period of colder temperatures during an interglacial (warm period) separating the glacial periods of an ice age. Such periods are of insufficient duration or intensity to be considered glacial periods

Stenohaline: stenohaline organisms have a low tolerance to salinity changes. Stenohaline organisms live in both freshwater and marine environments

Stenothermophilous: an organism that prefers a narrow temperature range

Stream load: stream load is a geologic term referring to the solid matter carried by a stream; it is subdivided into three types: dissolved load, suspended load, and bed load

Subarctic: the Subarctic is a region in the Northern Hemisphere immediately south of the true Arctic and covering much of Alaska, Canada, north of Scandinavia, Siberia, and northern Mongolia. Generally, subarctic regions fall between 50°N and 70°N latitude, depending on local climates

Sympatry: two species or populations with overlapping ranges occurring in the same area

Synclinorium: a synclinorium is a large syncline with superimposed smaller folds

Teratological specimen: any individual affected by abnormalities of physiological development either referred to birth defects or related to other developmental stages, including puberty

Thalweg: the thalweg is a line drawn to join the lowest points along the entire length of a stream bed or valley in its downward slope, defining its deepest channel

Thanatocoenosis: an assemblage of organisms brought together after death. They often originate from different habitats, having been brought together by water current

Tufa: tufa is a variety of limestone, formed by the precipitation of carbonate minerals from ambient temperature water bodies

Trophic level: the trophic level of an organism is the position it occupies in a food chain

TWINSPAN: TWINSPAN stands for Two-Way INdicator SPecies Analyses. It is based on Reciprocal Averaging ordination (RA) and is best envisaged in terms of samples characterised by species' abundances

U-shaped valley: a U-shaped valley is formed by the process of glaciation. It has a characteristic U-shape, with steep, straight sides, and a flat bottom

Ultramafic rocks: ultramafic rocks are igneous and meta-igneous rocks with very low silica content (less than 45%), generally > 18% MgO, high FeO, low potassium, and are composed of usually greater than 90% mafic minerals (dark coloured, high magnesium and iron content)

Umbilicus: the umbilicus is the axially aligned, hollow cone-shaped space within the whorls of a coiled gastropod shell

Umbone: umbone or umbo is the thickest and oldest (often somewhat protruding) part of a bivalve shell which was formed when the animal was a juvenile; it corresponds to the prodissoconch

Viviparity: in animals, viviparity means development of the embryo inside the body of the mother, eventually leading to live birth (as opposed to laying eggs)

Watershed: a watershed refers to a divide that separates one drainage basin (catchment) from another drainage basin

Zoochory: dispersal of plants, seeds or living organisms by the agency of living animal vectors

PLATES

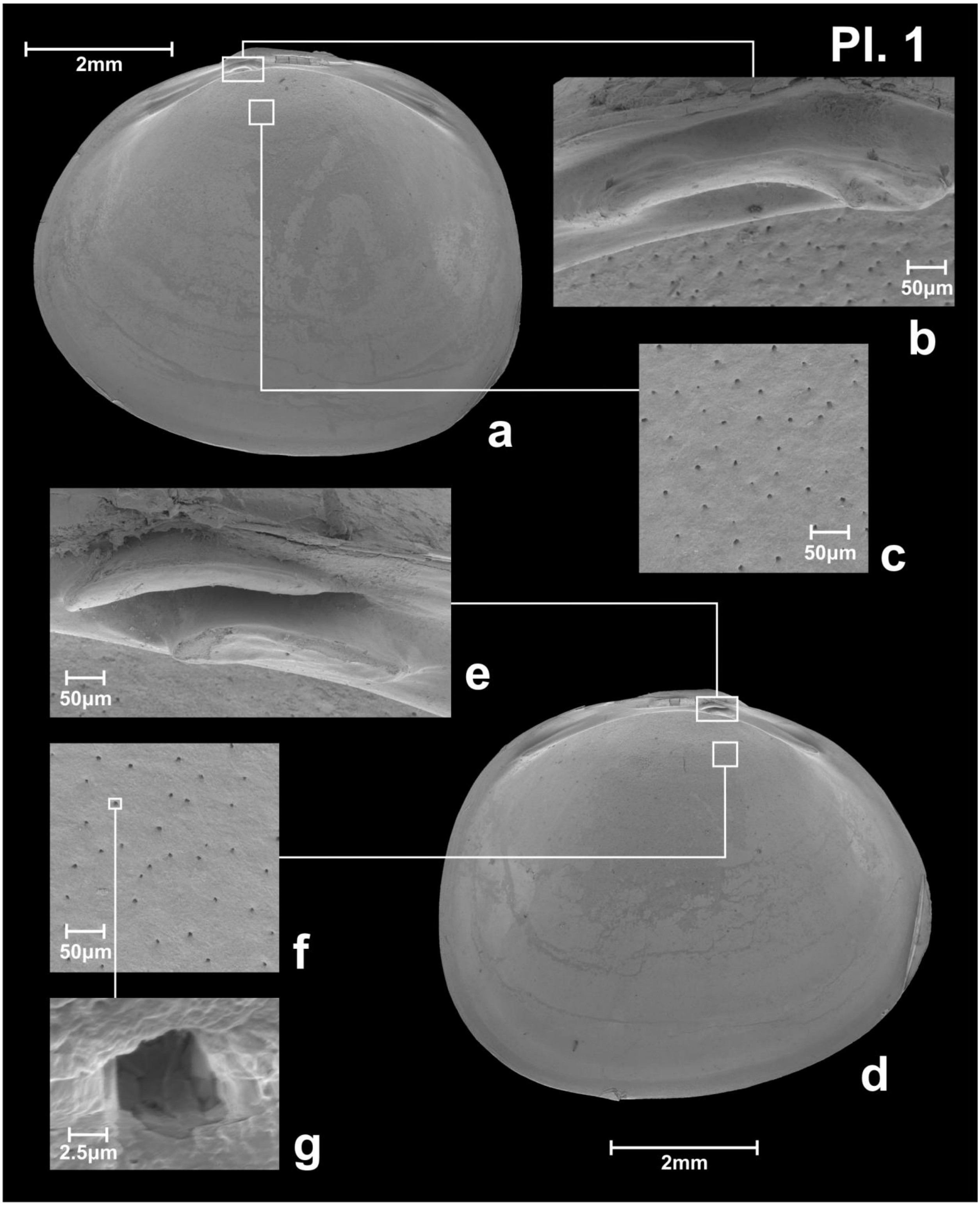


Fig. a. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 199, right valve inner view;
Fig. b. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 199, detail of the cardinal tooth C_3;
Fig. c. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 199,
detail of the micropores occurring on the internal valve side;
Fig. d. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 199, left valve inner view;
Fig. e. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 199,
detail of the cardinal teeth C_2 and C_4; Fig. f. Sphaerium corneum (Linnaeus, 1758),
specimen from station 199, detail of the micropores occurring on the internal valve side;
Fig. g. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 199, detail of a micropore occurring on the internal valve side.

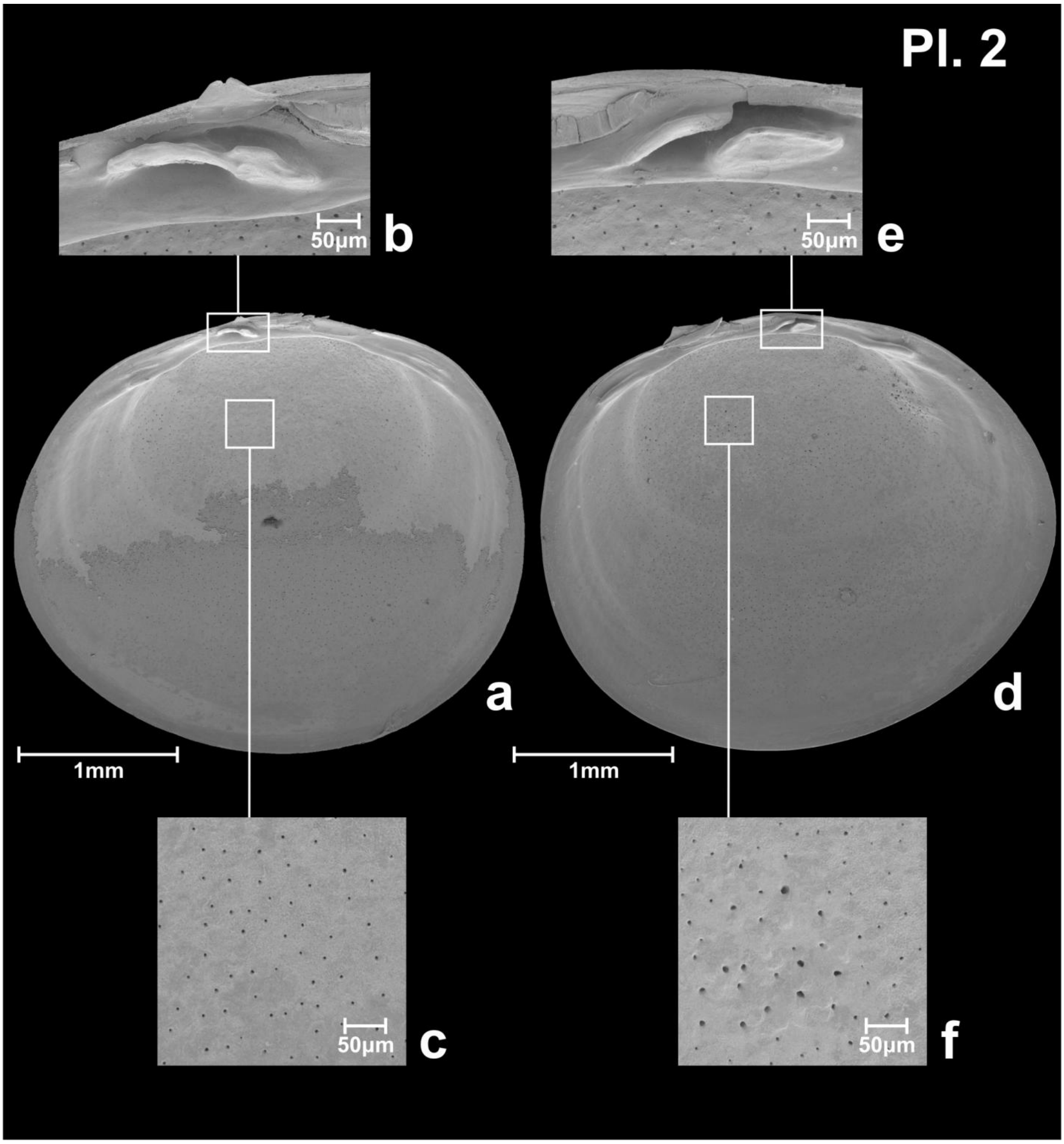


Fig. a. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 311, right valve inner view;
Fig. b. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 311,
detail of the cardinal tooth C_3;
Fig. c. *Sphaerium corneum* (Linnaeus, 1758),
specimen from station 311, detail of the micropores occurring on the internal valve side;
Fig. d. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 311, left valve inner view;
Fig. e. *Sphaerium corneum* (Linnaeus, 1758), specimen from station 311,
detail of the cardinal teeth C_2 and C_4;
Fig. f. Sphaerium corneum (Linnaeus, 1758),
specimen from station 311, detail of the micropores occurring on the internal valve side.

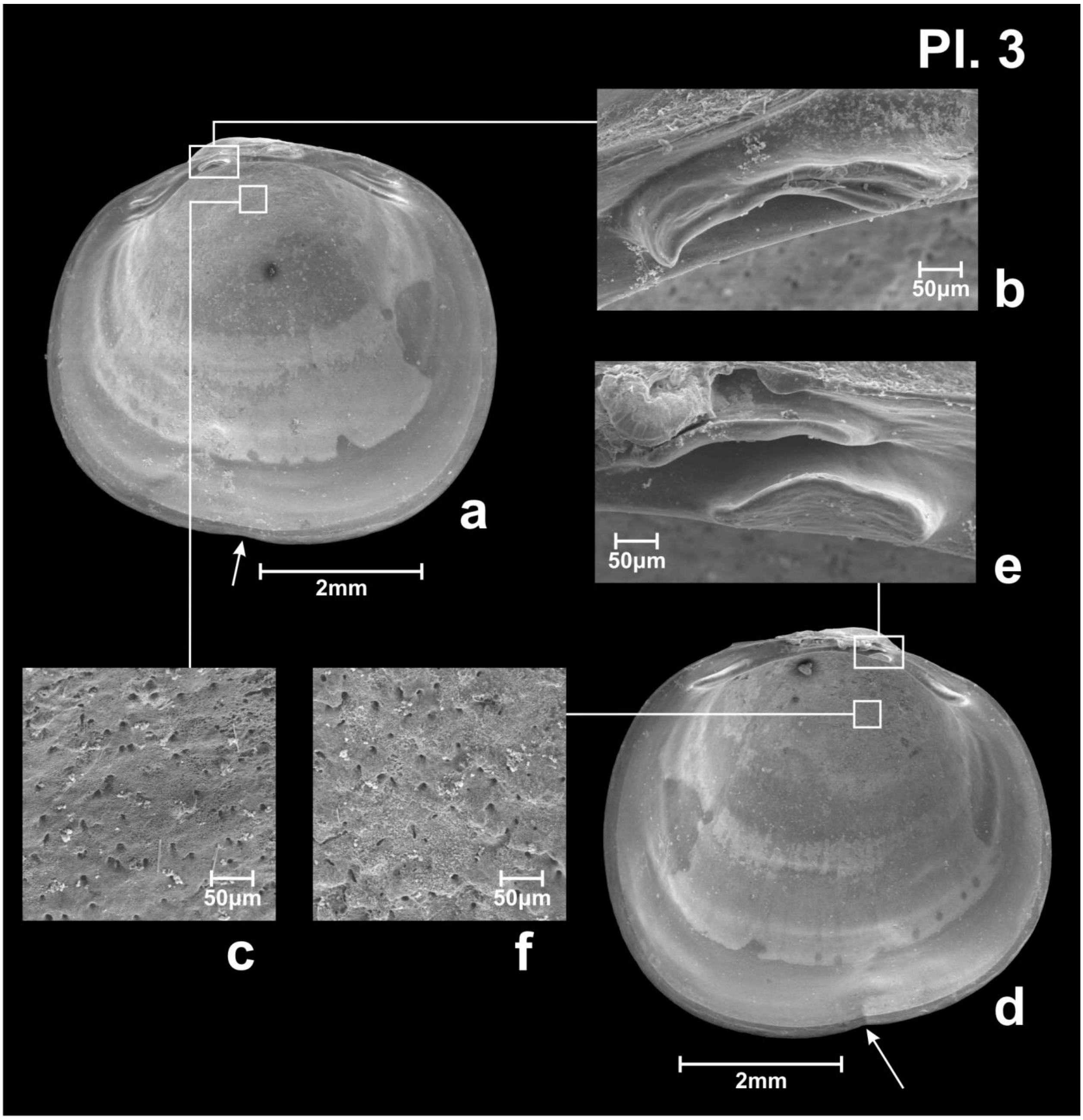


Fig. a. *Sphaerium corneum* (Linnaeus, 1758), diphyoidic specimen from station 7, right valve inner view, the arrow points to the deformation;
Fig. b. *Sphaerium corneum* (Linnaeus, 1758), diphyoidic specimen from station 7, detail of the cardinal tooth C_3;
Fig. c. *Sphaerium corneum* (Linnaeus, 1758), diphyoidic specimen from station 7, detail of the micropores occurring on the internal valve side;
Fig. d. *Sphaerium corneum* (Linnaeus, 1758), diphyoidic specimen from station 7, left valve inner view; the arrow points to the deformation;
Fig. e. *Sphaerium corneum* (Linnaeus, 1758), diphyoidic specimen from station 7, detail of the cardinal teeth C_2 and C_4;
Fig. f. *Sphaerium corneum* (Linnaeus, 1758), diphyoidic specimen from station 7, detail of the micropores occurring on the internal valve side.

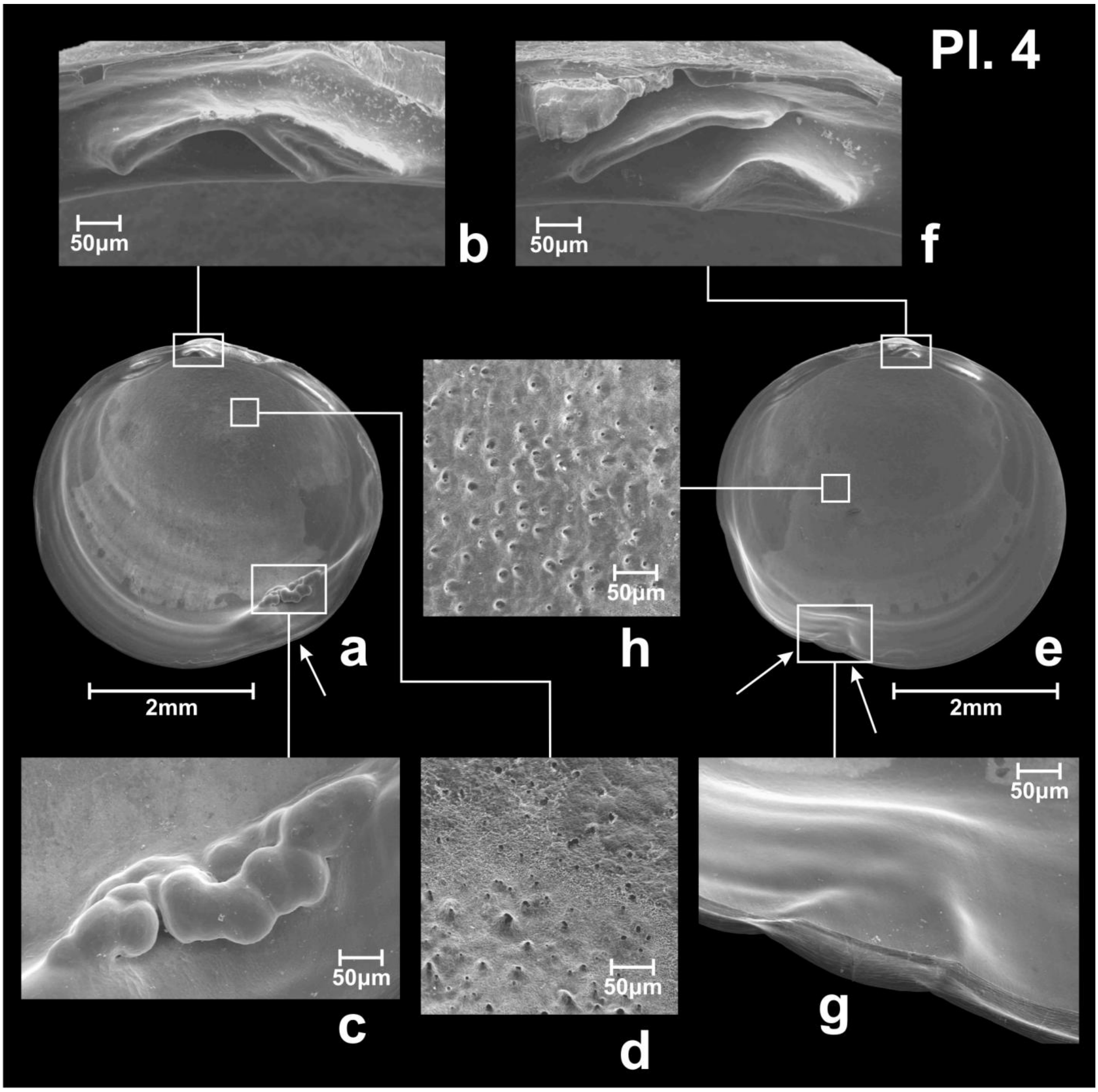


Fig. a. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, right valve inner view, the arrow points to the deformation; note P_3 reversal from the left valve
Fig. b. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, detail of the cardinal tooth C_3;
Fig. c. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, detail of the repaired ventral edge of the valve, see the globular microstructures associated with the suture zone;
Fig. d. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, detail of the micropores occurring on the internal valve side
Fig. e. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, left valve inner view; the arrow points to the deformation; note P_1 and P_2 reversal from the right valve
Fig. f. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, detail of the cardinal teeth C_2 and C_4;
Fig. g. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, detail of the repaired ventral edge of the valve;
Fig. h. *Sphaerium corneum* (Linnaeus, 1758), young teratological specimen from station 7, detail of the micropores occurring on the internal valve side.

PLATE 5

Fig. a. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, right valve inner view;

Fig. b. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, detail of the cardinal tooth C_3;

Fig. c. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, detail of the micropores occurring on the internal valve side;

Fig. d. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, left valve inner view;

Fig. e. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, detail of the micropores occurring on the internal valve side;

Fig. g. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, right valve inner view;

Fig. h. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the cardinal tooth C_3;

Fig. i. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the micropores occurring on the internal valve side;

Fig. j. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, left valve inner view;

Fig. k. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the micropores occurring on the internal valve side.

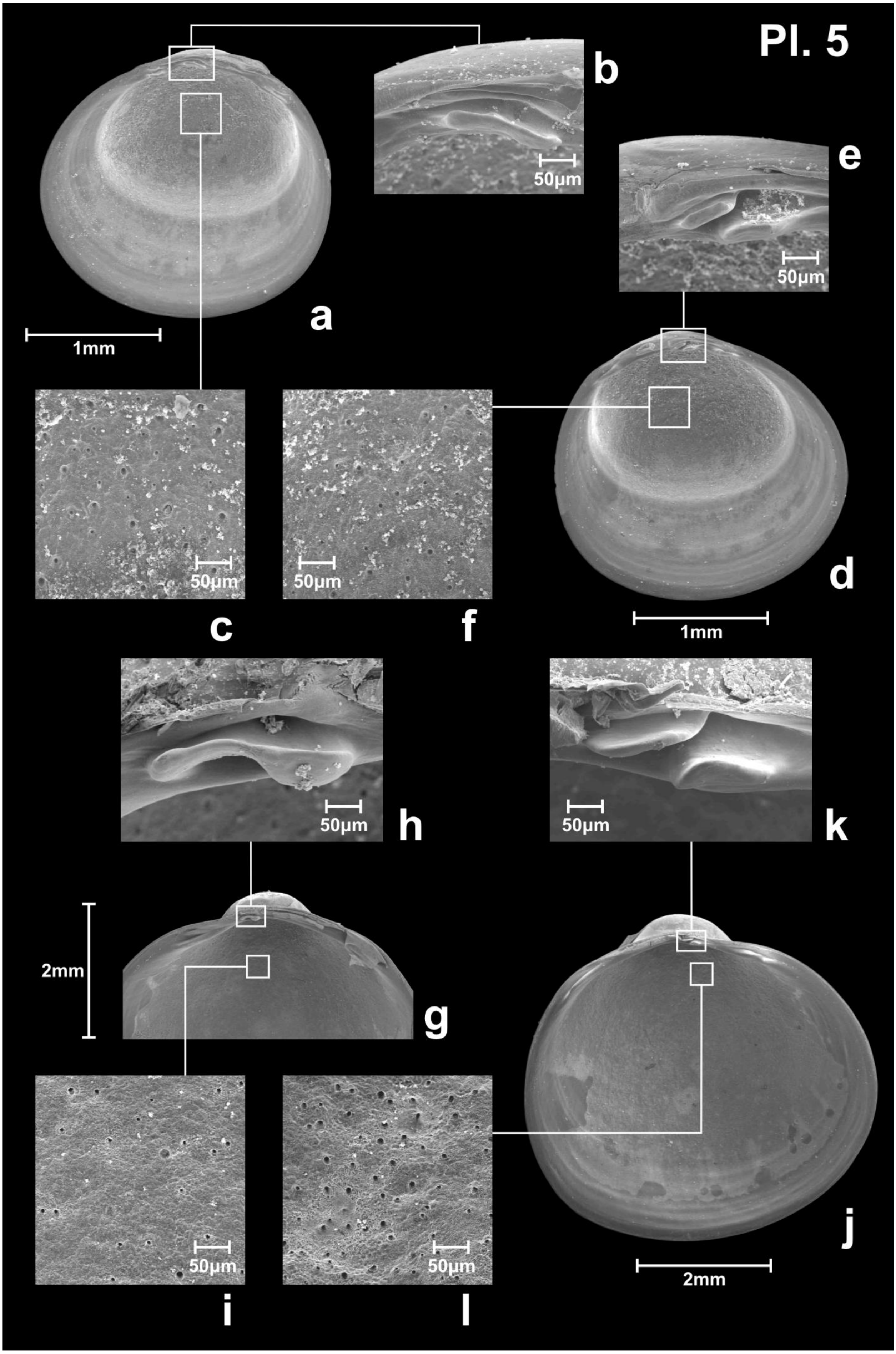

Pl. 5
a
b
c
d
e
f
g
h
i
j
k
l
1mm
1mm
2mm
2mm
50µm
50µm
50µm
50µm
50µm
50µm
50µm
50µm

PLATE 6

Fig. a. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, right valve inner view;

Fig. b. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the cardinal tooth C_3;

Fig. c. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the micropores occurring on the internal valve side;

Fig. d. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, left valve inner view;

Fig. e. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Musculium lacustre* (O. F. Müller, 1774), specimen from station 237, detail of the micropores occurring on the internal valve side;

Fig. g. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, right valve outer view;

Fig. h. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, detail of the embryonic ribbon;

Fig. i. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, left valve outer view;

Fig. j. *Musculium lacustre* (O. F. Müller, 1774), young specimen from station 237, detail of the prodissoconch region.

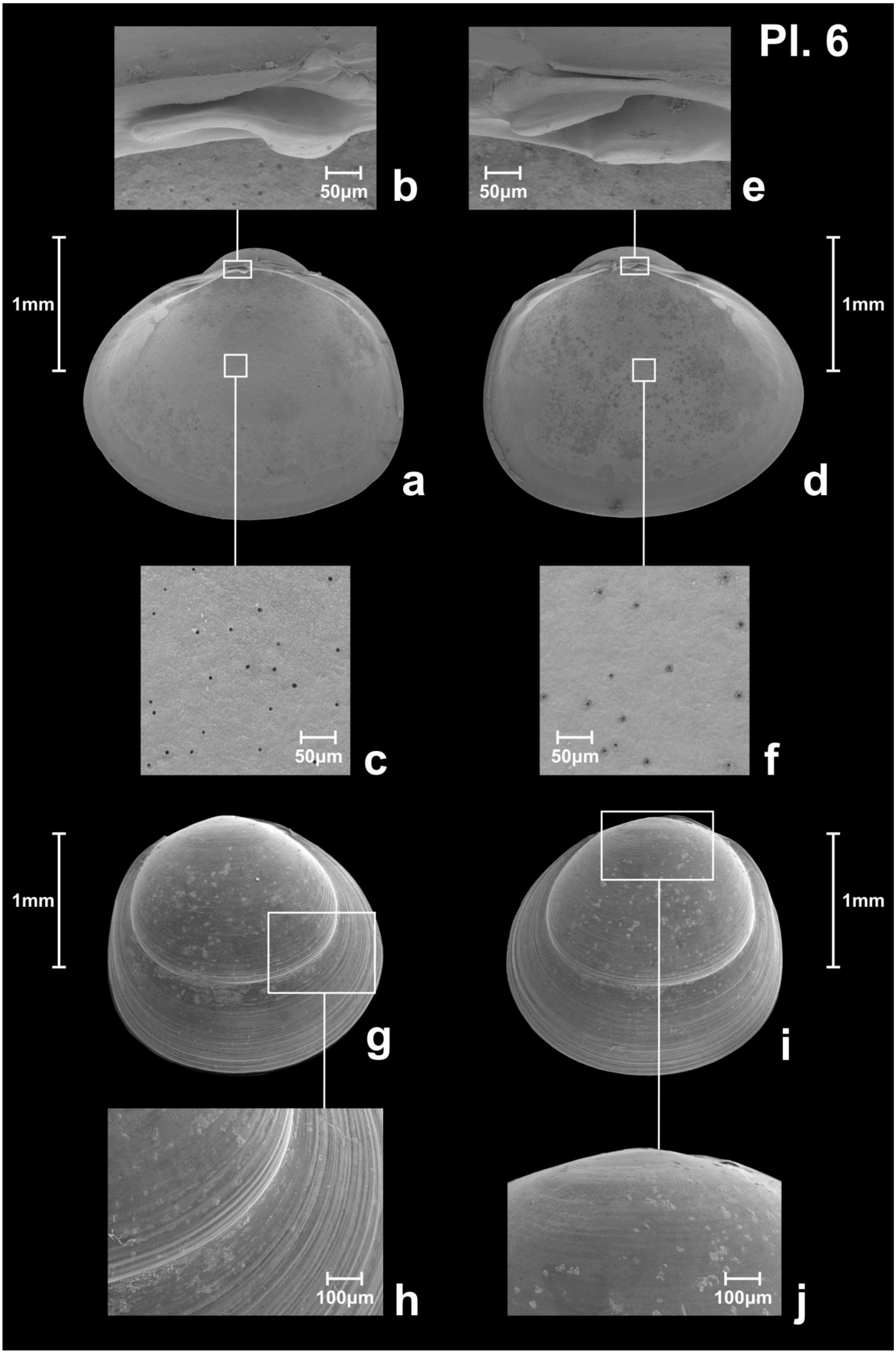

Pl. 6
50µm
b
50µm
e
1mm
1mm
a
d
50µm
c
50µm
f
1mm
1mm
g
i
100µm
h
100µm
j

PLATE 7

Fig. a. *Pisidium casertanum* (Poli, 1791), specimen from station 280, right valve inner view;

Fig. b. *Pisidium casertanum* (Poli, 1791), specimen from station 280, detail of the cardinal tooth C_3;

Fig. c. *Pisidium casertanum* (Poli, 1791), specimen from station 280, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium casertanum* (Poli, 1791), specimen from station 280, left valve inner view;

Fig. e. *Pisidium casertanum* (Poli, 1791), specimen from station 280, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium casertanum* (Poli, 1791), specimen from station 280, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium casertanum* (Poli, 1791), specimen from station 318, right valve inner view;

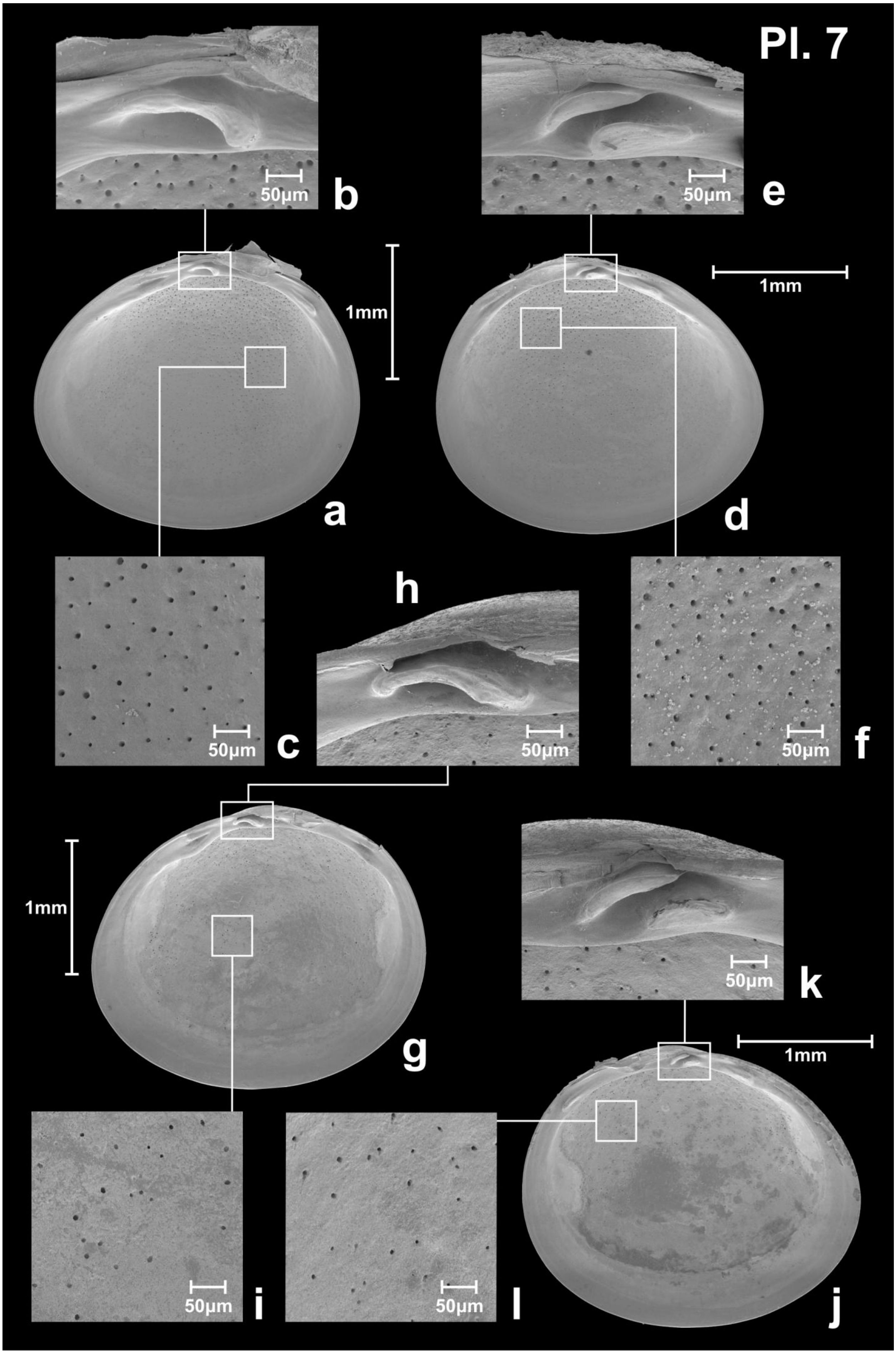
Fig. h. *Pisidium casertanum* (Poli, 1791), specimen from station 318, detail of the cardinal tooth C_3;

Fig. i. *Pisidium casertanum* (Poli, 1791), specimen from station 318, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium casertanum* (Poli, 1791), specimen from station 318, left valve inner view;

Fig. k. *Pisidium casertanum* (Poli, 1791), specimen from station 318, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium casertanum* (Poli, 1791), specimen from station 318, detail of the micropores occurring on the internal valve side.


Pl. 7
b
50µm
e
50µm
1mm
1mm
a
d
h
c
50µm
50µm
f
50µm
1mm
k
50µm
1mm
g
i
50µm
l
50µm
j

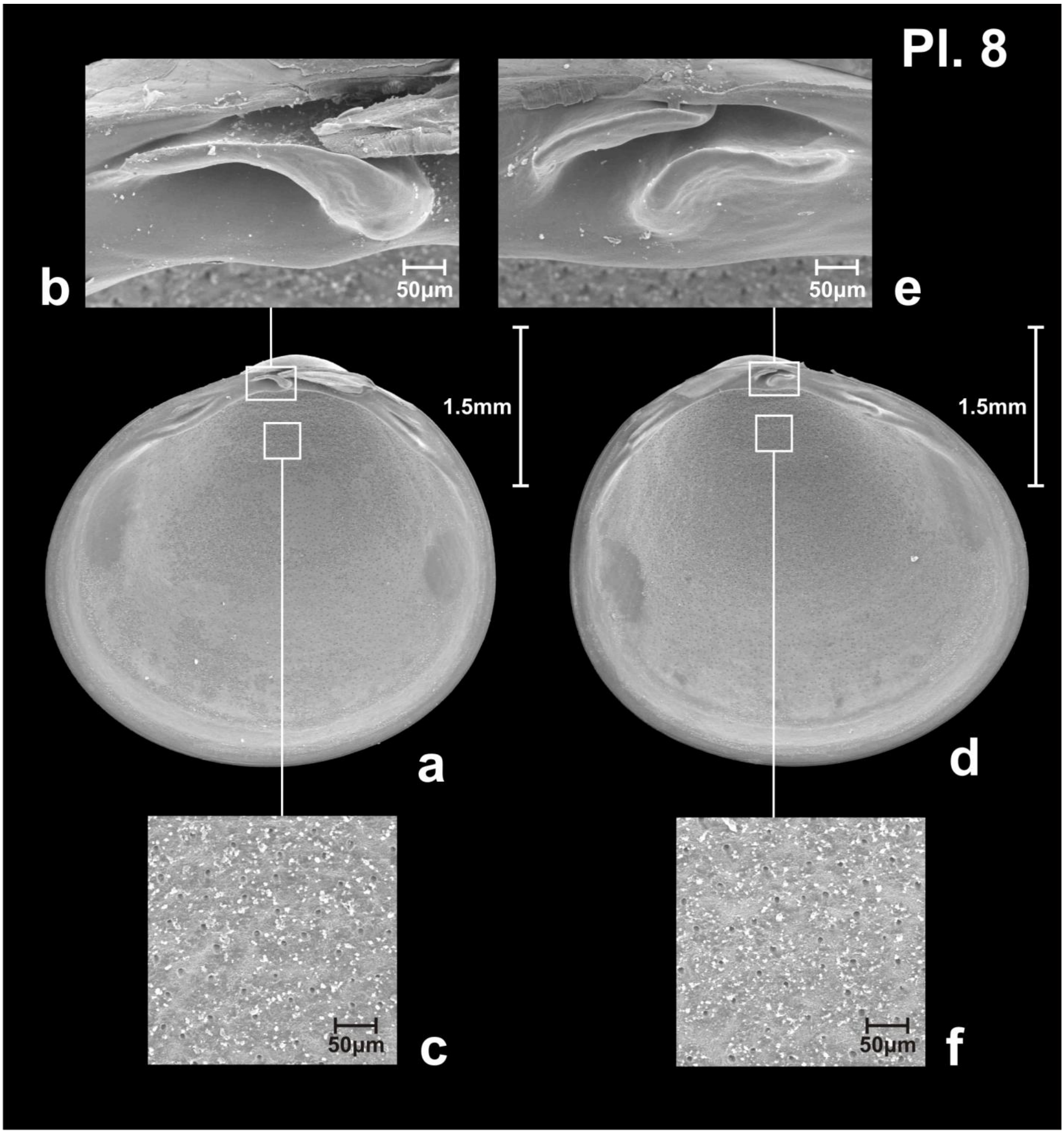


Fig. a. *Pisidium casertanum* (Poli, 1791), specimen from station 248, right valve inner view;
Fig. b. *Pisidium casertanum* (Poli, 1791), specimen from station 248, detail of the cardinal tooth C_3;
Fig. c. *Pisidium casertanum* (Poli, 1791),
specimen from station 248, detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium casertanum* (Poli, 1791), specimen from station 248, left valve inner view;
Fig. e. *Pisidium casertanum* (Poli, 1791), specimen from station 248,
detail of the cardinal teeth C_2 and C_4;
Fig. f. *Pisidium casertanum* (Poli, 1791), specimen from station 248,
detail of the micropores occurring on the internal valve side.

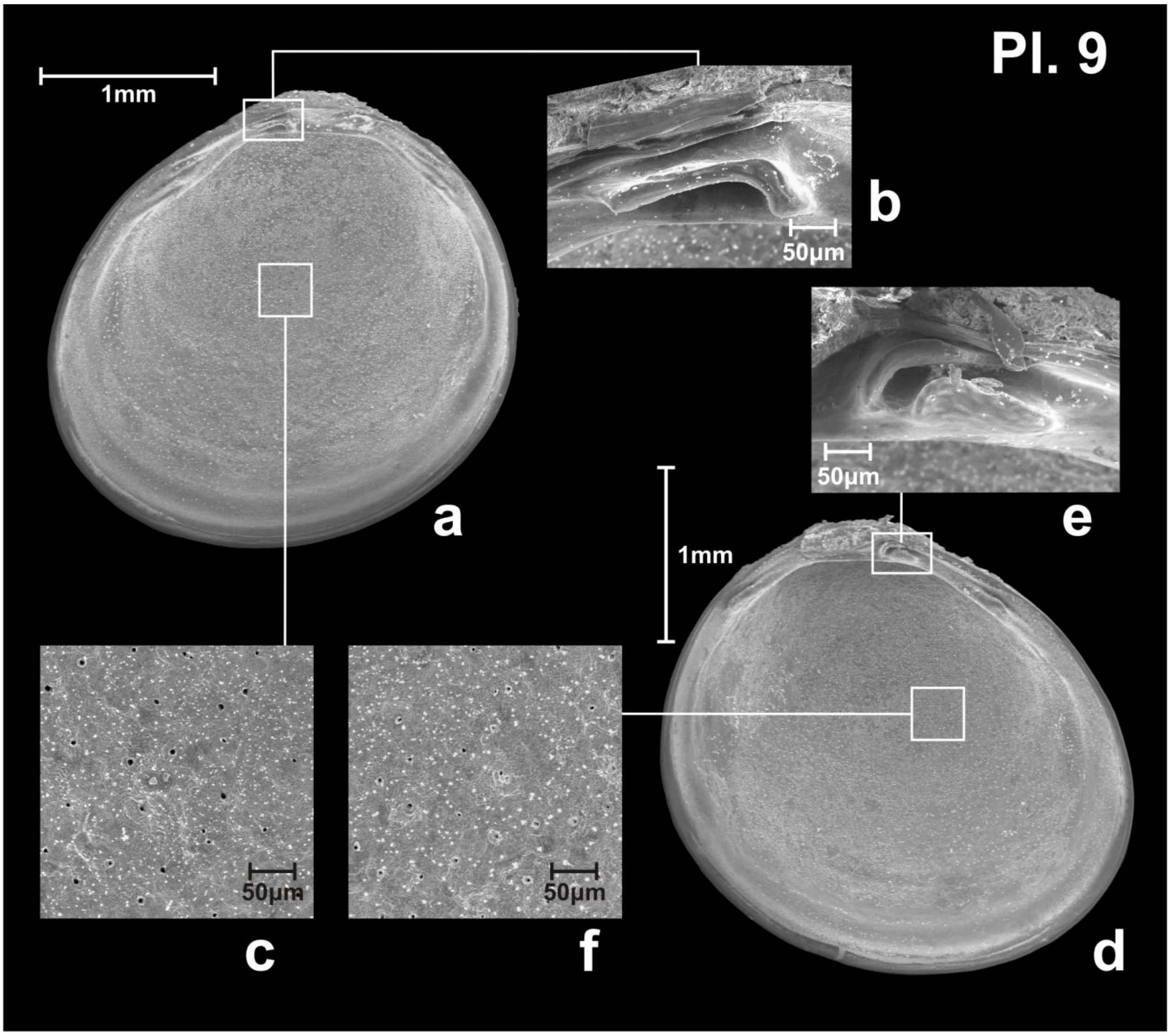


Fig. a. *Pisidium casertanum* (Poli, 1791), specimen from station 72, right valve inner view;
Fig. b. *Pisidium casertanum* (Poli, 1791), specimen from station 72, detail of the cardinal tooth C_3;
Fig. c. *Pisidium casertanum* (Poli, 1791), specimen from station 72,
detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium casertanum* (Poli, 1791), specimen from station 72, left valve inner view;
Fig. e. *Pisidium casertanum* (Poli, 1791), specimen from station 72,
detail of cardinal teeth C_2 and C_4;
Fig. f. *Pisidium casertanum* (Poli, 1791), specimen from station 72,
detail of the micropores occurring on the internal valve side.

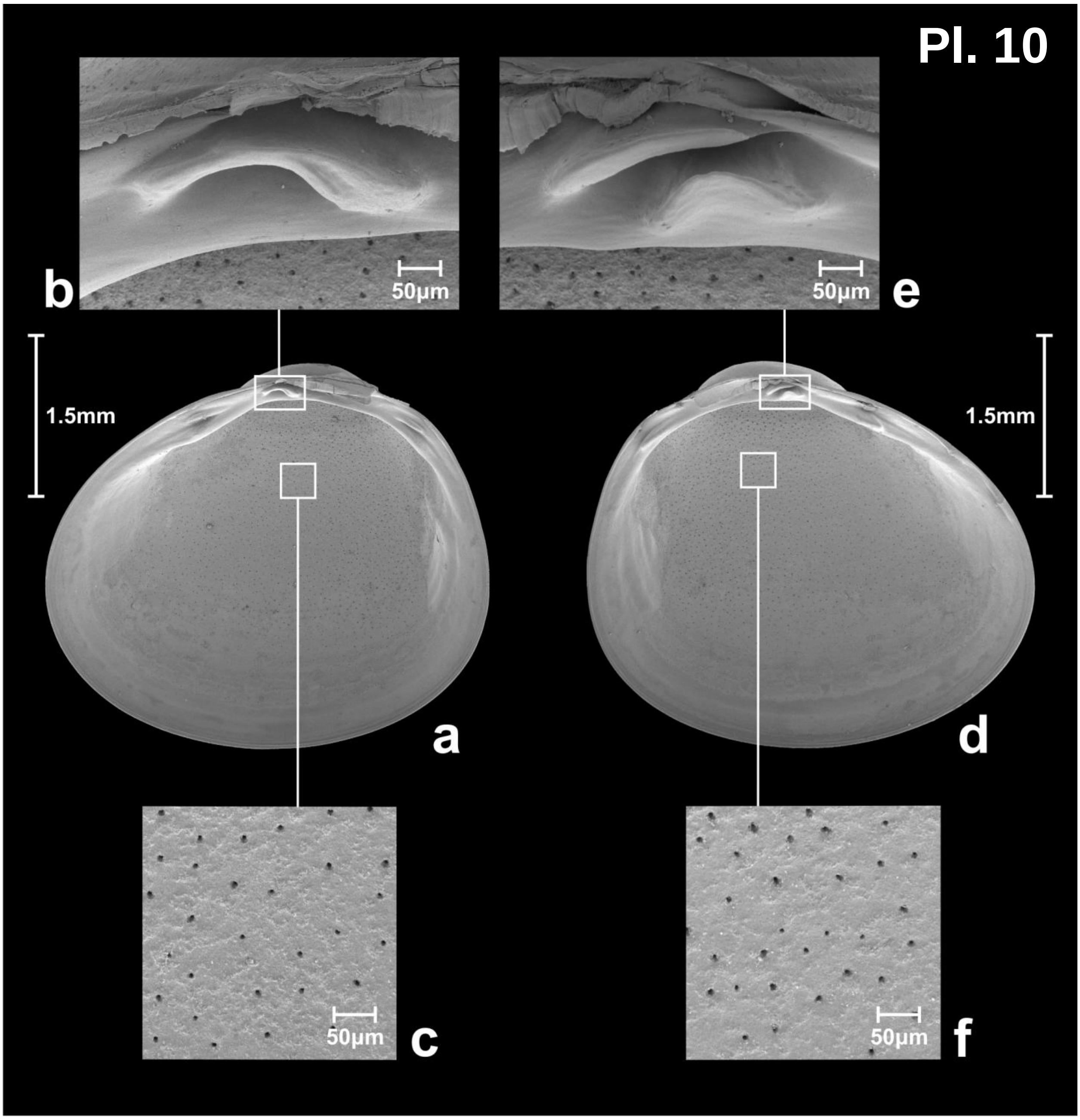


Fig. a. *Pisidium casertanum* (Poli, 1791), specimen from station 226, right valve inner view;
Fig. b. *Pisidium casertanum* (Poli, 1791), specimen from station 226, detail of the cardinal tooth C3;
Fig. c. *Pisidium casertanum* (Poli, 1791), specimen from station 226,
detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium casertanum* (Poli, 1791), specimen from station 226, left valve inner view;
Fig. e. *Pisidium casertanum* (Poli, 1791), specimen from station 226,
detail of the cardinal teeth C2 and C4;
Fig. f. *Pisidium casertanum* (Poli, 1791), specimen from station 226,
detail of the micropores occurring on the internal valve side.

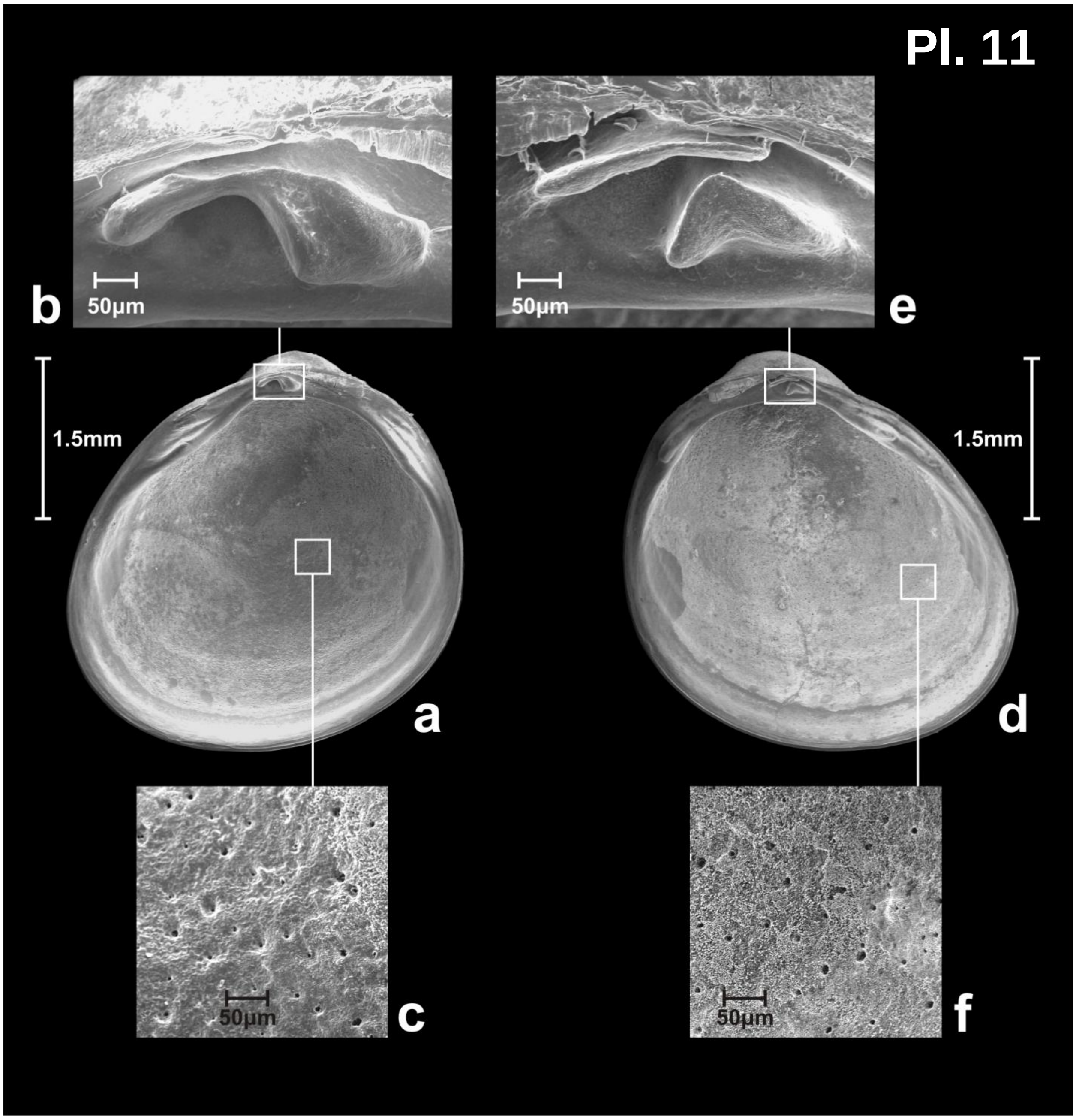


Fig. a. *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, specimen from station 11, right valve inner view;
Fig. b. *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, specimen from station 11, detail of the cardinal tooth C_3;
Fig. c. *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, specimen from station 11, detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, specimen from station 11 left valve inner view;
Fig. e. *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, specimen from station 11, detail of the cardinal teeth C_2 and C_4;
Fig. f. *Pisidium casertanum* f. *ponderosa* Stelfox, 1918, specimen from station 11, detail of the micropores occurring on the internal valve side.

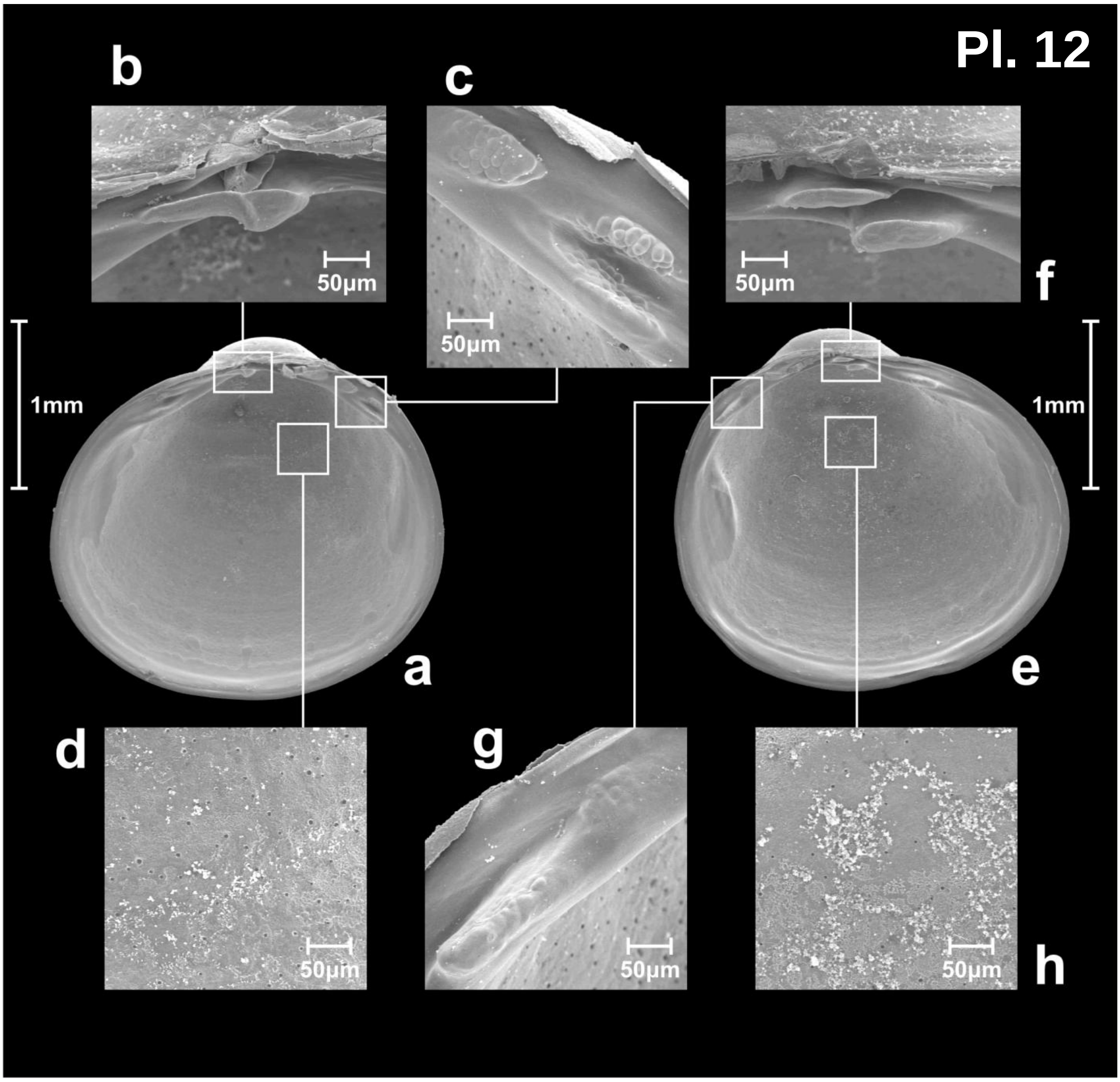


Fig. a. *Pisidium personatum* Malm, 1855, specimen from station 226, right valve inner view;
Fig. b. *Pisidium personatum* Malm, 1855, specimen from station 226, detail of the cardinal tooth C_3;
Fig. c. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the callus and of the posterior teeth P_1 and P_3;
Fig. d. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the micropores occurring on the internal valve side;
Fig. e. *Pisidium personatum* Malm, 1855, specimen from station 226, left valve inner view;
Fig. f. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the cardinal teeth C_2 and C_4;
Fig. g. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the weak callus located at the right end of the posterior tooth P_2;
Fig. h. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the micropores occurring on the internal valve side.

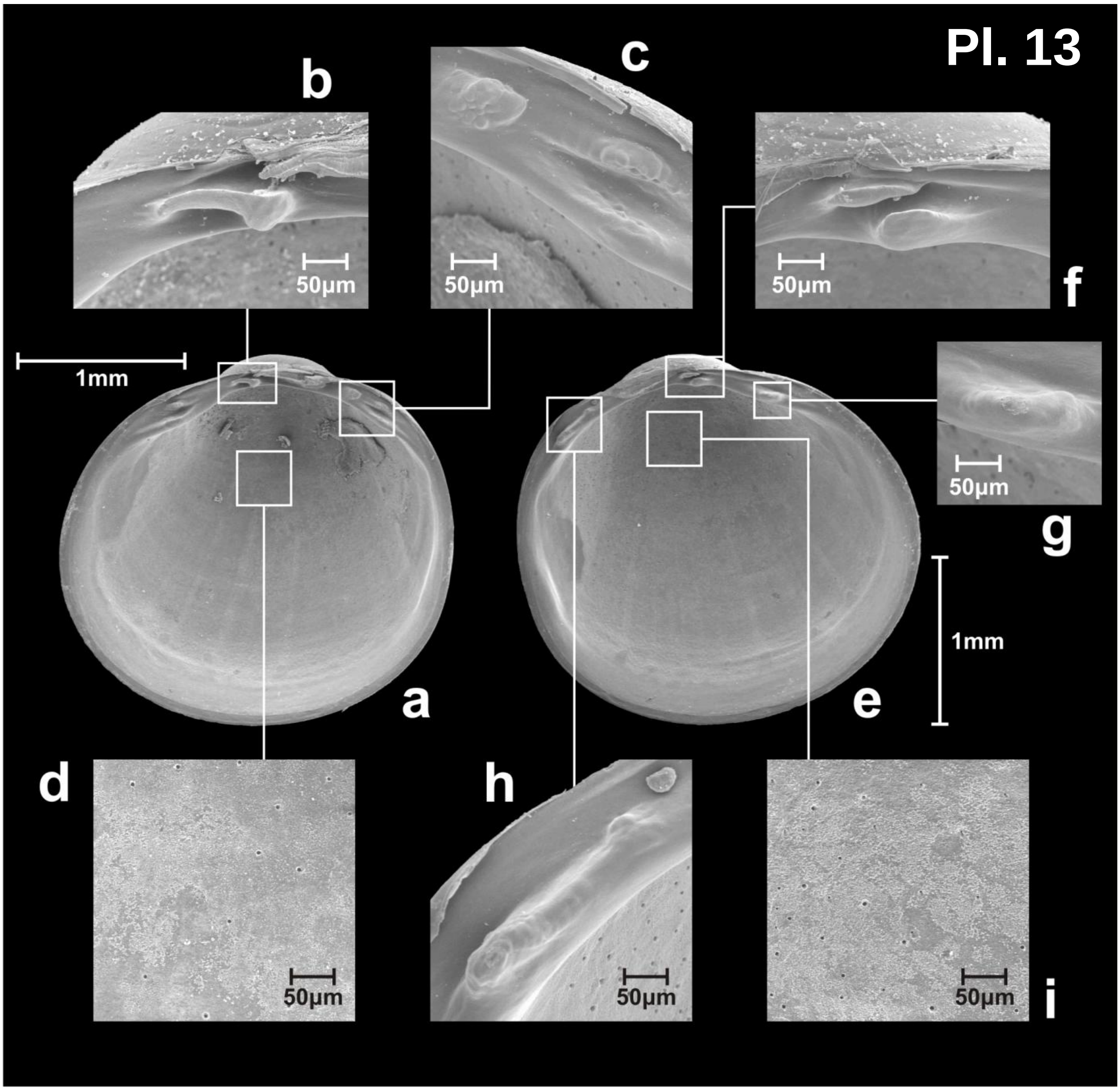


Fig. a. *Pisidium personatum* Malm, 1855, specimen from station 226, right valve inner view;
Fig. b. *Pisidium personatum* Malm, 1855, specimen from station 226, detail of the cardinal tooth C_3;
Fig. c. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the callus and of the posterior teeth P_1 and P_3;
Fig. d. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the micropores occurring on the internal valve side;
Fig. e. *Pisidium personatum* Malm, 1855, specimen from station 226, left valve inner view;
Fig. f. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the cardinal teeth C_2 and C_4;
Fig. g. *Pisidium personatum* Malm, 1855, specimen from station 226, detail of the anterior tooth A_2;
Fig. h. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the weak callus located at the right end of the posterior tooth P_2;
Fig. i. *Pisidium personatum* Malm, 1855, specimen from station 226,
detail of the micropores occurring on the internal valve side.

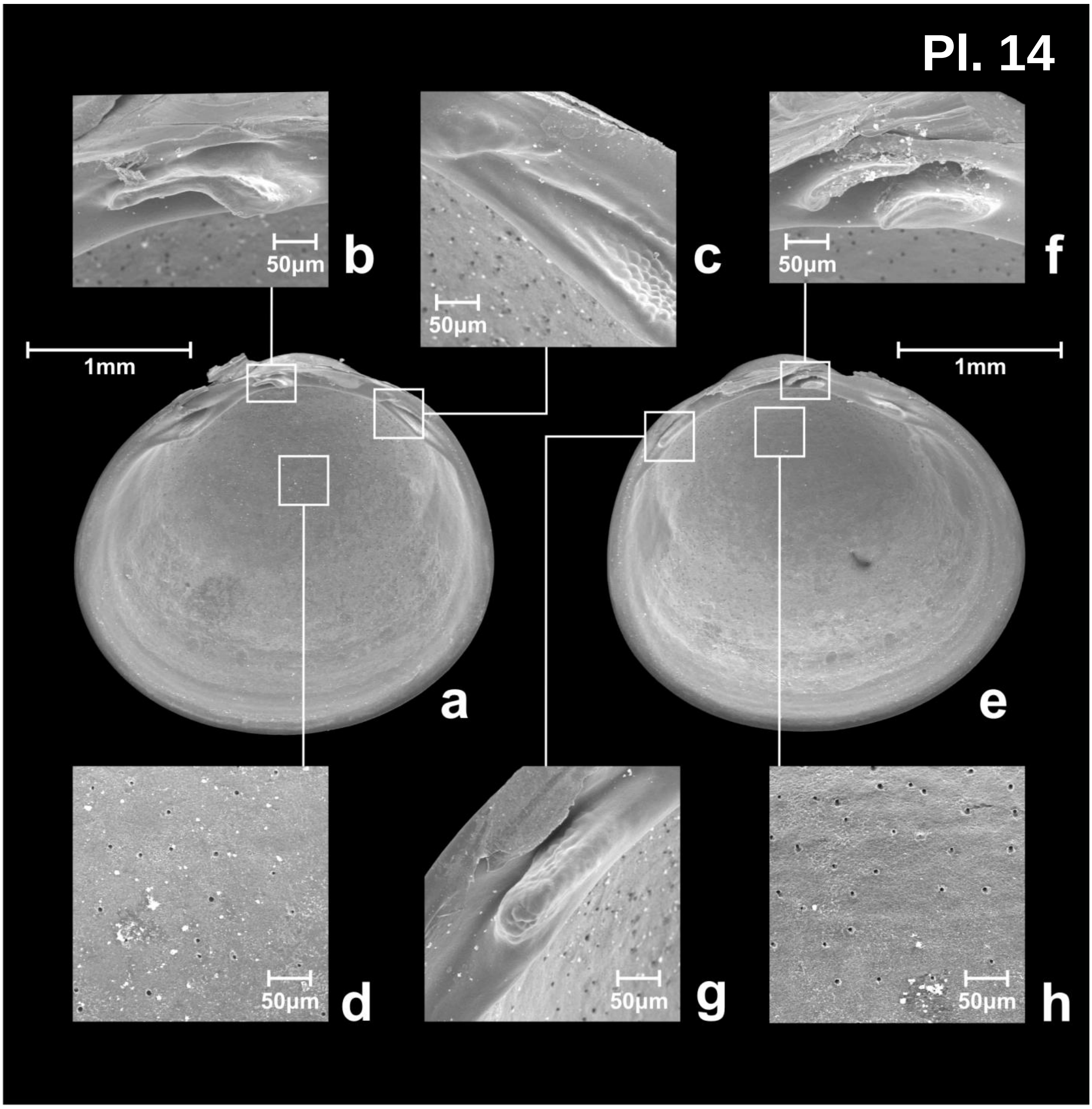


Fig. a. *Pisidium personatum* Malm, 1855, specimen from station 248, right valve inner view;
Fig. b. *Pisidium personatum* Malm, 1855, specimen from station 248, detail of the cardinal tooth C_3;
Fig. c. *Pisidium personatum* Malm, 1855, specimen from station 248, detail of the callus and of the posterior teeth P_1 and P_3;
Fig. d. *Pisidium personatum* Malm, 1855, specimen from station 248, detail of the micropores occurring on the internal valve side;
Fig. e. *Pisidium personatum* Malm, 1855, specimen from station 248, left valve inner view;
Fig. f. *Pisidium personatum* Malm, 1855, specimen from station 248, detail of the cardinal teeth C_2 and C_4;
Fig. g. *Pisidium personatum* Malm, 1855, specimen from station 248, detail of the weak callus located at the right end of the posterior tooth P_2;
Fig. h. *Pisidium personatum* Malm, 1855, specimen from station 248, detail of the micropores occurring on the internal valve side.

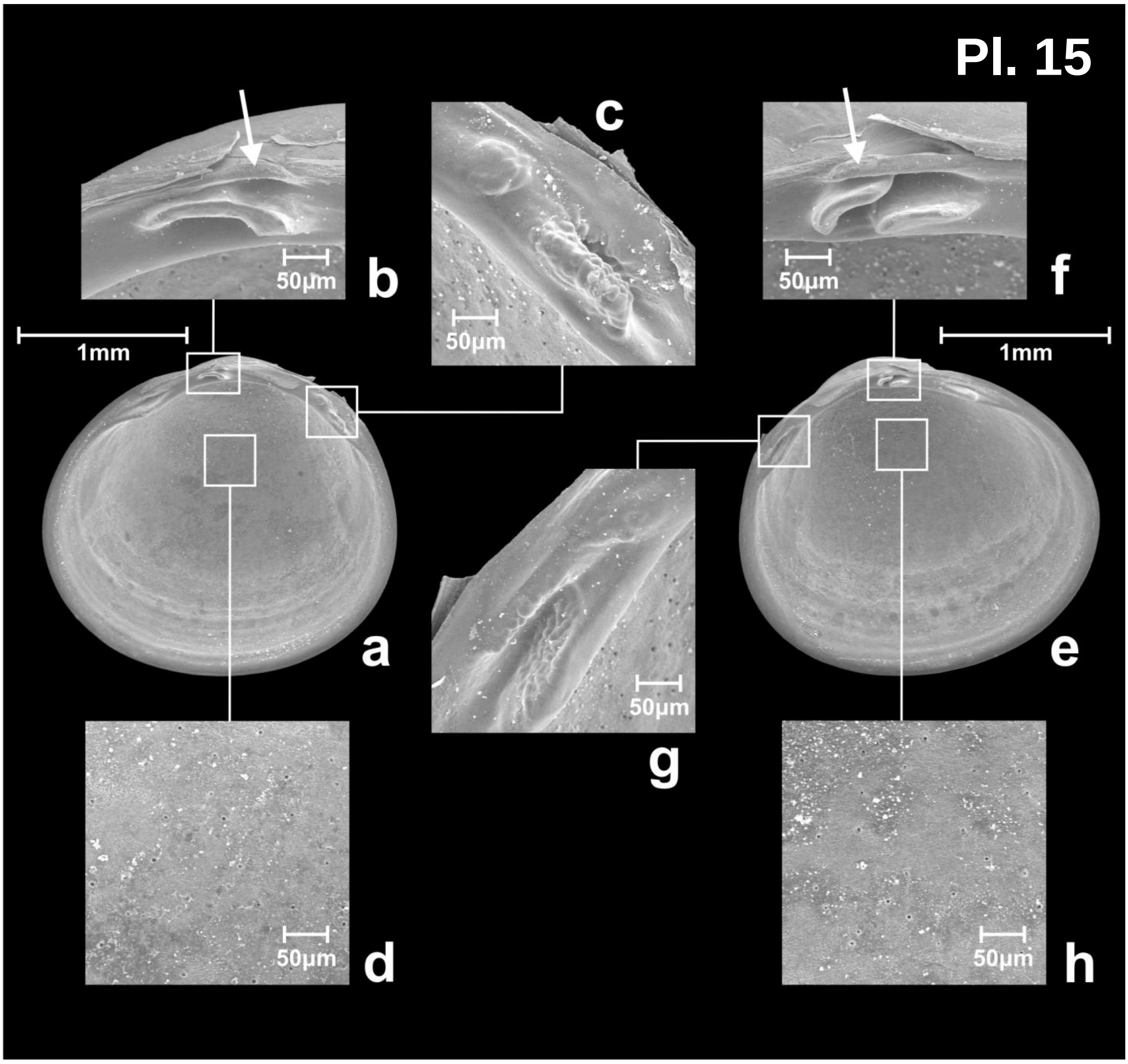


Fig. a. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, right valve inner view; note P_1-P_3 reversal on the left valve;
Fig. b. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, detail of the cardinal tooth C_3; Note the sharp dorsal edge of the hinge originating a 'pseudo-tooth' (see white arrow);
Fig. c. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, detail of the right valve callus (not inverted) and of the inverted P_2, normally located to the left valve;
Fig. d. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, detail of the micropores occurring on the internal valve side;
Fig. e. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, left valve inner view; note P_1 and P_3 reversal from the right valve;
Fig. f. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, detail of the cardinal teeth C_2 and C_4; note the sharp dorsal edge of the hinge originating a 'pseudo-tooth' (see white arrow);
Fig. g. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, detail of the left valve weak callus (not inverted) and of the inverted P_1 and P_3 teeth, normally located to the right valve;
Fig. h. *Pisidium personatum* Malm, 1855, teratological specimen from station 248, detail of the micropores occurring on the internal valve side;

PLATE 16

Fig. a. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, right valve inner view;

Fig. b. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the cardinal tooth C_3;

Fig. c. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the posterior teeth P_1 and P_3, see the microstructures associated with them and the pseudocallus located at the left end of P_3;

Fig. d. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the micropores occurring on the internal valve side;

Fig. e. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, left valve inner view;

Fig. f. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the cardinal teeth C_2 and C_4;

Fig. g. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the posterior tooth P_2;

Fig. h. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the micropores occurring on the internal valve side;

Fig. i. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, right valve inner view;

Fig. j. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the cardinal tooth C_3;

Fig. k. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the posterior teeth P_1 and P_3, see the microstructures associated with them and the pseudocallus located at the left end of P_3;

Fig. l. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the micropores occurring on the internal valve side;

Fig. m. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, left valve inner view;

Fig. n. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the cardinal teeth C_2 and C_4;

Fig. o. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the posterior tooth P_2;

Fig. p. *Pisidium obtusale* (Lamarck, 1818), specimen from station 248, detail of the micropores occurring on the internal valve side.

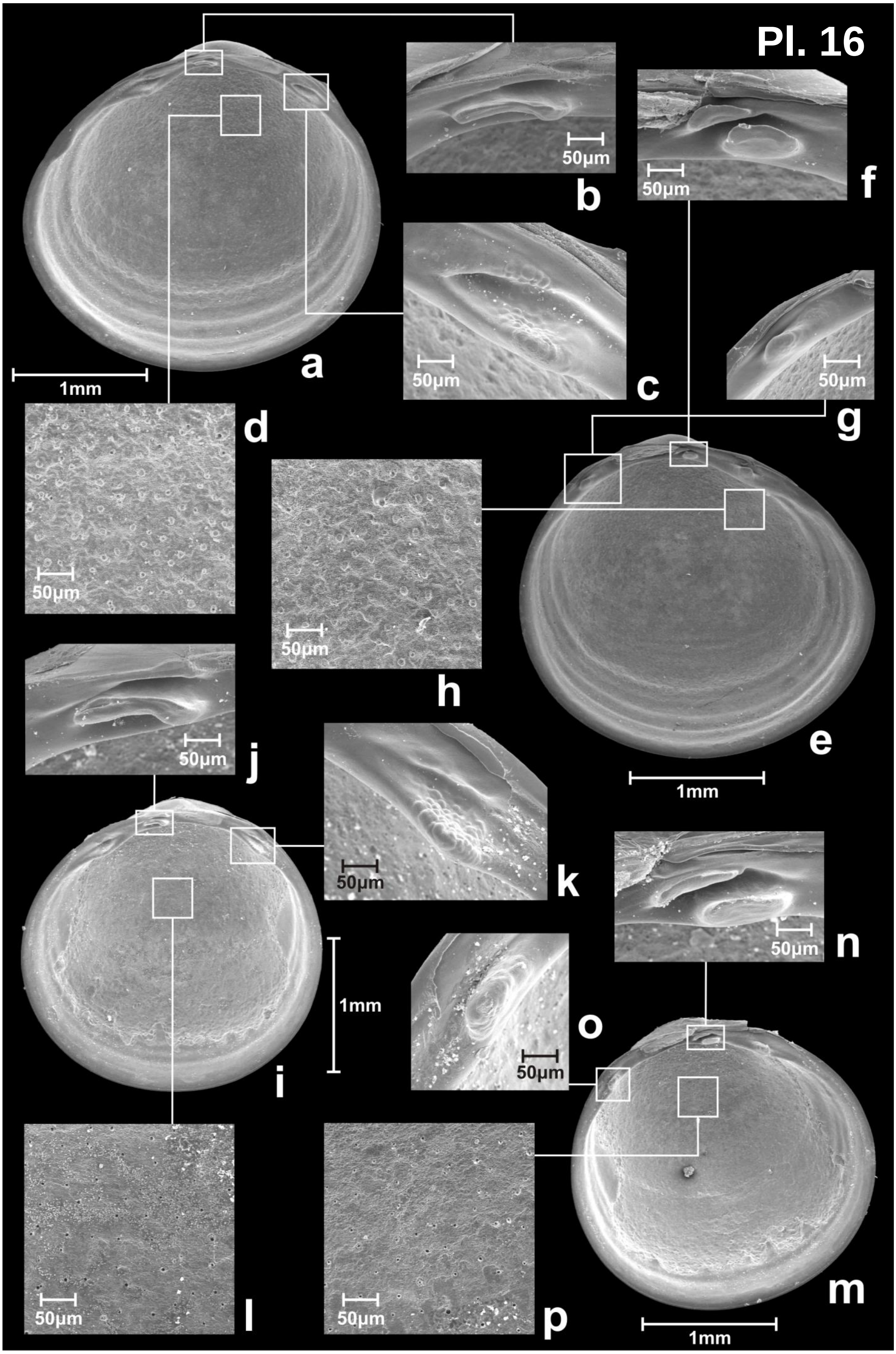

Pl. 16
1mm
50µm
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p

PLATE 17

Fig. a. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, right valve inner view;

Fig. b. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, detail of the inverted cardinal teeth C_2 and C_4 normally located to the left valve;

Fig. c. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, detail of the posterior teeth P_1 and P_3, see the microstructures associated with them and the pseudocallus located at the left end of P_3;

Fig. d. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, detail of the small A_1 and A_3 teeth on the right valve and the microstructures associated with them;

Fig. e. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, detail of the micropores occurring on the internal valve side;

Fig. f. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, left valve inner view;

Fig. g. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, detail of the inverted cardinal teeth C_3, normally located on the right valve, note the occurrence of an extra cardinal tooth forming a sort of sharp dorsal edge of the hinge (see white arrow);

Fig. h. *Pisidium obtusale* (Lamarck, 1818), teratological specimen from station 299, detail of the tooth A_2 with an associated small tooth (see white arrow), note the microstructures associated with them;

Fig. i. *Pisidium obtusale* (Lamarck, 1818), specimen from station 299, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium obtusale* (Lamarck, 1818), specimen from station 216, right valve inner view;

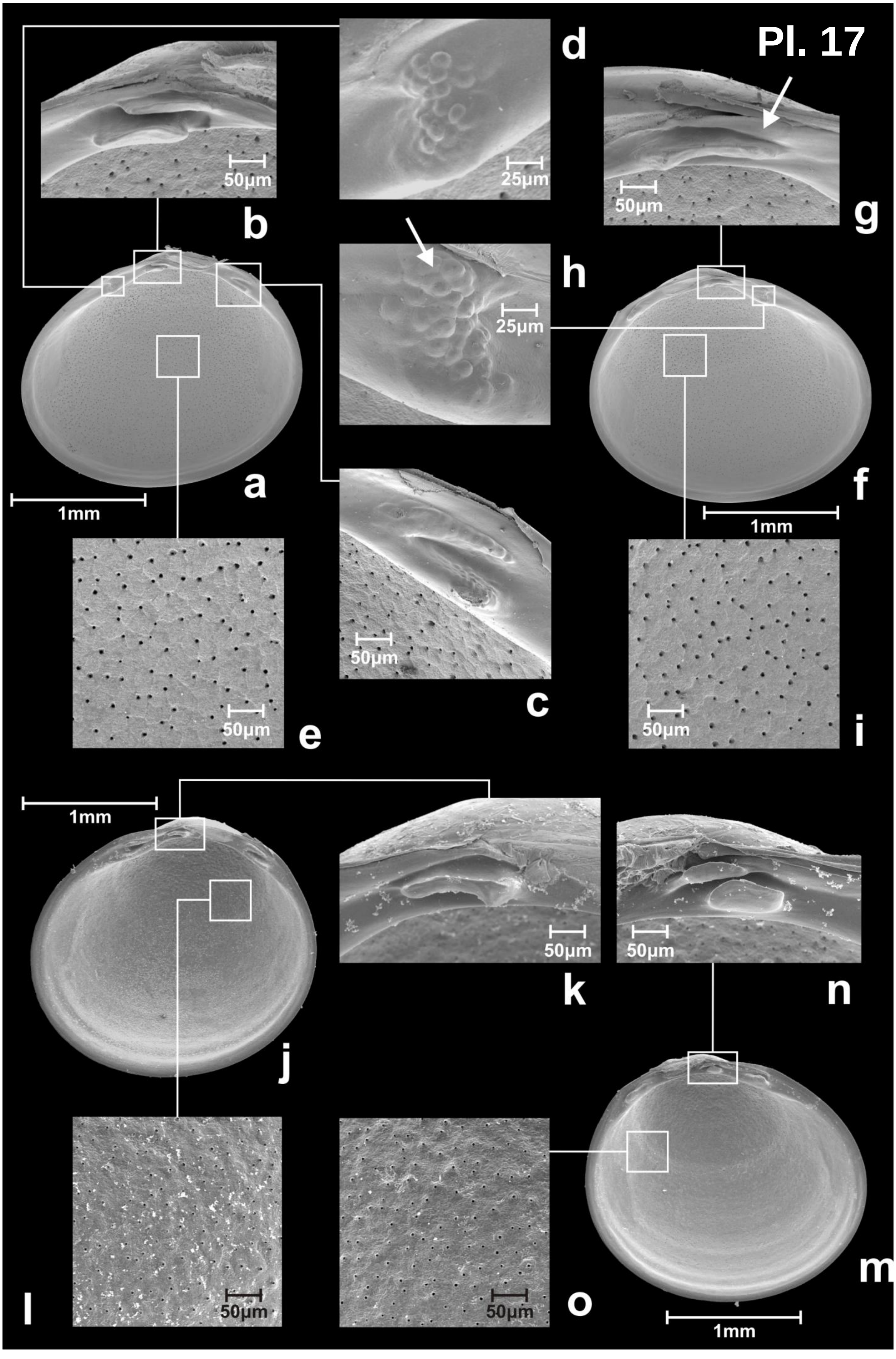
Fig. k. *Pisidium obtusale* (Lamarck, 1818), specimen from station 216, detail of the cardinal tooth C_3;

Fig. l. *Pisidium obtusale* (Lamarck, 1818), specimen from station 216, detail of the micropores occurring on the internal valve side;

Fig. m. *Pisidium obtusale* (Lamarck, 1818), specimen from station 216, left valve inner view;

Fig. n. *Pisidium obtusale* (Lamarck, 1818), specimen from station 216, detail of the cardinal teeth C_2 and C_4;

Fig. o. *Pisidium obtusale* (Lamarck, 1818), specimen from station 216, detail of the micropores occurring on the internal valve side.



Pl. 17
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
1mm
50µm
25µm

Plate 18

Fig. a. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, right valve inner view, the arrow points to the deformation;

Fig. b. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the cardinal tooth C_3;

Fig. c. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the posterior teeth P_1 and P_3, see the microstructures associated with them and the pseudocallus located at the left end of P_3;

Fig. d. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the micropores occurring on the internal valve side;

Fig. e. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, left valve inner view, the arrow points to the deformation;

Fig. f. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the cardinal teeth C_2 and C_4;

Fig. g. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the micropores occurring on the internal valve side;

Fig. h. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, right valve inner view, the arrow points to the deformation;

Fig. i. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the cardinal tooth C_3;

Fig. j. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the posterior teeth P_1 and P_3, see the microstructures associated with them and the pseudocallus located at the left end of P_3;

Fig. k. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the micropores occurring on the internal valve side;

Fig. l. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, left valve inner view, the arrow points to the deformation;

Fig. m. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the cardinal teeth C_2 and C_4;

Fig. n. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the posterior tooth P_2, see the low relief feature located at its top end (see white arrow);

Fig. o. *Pisidium obtusale* (Lamarck, 1818), diphyoidic specimen from station 330, detail of the micropores occurring on the internal valve side.

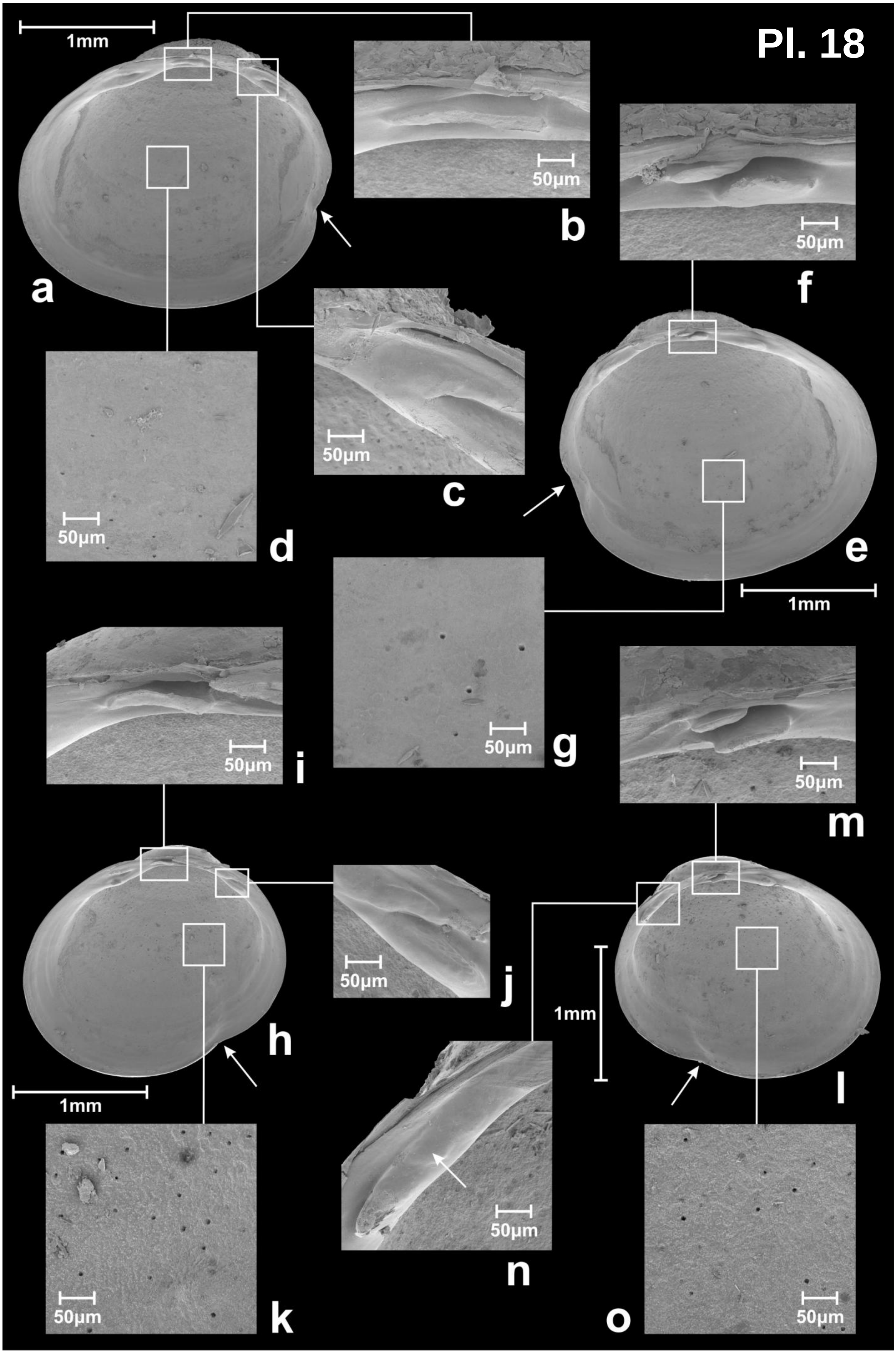

Pl. 18
1mm
a
b
50µm
c
50µm
d
50µm
e
1mm
f
50µm
g
50µm
h
1mm
i
50µm
j
50µm
k
50µm
l
1mm
m
50µm
n
50µm
o
50µm

PLATE 19

Fig. a. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, right valve inner view;

Fig. b. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, detail of the cardinal tooth C_3;

Fig. c. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, detail of the micropores occurring on the internal valve side;

Fig. e. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, left valve inner view;

Fig. f. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, detail of the cardinal teeth C_2 and C_4;

Fig. g. *Pisidium subtruncatum* Malm, 1855 specimen from station 177, detail of the micropores occurring on the internal valve side;

Fig. h. *Pisidium subtruncatum* Malm, 1855, specimen from station 306, right valve inner view;

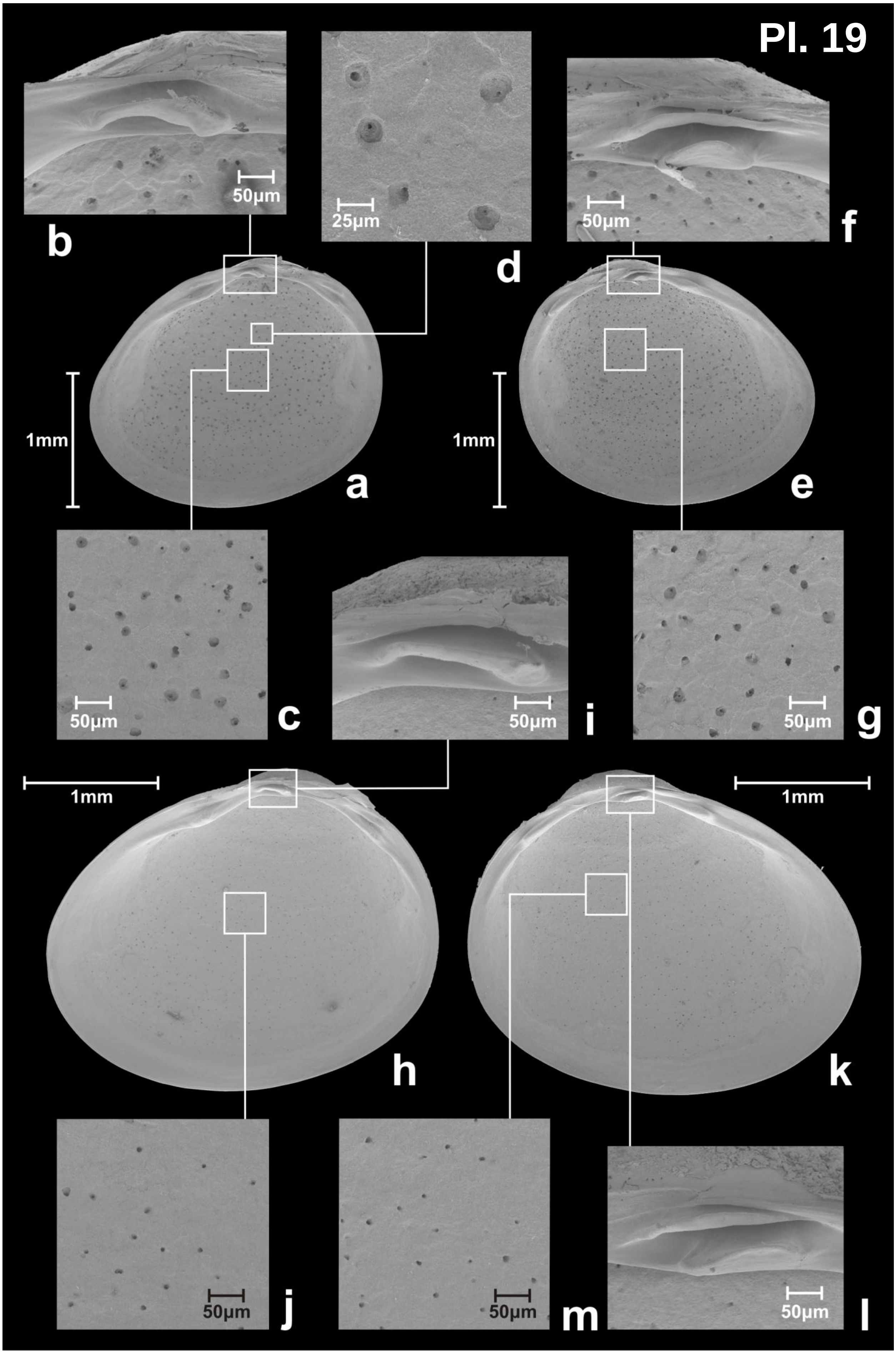
Fig. i. *Pisidium subtruncatum* Malm, 1855, specimen from station 306, detail of the cardinal tooth C_3;

Fig. j. *Pisidium subtruncatum* Malm, 1855, specimen from station 306, detail of the micropores occurring on the internal valve side;

Fig. k. *Pisidium subtruncatum* Malm, 1855, specimen from station 306, left valve inner view;

Fig. l. *Pisidium subtruncatum* Malm, 1855, specimen from station 306, detail of the cardinal teeth C_2 and C_4;

Fig. m. *Pisidium subtruncatum* Malm, 1855, specimen from station 306, detail of the micropores occurring on the internal valve side.


Pl. 19
b
50µm
d
25µm
f
50µm
a
1mm
e
1mm
c
50µm
i
50µm
g
50µm
h
1mm
k
1mm
j
50µm
m
50µm
l
50µm

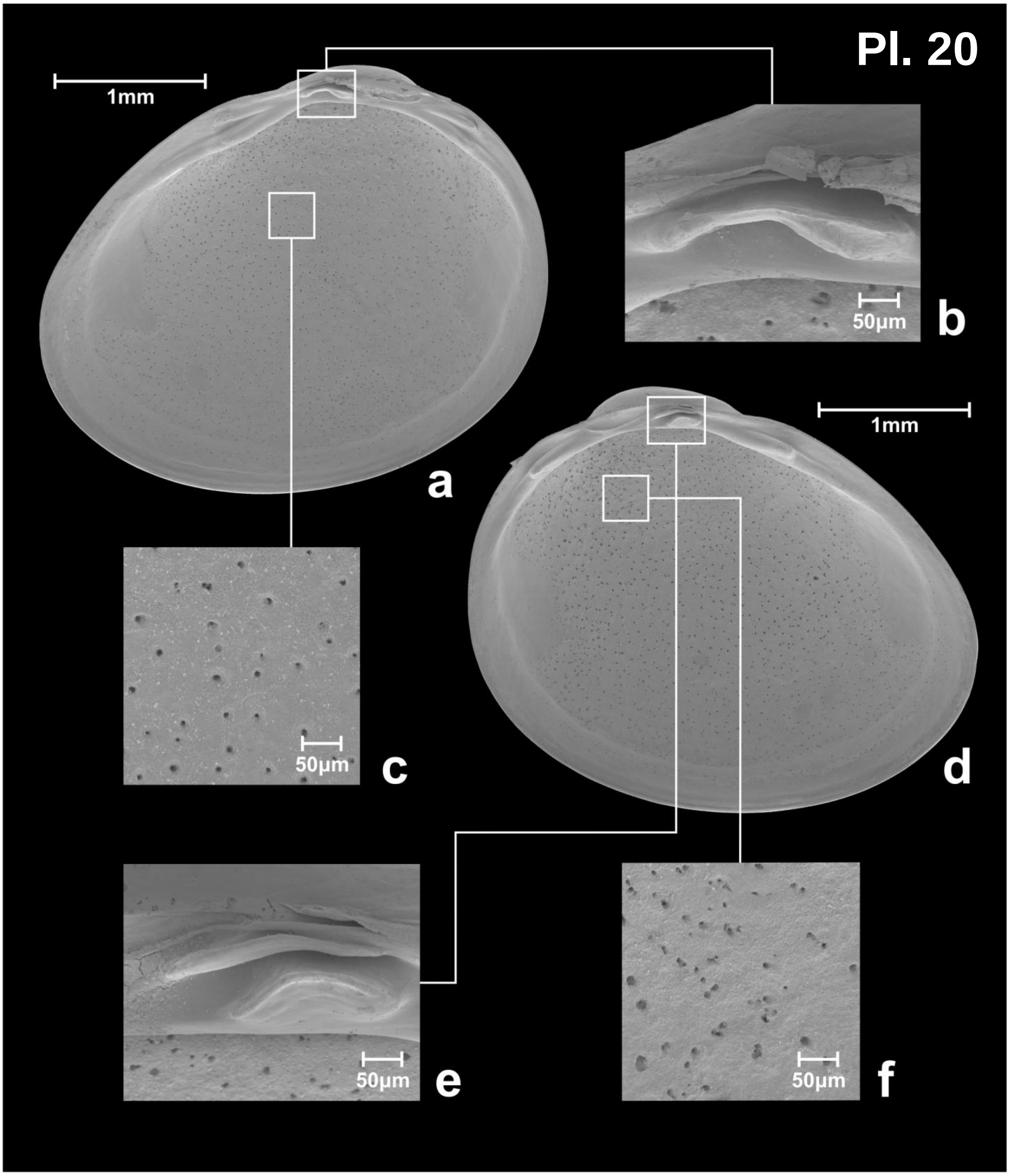


Fig. a. *Pisidium subtruncatum* Malm, 1855, specimen from station 239, right valve inner view;
Fig. b. *Pisidium subtruncatum* Malm, 1855, specimen from station 239,
detail of the cardinal tooth C_3;
Fig. c. *Pisidium subtruncatum* Malm, 1855,
specimen from station 239, detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium subtruncatum* Malm, 1855, specimen from station 239, left valve inner view;
Fig. e. *Pisidium subtruncatum* Malm, 1855, specimen from station 239,
detail of the cardinal teeth C_2 and C_4;
Fig. f. *Pisidium subtruncatum* Malm, 1855,
specimen from station 239, detail of the micropores occurring on the internal valve side.

PLATE 21

Fig. a. *Pisidium milium* Held, 1836 specimen from station 138, right valve inner view;

Fig. b. *Pisidium milium* Held, 1836 specimen from station 138, detail of the cardinal tooth C_3;

Fig. c. *Pisidium milium* Held, 1836 specimen from station 138, detail of the posterior teeth P_1 and P_3, see the microstructures associated with them;

Fig. d. *Pisidium milium* Held, 1836 specimen from station 138, detail of the micropores occurring on the internal valve side;

Fig. e. *Pisidium milium* Held, 1836 specimen from station 138, left valve inner view;

Fig. f. *Pisidium milium* Held, 1836 specimen from station 138, detail of the cardinal teeth C_2 and C_4;

Fig. g. *Pisidium milium* Held, 1836 specimen from station 138, detail of the micropores occurring on the internal valve side;

Fig. h. *Pisidium milium* (Held, 1836), specimen from station 160, right valve inner view;

Fig. i. *Pisidium milium* (Held, 1836), specimen from station 160, detail of the cardinal tooth C_3;

Fig. j. *Pisidium milium* (Held, 1836), specimen from station 160, detail of the micropores occurring on the internal valve side;

Fig. k. *Pisidium milium* (Held, 1836), specimen from station 160, detail of a micropore;

Fig. l. *Pisidium milium* (Held, 1836), specimen from station 160, left valve inner view;

Fig. m. *Pisidium milium* (Held, 1836), specimen from station 160, detail of cardinal teeth C_2 and C_4;

Fig. n. *Pisidium milium* (Held, 1836), specimen from station 160, detail of the micropores occurring on the internal valve side;

Fig. q. *Pisidium milium* (Held, 1836), specimen from station 160, detail of a micropore.

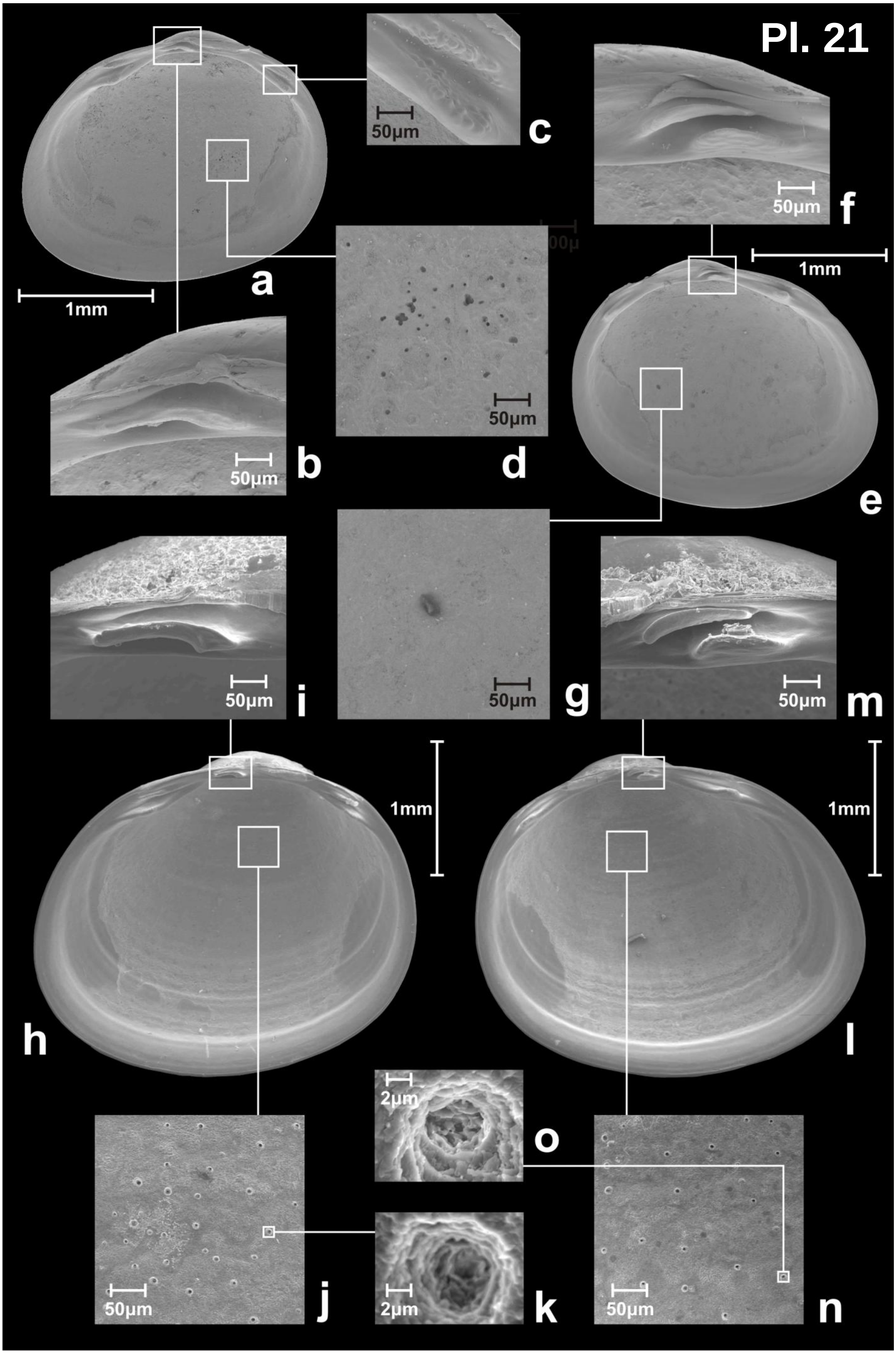

Pl. 21
50µm
c
50µm
f
1mm
a
1mm
50µm
b
50µm
d
e
50µm
i
50µm
g
50µm
m
1mm
1mm
h
l
2µm
o
50µm
j
2µm
k
50µm
n

PLATE 22

Fig. a. *Pisidium milium* (Held, 1836) specimen from station 81, right valve inner view;

Fig. b. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the cardinal tooth C_3;

Fig. c. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium milium* (Held, 1836) specimen from station 81, left valve inner view;

Fig. e. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium milium* (Held, 1836) specimen from station 81, right valve inner view;

Fig. h. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the cardinal tooth C_3;

Fig. i. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium milium* (Held, 1836) specimen from station 81, left valve inner view;

Fig. k. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium milium* (Held, 1836) specimen from station 81, detail of the micropores occurring on the internal valve side.

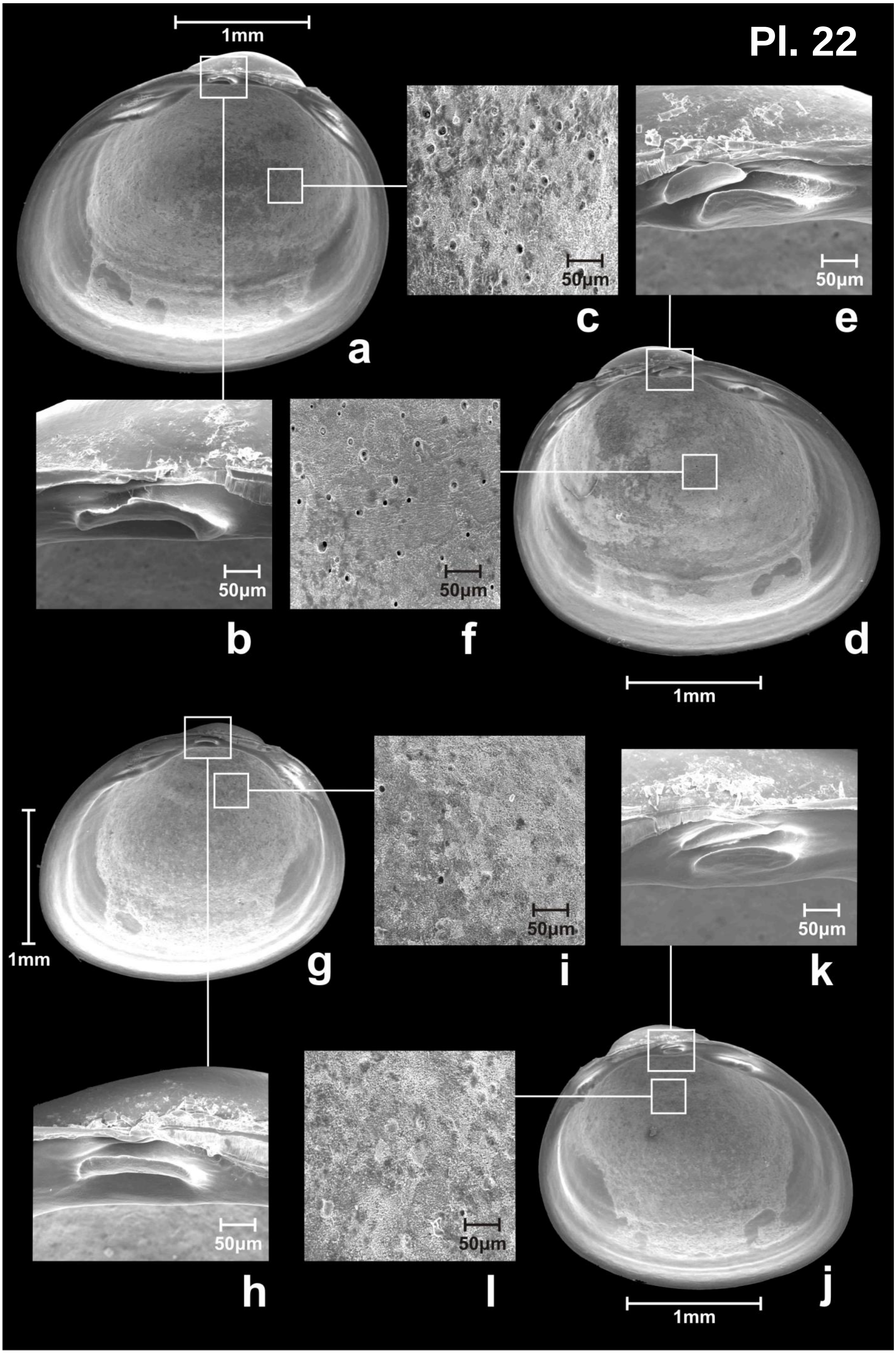

Pl. 22
1mm
50µm
a
b
c
d
e
f
g
h
i
j
k
l

PLATE 23

Fig. a. *Pisidium nitidum* Jenyns, 1832, specimen from station 161, right valve inner view;

Fig. b. *Pisidium nitidum* Jenyns, 1832, specimen from station 161, detail of the cardinal tooth C_3;

Fig. c. *Pisidium nitidum* Jenyns, 1832, specimen from station 161, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium nitidum* Jenyns, 1832, specimen from station 161, left valve inner view;

Fig. e. *Pisidium nitidum* Jenyns, 1832, specimen from station 161, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium nitidum* Jenyns, 1832, specimen from station 161, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium nitidum* Jenyns, 1832, specimen from station 177, right valve inner view;

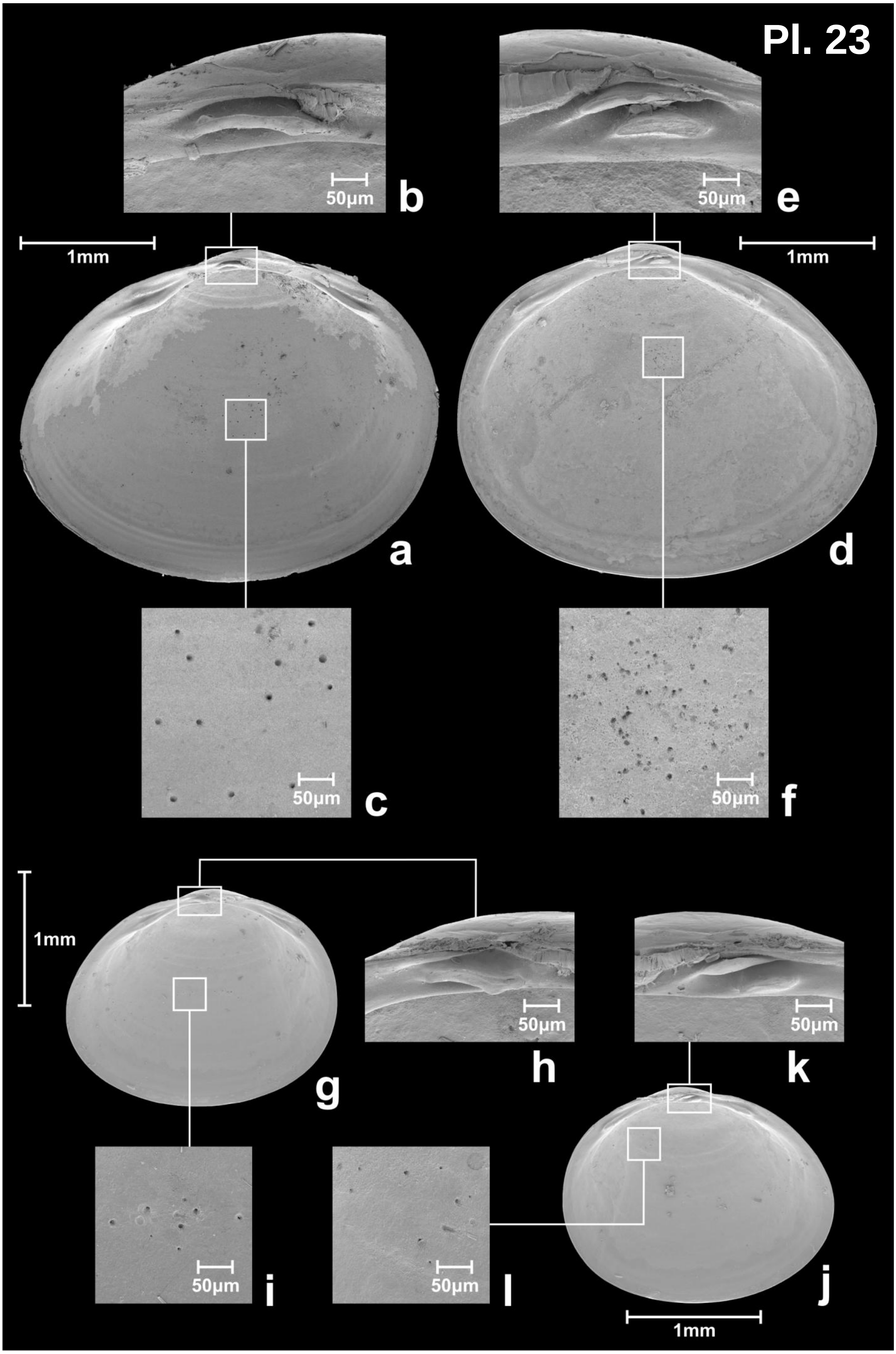
Fig. h. *Pisidium nitidum* Jenyns, 1832, specimen from station 177, detail of the cardinal tooth C_3;

Fig. i. *Pisidium nitidum* Jenyns, 1832, specimen from station 177, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium nitidum* Jenyns, 1832, specimen from station 177, left valve inner view;

Fig. k. *Pisidium nitidum* Jenyns, 1832, specimen from station 177, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium nitidum* Jenyns, 1832, specimen from station 177, detail of the micropores occurring on the internal valve side.



Pl. 23
50µm
b
50µm
e
1mm
1mm
a
d
50µm
c
50µm
f
1mm
50µm
50µm
h
k
g
50µm
i
50µm
l
j
1mm

PLATE 24

Fig. a. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, right valve inner view, the arrow points to the deformation;

Fig. b. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the cardinal tooth C_3;

Fig. c. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, left valve inner view, the arrow points to the deformation;

Fig. e. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, right valve inner view, the arrow points to the deformation;

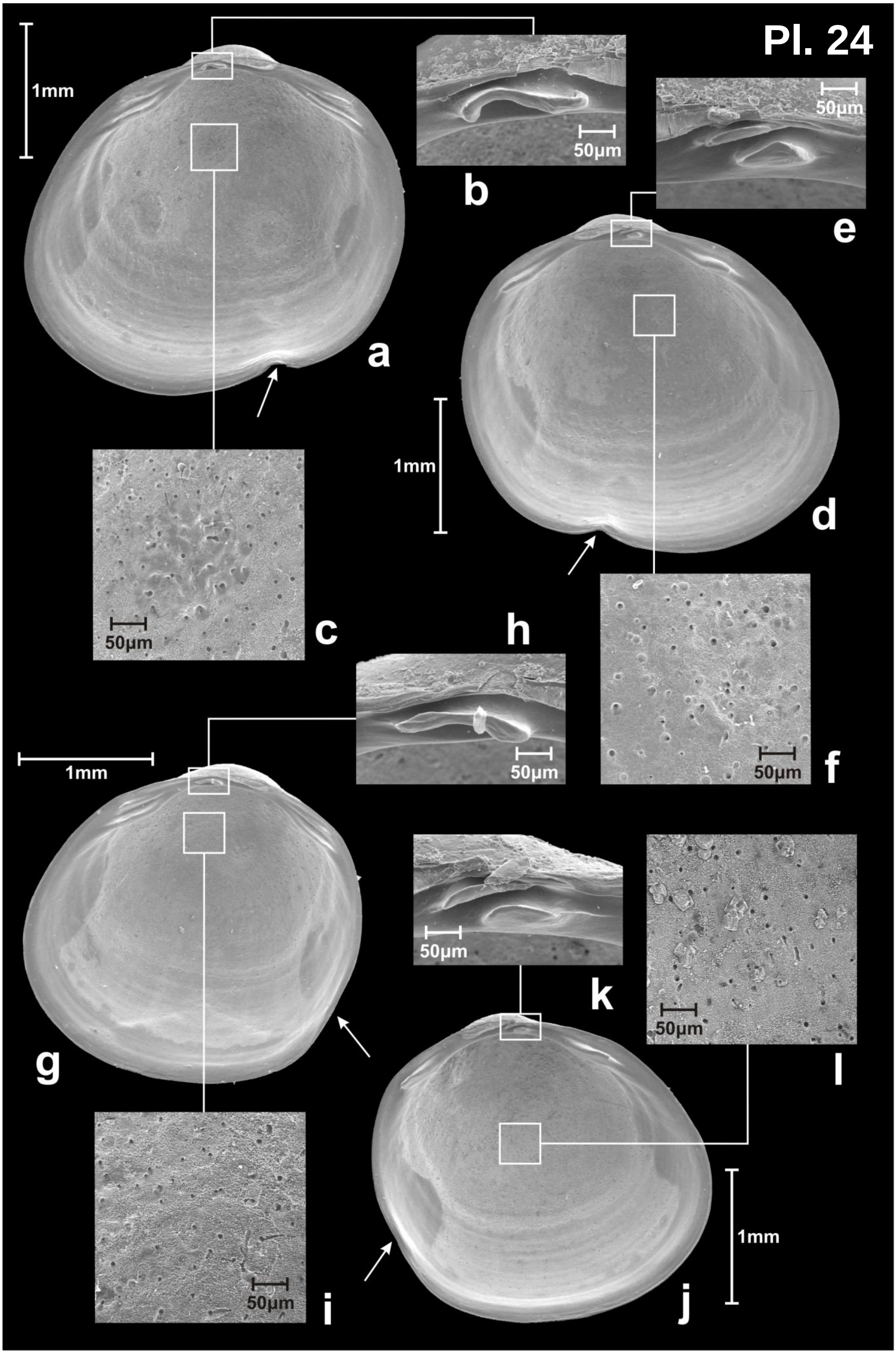
Fig. h. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the cardinal tooth C_3;

Fig. i. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, left valve inner view, the arrow points to the deformation;

Fig. k. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium nitidum* Jenyns, 1832, diphyoidic specimen from station 183, detail of the micropores occurring on the internal valve side.


Pl. 24
1mm
50µm
a
b
c
d
e
f
g
h
i
j
k
l

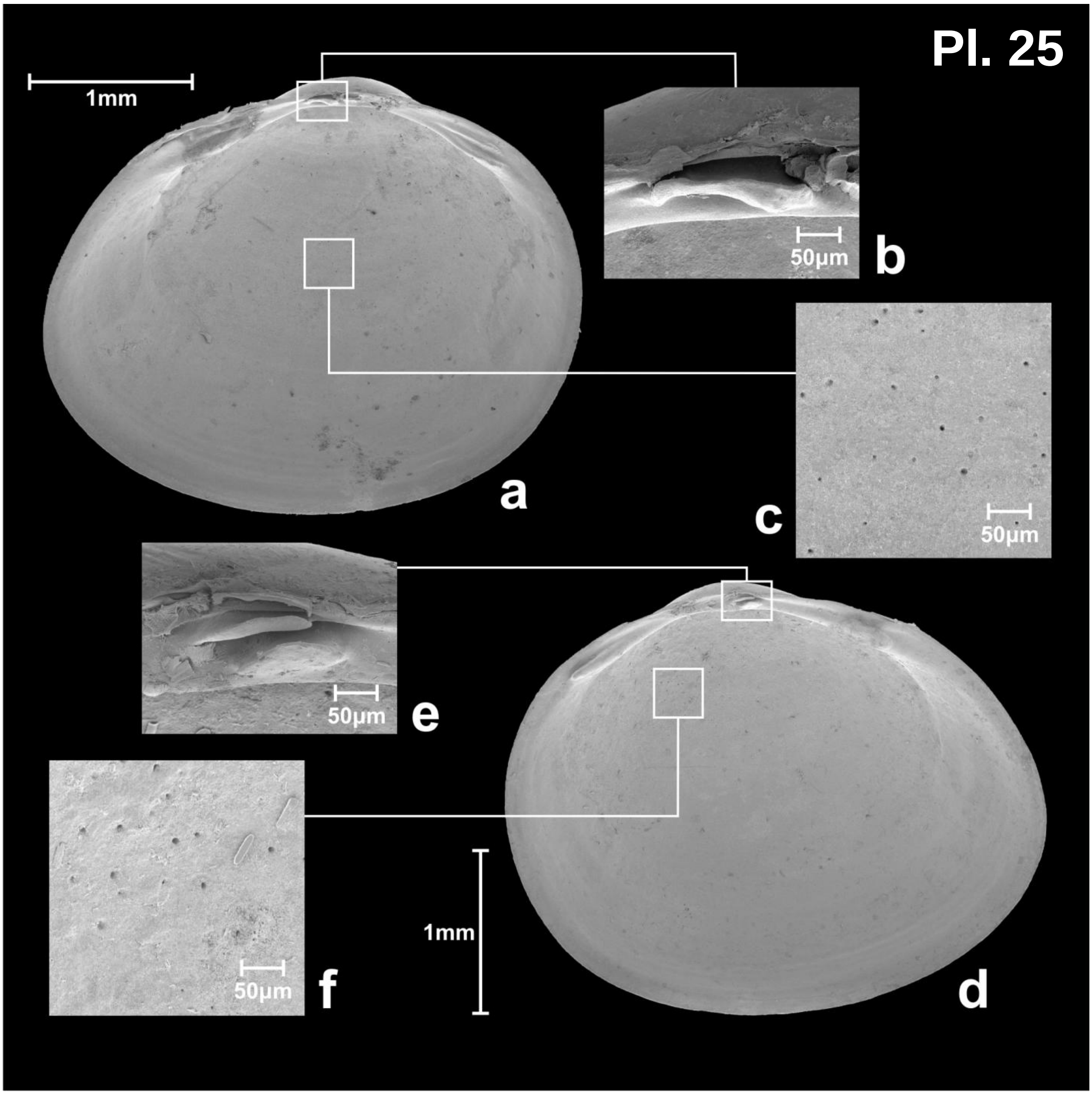


Fig. a. *Pisidium nitidum* Jenyns, 1832, specimen from station 196, right valve inner view;
Fig. b. *Pisidium nitidum* Jenyns, 1832, specimen from station 196, detail of the cardinal tooth C_3;
Fig. c. *Pisidium nitidum* Jenyns, 1832, specimen from station 196,
detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium nitidum* Jenyns, 1832, specimen from station 196, left valve inner view;
Fig. e. *Pisidium nitidum* Jenyns, 1832, specimen from station 196,
detail of the cardinal teeth C_2 and C_4;
Fig. f. *Pisidium nitidum* Jenyns, 1832, specimen from station 196,
detail of the micropores occurring on the internal valve side.

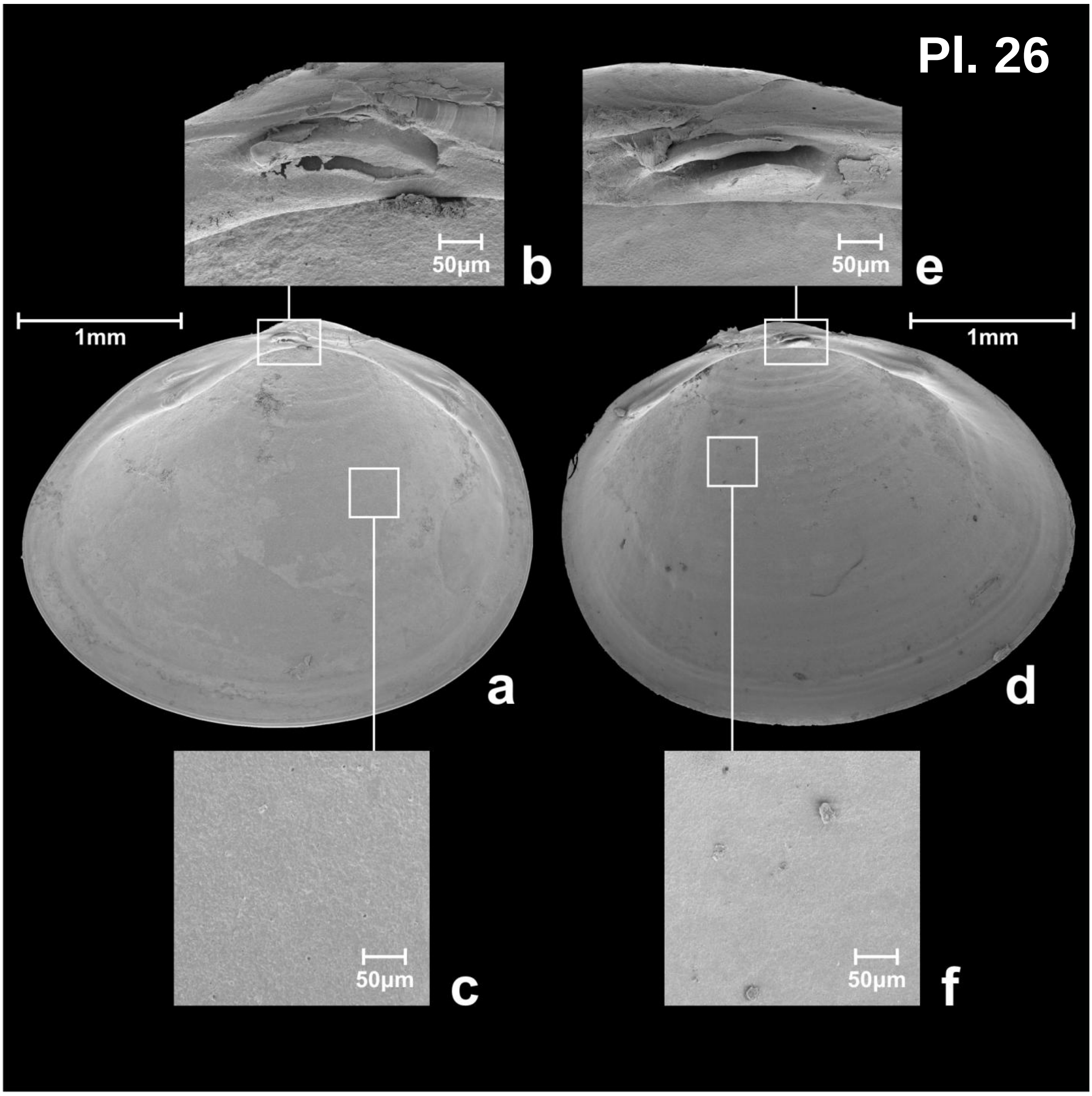


Fig. a. *Pisidium nitidum* Jenyns, 1832, specimen from station 194, right valve inner view;
Fig. b. *Pisidium nitidum* Jenyns, 1832, specimen from station 194, detail of the cardinal tooth C_3;
Fig. c. *Pisidium nitidum* Jenyns, 1832, specimen from station 194,
detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium nitidum* Jenyns, 1832, specimen from station 194, left valve inner view;
Fig. e. *Pisidium nitidum* Jenyns, 1832, specimen from station 194,
detail of the cardinal teeth C_2 and C_4;
Fig. f. *Pisidium nitidum* Jenyns, 1832, specimen from station 194,
detail of the micropores occurring on the internal valve side.

PLATE 27

Fig. a. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 183, right valve inner view;

Fig. b. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 183, detail of the cardinal tooth C_3;

Fig. c. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 183, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 183, left valve inner view;

Fig. e. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 183, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 183, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 99, right valve inner view;

Fig. h. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 99, detail of the cardinal tooth C_3;

Fig. i. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 99, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 99, left valve inner view;

Fig. k. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 99, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 99, detail of the micropores occurring on the internal valve side.

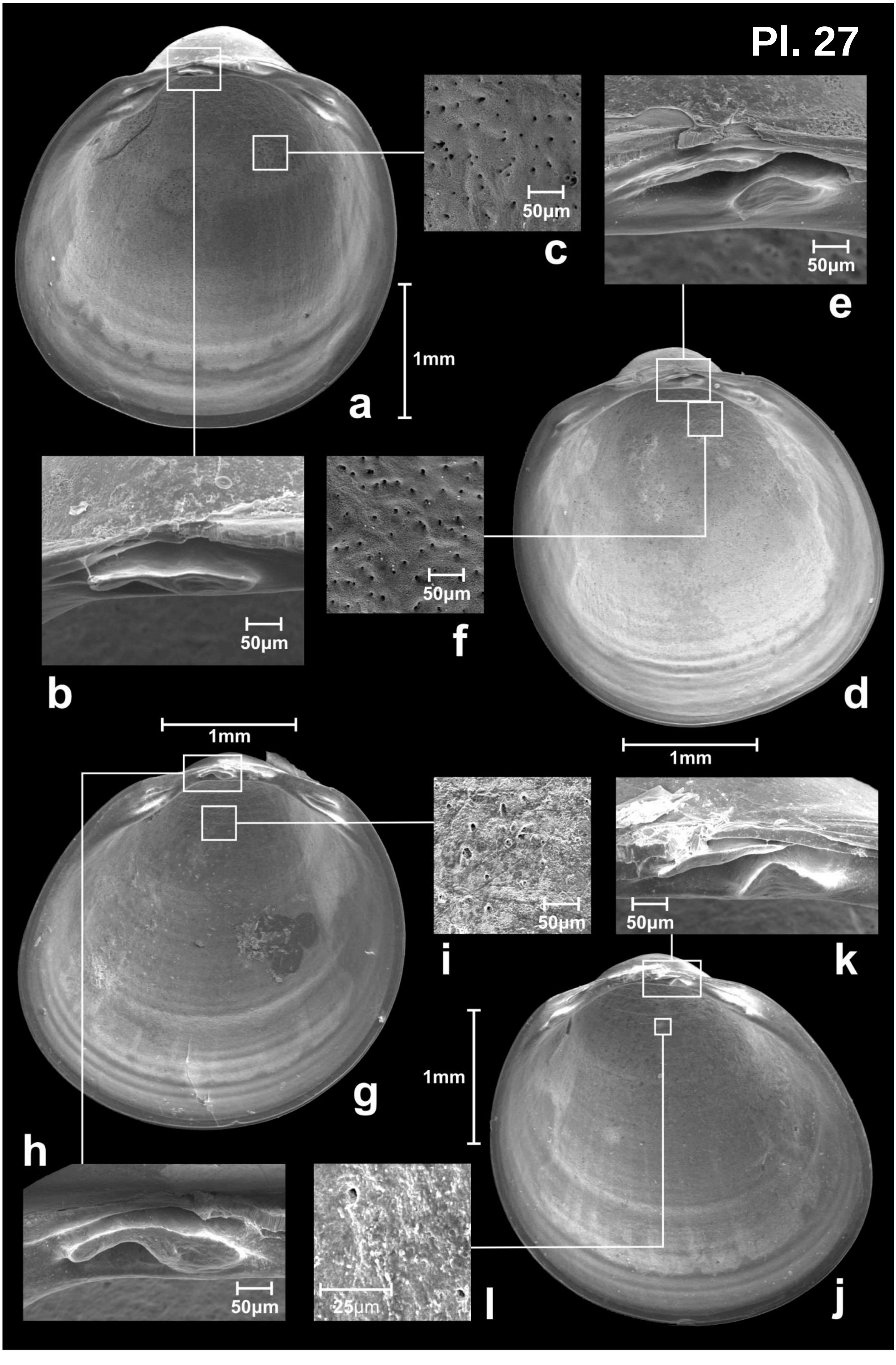

Pl. 27
a
b
c
d
e
f
g
h
i
j
k
l
1mm
50µm
25µm

Plate 28

Fig. a. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, right valve inner view;

Fig. b. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, detail of the cardinal tooth C_3;

Fig. c. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, left valve inner view;

Fig. e. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, pore detail of the figure f;

Fig. h. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, left valve outer view;

Fig. i. *Pisidium lilljeborgii* Clessin, 1886 specimen from station 71, detail of the embryonic ribbon.

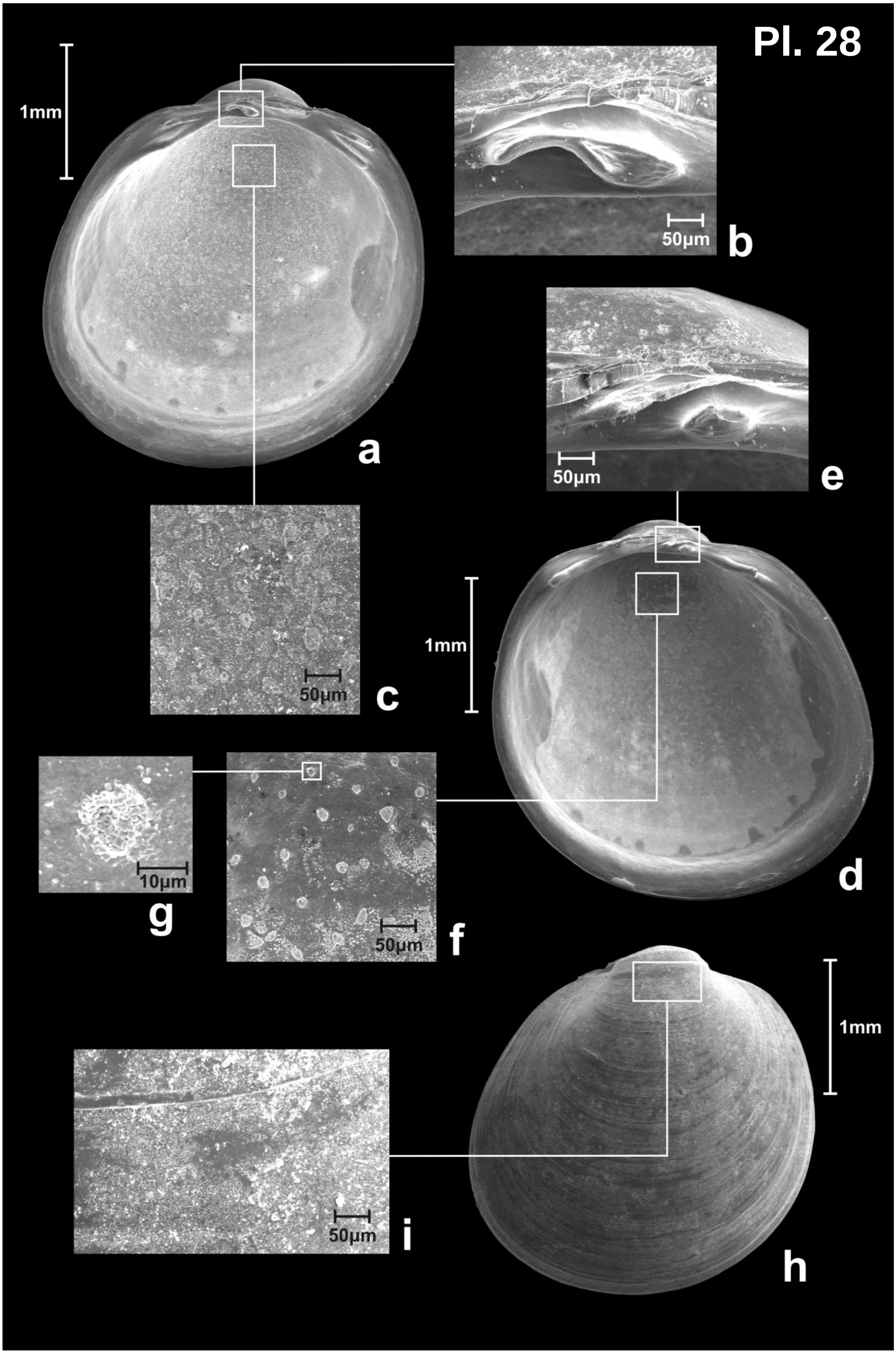

Pl. 28
1mm
50µm
b
a
50µm
e
50µm
c
1mm
10µm
g
50µm
f
d
1mm
50µm
i
h

PLATE 29

Fig. a. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, right valve inner view;

Fig. b. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, detail of the cardinal tooth C_3;

Fig. c. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, detail of the anterior teeth A1 and A3 of the right valve, see the microstructures associated with them;

Fig. d. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, detail of the micropores occurring on the internal valve side;

Fig. e. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, left valve inner view;

Fig. f. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, detail of the cardinal teeth C_2 and C_4;

Fig. g. *Pisidium hibernicum* Westerlund, 1894, specimen from station 330, detail of the micropores occurring on the internal valve side;

Fig. h. *Pisidium hibernicum* Westerlund, 1894, specimen from station 135, right valve inner view;

Fig. i. *Pisidium hibernicum* Westerlund, 1894, from station 135, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium hibernicum* Westerlund, 1894, specimen from station 135, left valve inner view;

Fig. k. *Pisidium hibernicum* Westerlund, 1894, specimen from station 135, detail of the micropores occurring on the internal valve side.

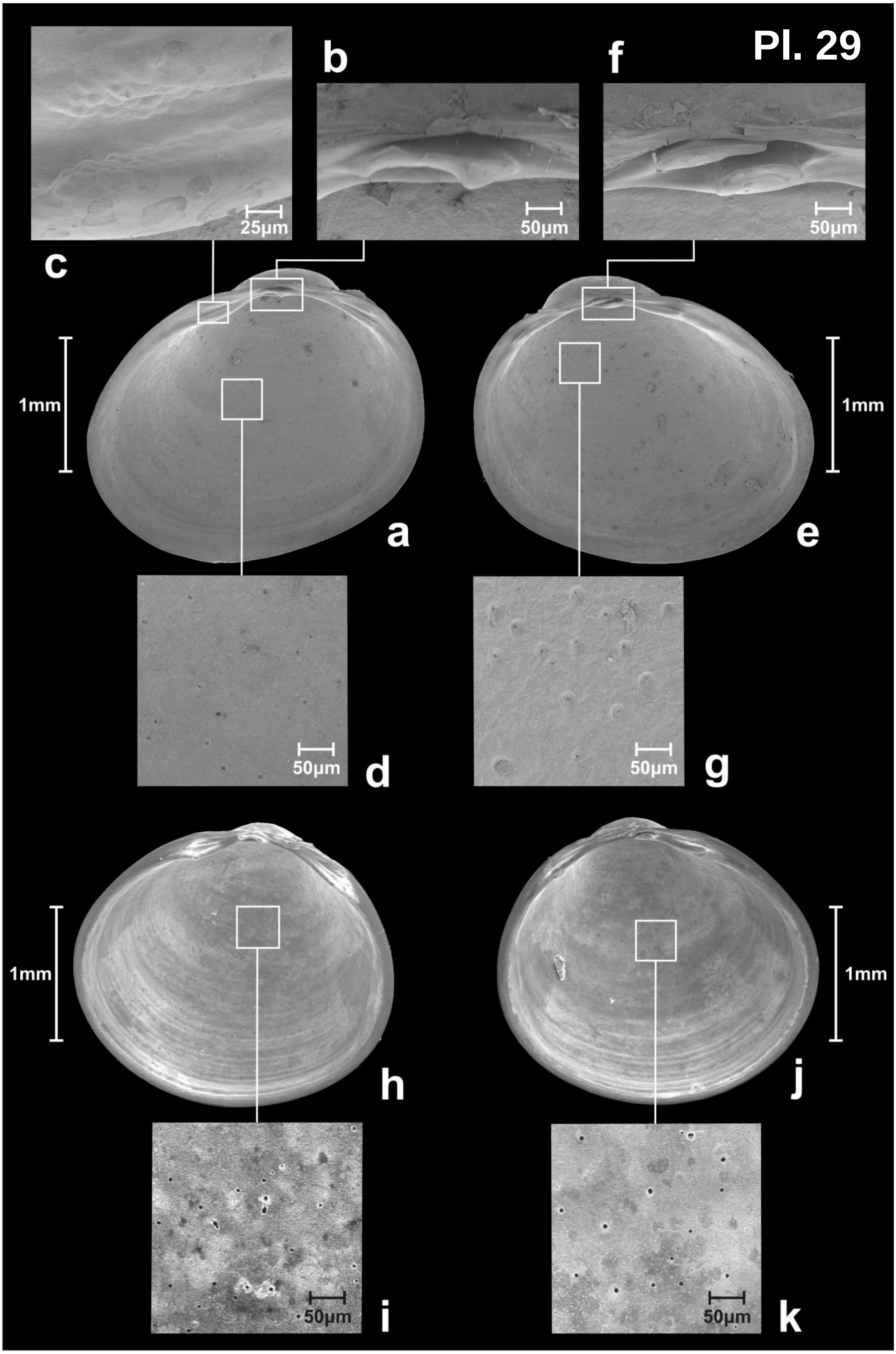

Pl. 29
a
b
c
d
e
f
g
h
i
j
k
25µm
50µm
1mm

PLATE 30

Fig. a. *Pisidium hibernicum* Westerlund, 1894, atypical specimen from station 194, right valve inner view;

Fig. b. *Pisidium hibernicum* Westerlund, 1894, atypical specimen from station 194, detail of the cardinal tooth C_3, note the peculiar shape of C_3, characterised by a double convexity;

Fig. c. *Pisidium hibernicum* Westerlund, 1894, atypical specimen from station 194, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium hibernicum* Westerlund, 1894, atypical specimen from station 194, left valve inner view, note the complete separation among C_2 and C_4;

Fig. e. *Pisidium hibernicum* Westerlund, 1894, atypical specimen from station 194, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium hibernicum* Westerlund, 1894, atypical specimen from station 194, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 99, right valve inner view, the arrow points to the deformation;

Fig. h. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 99, detail of the cardinal tooth C_3;

Fig. i. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 99, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 99, left valve inner view, the arrow points to the deformation;

Fig. k. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 99, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 99, detail of the micropores occurring on the internal valve side.

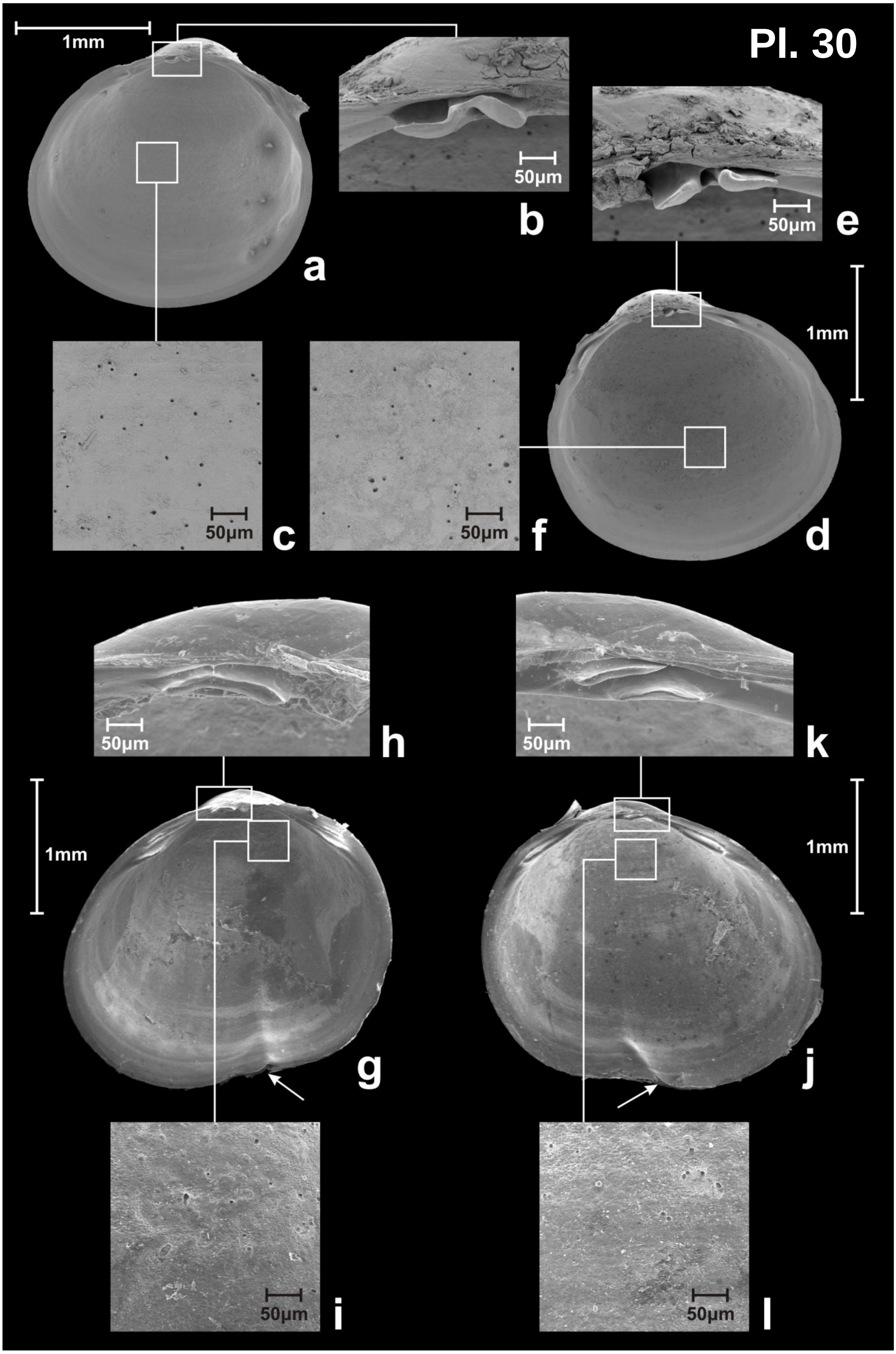

Pl. 30
1mm
50µm
a
b
c
d
e
f
g
h
i
j
k
l

PLATE 31

Fig. a. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, right valve inner view, the arrow points to the deformation;

Fig. b. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the cardinal tooth C_3;

Fig. c. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the micropores occurring on the internal valve side;

Fig. d. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, left valve inner view, the arrow points to the deformation;

Fig. e. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the cardinal teeth C_2 and C_4;

Fig. f. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the micropores occurring on the internal valve side;

Fig. g. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, right valve inner view, the arrow points to the deformation;

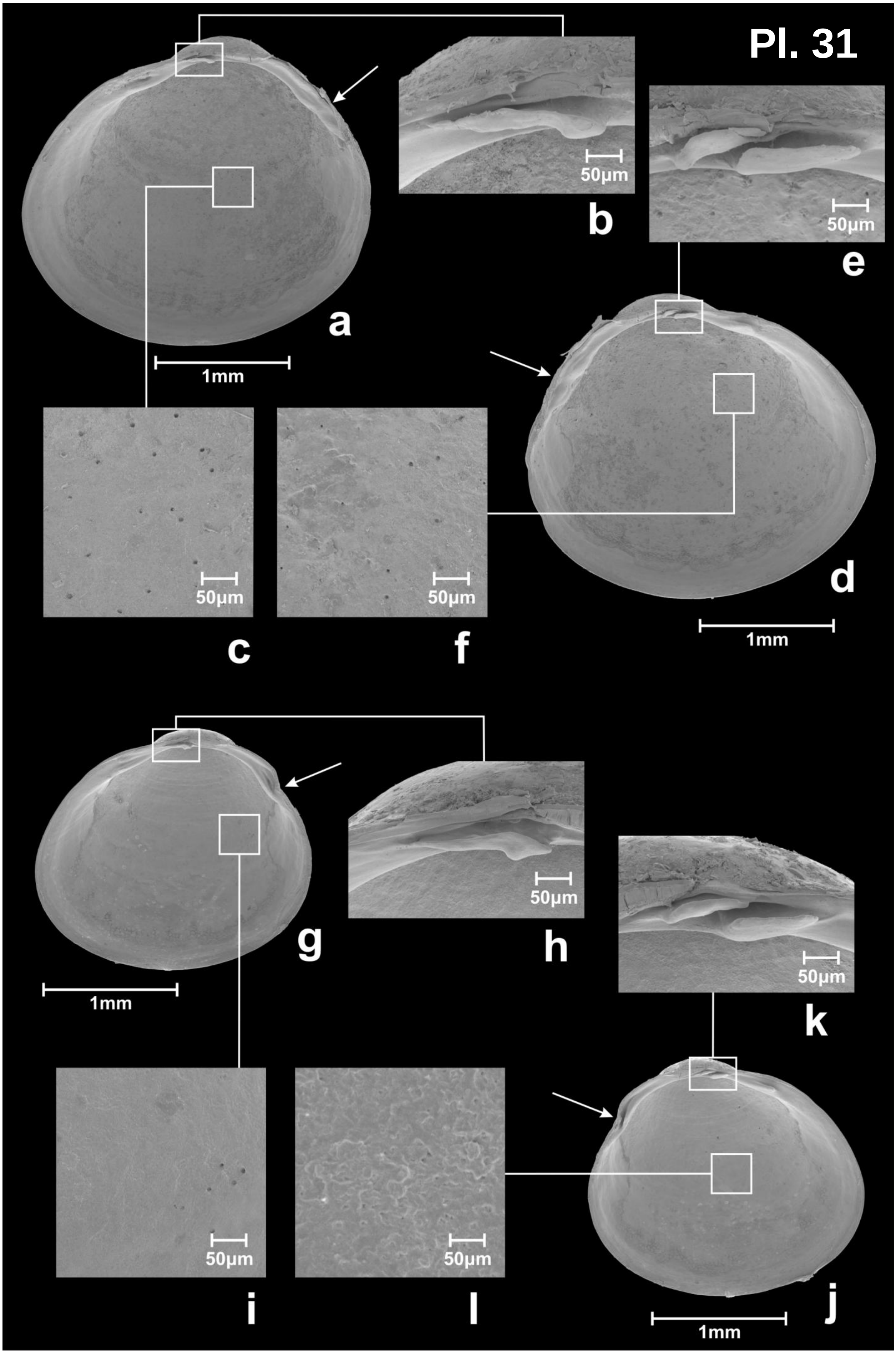
Fig. h. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the cardinal tooth C_3;

Fig. i. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the micropores occurring on the internal valve side;

Fig. j. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, left valve inner view, the arrow points to the deformation;

Fig. k. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the cardinal teeth C_2 and C_4;

Fig. l. *Pisidium hibernicum* Westerlund, 1894, diphyoidic specimen from station 331, detail of the micropores occurring on the internal valve side.


Pl. 31
a
b
c
d
e
f
g
h
i
j
k
l
1mm
50µm

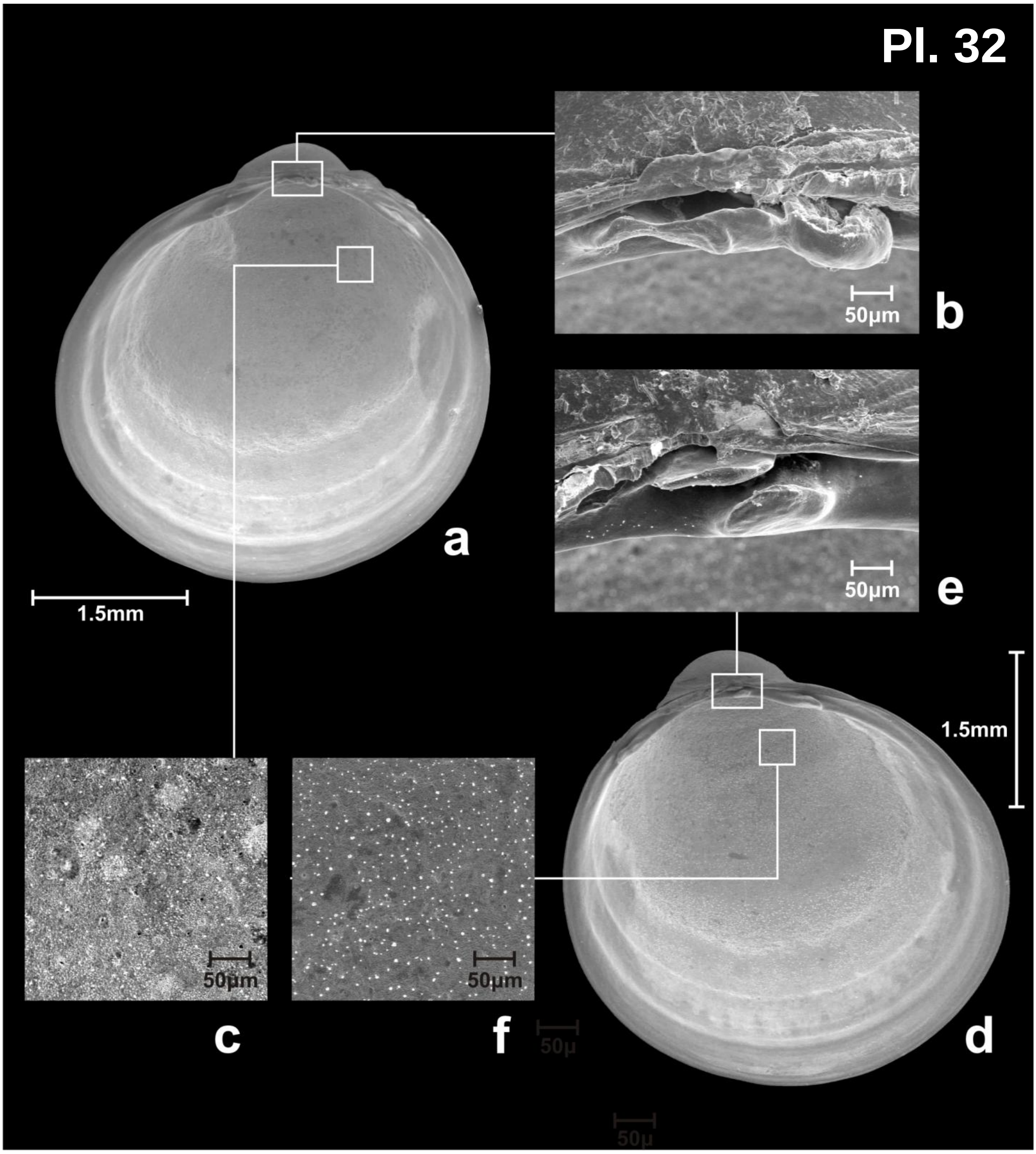


Fig. a. *Pisidium hibernicum* Westerlund, 1894 specimen from station 134, right valve inner view;
Fig. b. *Pisidium hibernicum* Westerlund, 1894 specimen from station 134,
detail of the cardinal tooth C_3;
Fig. c. *Pisidium hibernicum* Westerlund, 1894 specimen from station 134,
detail of the micropores occurring on the internal valve side;
Fig. d. *Pisidium hibernicum* Westerlund, 1894 specimen from station 134, left valve inner view;
Fig. e. *Pisidium hibernicum* Westerlund, 1894 specimen from station 134,
detail of the cardinal teeth C_2 and C_4;
Fig. f. *Pisidium hibernicum* Westerlund, 1894 specimen from station 134,
detail of the micropores occurring on the internal valve side.

Plate 33

Fig. a. *Ecrobia ventrosa* (Montagu, 1803), specimen from station 189, frontal view;

Fig. b. *Hydrobia cf. acuta neglecta* Muus, 1963, specimen from station 223, frontal view;

Fig. c. *Hydrobia cf. acuta neglecta* Muus, 1963, specimen from station 223, protoconch detail;

Fig. d. *Peringia ulvae* (Pennant, 1777), specimen from station 188, frontal view;

Fig. e. *Peringia ulvae* (Pennant, 1777), specimen from station 189, frontal view;

Fig. f. *Peringia ulvae* (Pennant, 1777), specimen from station 189, protoconch detail;

Fig. g. *Potamopyrgus antipodarum* (Gray, 1843), specimen from station 243, frontal view;

Fig. h. *Potamopyrgus antipodarum* (Gray, 1843), specimen from station 243, detail of the protoconch;

Fig. i. *Potamopyrgus antipodarum* (Gray, 1843), specimen from station 243, detail of the hairy keel;

Fig. j. *Valvata piscinalis* (O. F. Müller, 1774), specimen from station 196, frontal view.

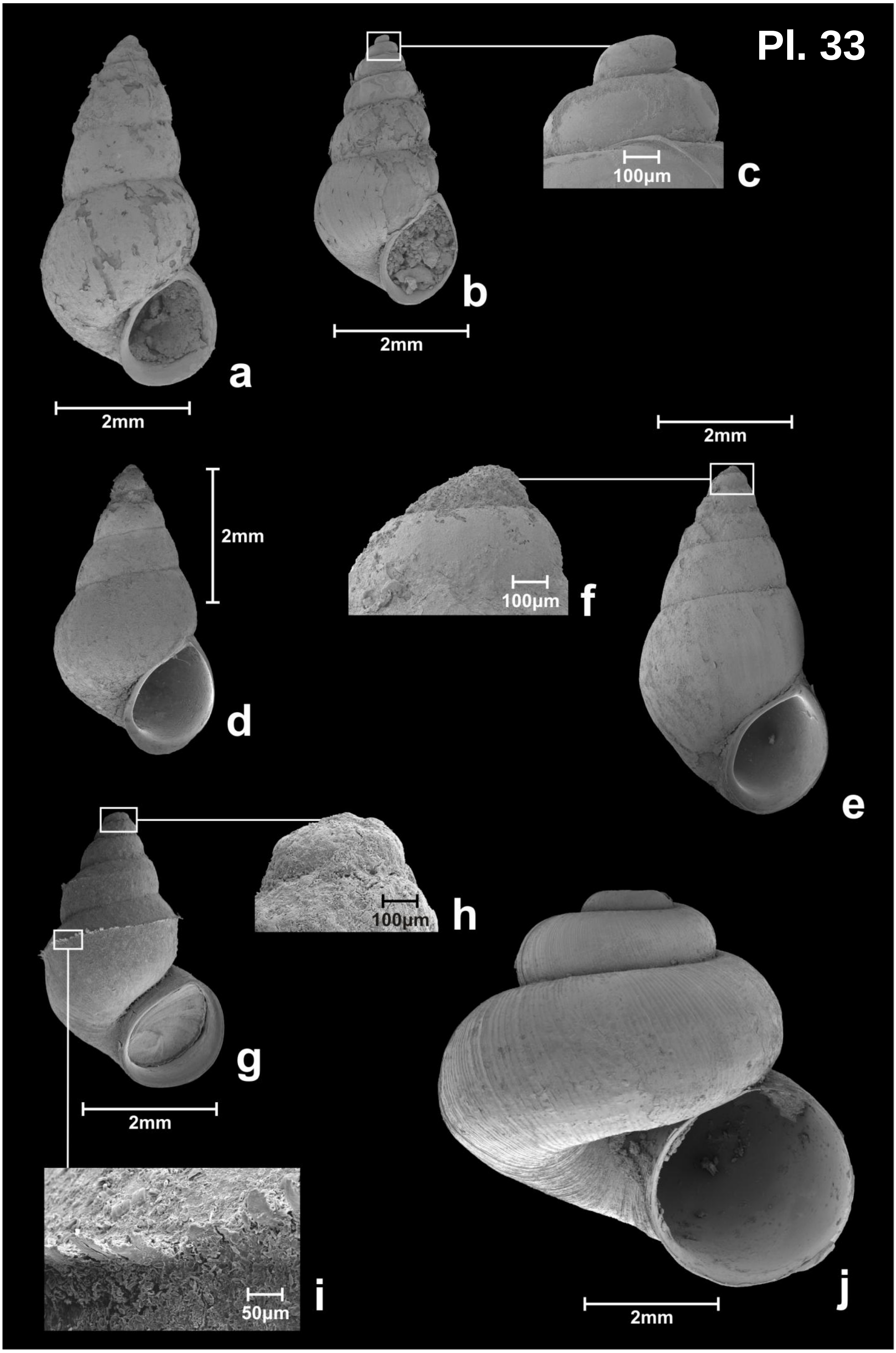

Pl. 33
a
2mm
b
2mm
c
100µm
d
2mm
e
2mm
f
100µm
g
2mm
h
100µm
i
50µm
j
2mm

PLATE 34

Fig. a. *Galba truncatula* (O. F. Müller, 1774), specimen from station 226, frontal view;

Fig. b. *Physella acuta* (Draparnaud, 1805), specimen from station 123, frontal view;

Fig. c. *Physa fontinalis* (Linnaeus, 1758), specimen from station 183, frontal view;

Fig. d. *Gyraulus albus* (O. F. Müller, 1774), specimen from station 314, angle view of the apical side;

Fig. e. *Gyraulus albus* (O. F. Müller, 1774), specimen from station 314, frontal view;

Fig. f. *Gyraulus laevis* (Alder, 1838), specimen from station 234, frontal view;

Fig. g. *Gyraulus laevis* (Alder, 1838), specimen from station 234, umbonal view;

Fig. h. *Gyraulus laevis* (Alder, 1838), specimen from station 234, detail of the shell microsculpture;

Fig. i. *Bathyomphalus contortus* (Linnaeus, 1758), specimen from station 290, frontal view;

Fig. j. *Gyraulus crista* (Linnaeus, 1758), despiralized specimen from station 17, frontal view;

Fig. k. *Gyraulus crista* (Linnaeus, 1758), despiralized specimen from station 17, angle view of the apical side;

Fig. l. *Hippeutis complanatus* (Linnaeus, 1758), specimen from station 199, frontal view.

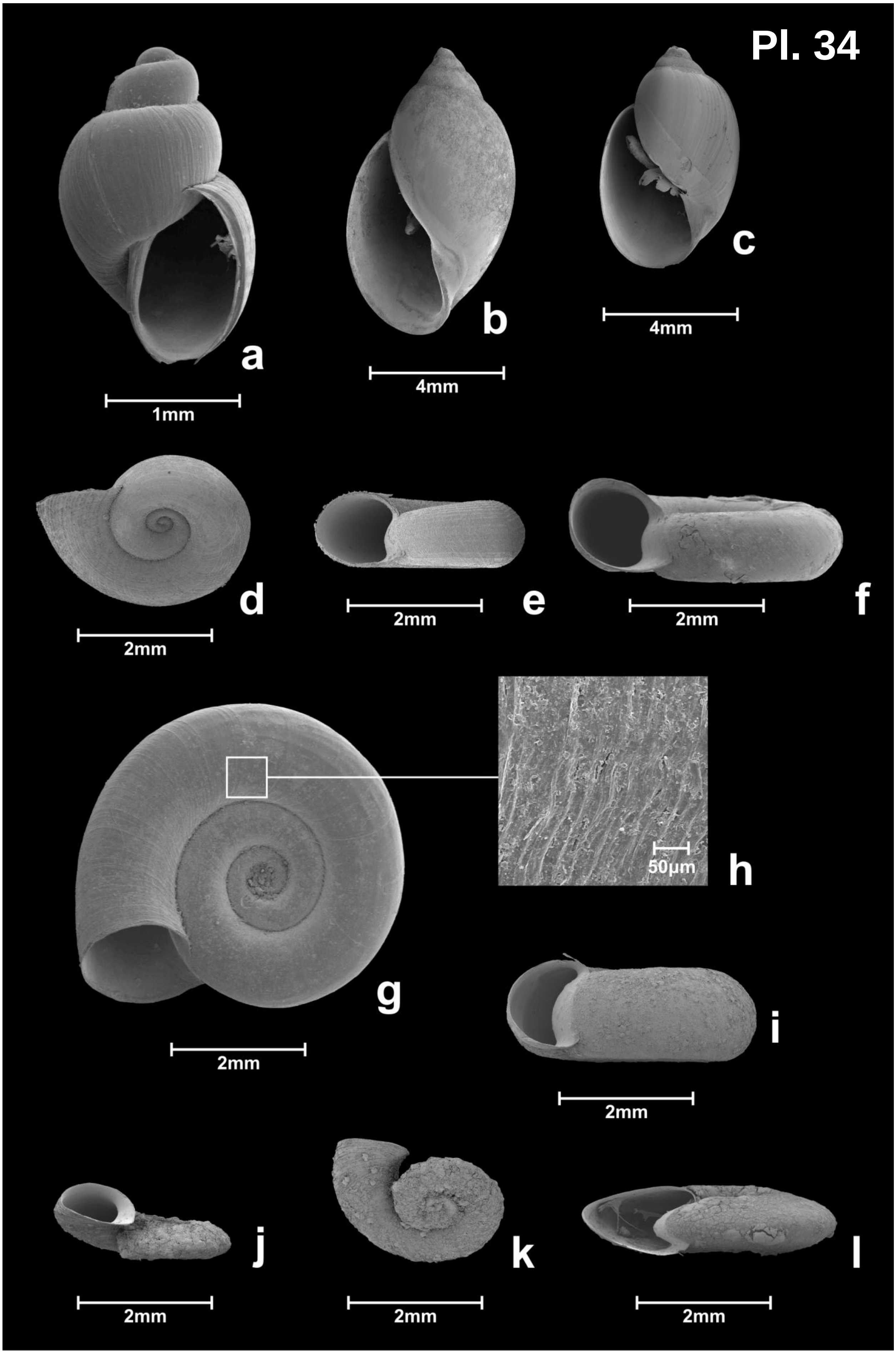

Pl. 34
a
1mm
b
4mm
c
4mm
d
2mm
e
2mm
f
2mm
g
2mm
h
50µm
i
2mm
j
2mm
k
2mm
l
2mm

PLATE 35

Fig. a. Uppermost sector of the Glen Callater; small ditches meandering through a peaty soil with sparse sub-fossil tree remnants referred to the cold-wet period established during the Mid Flandrian (ca. 5,000 years BP). Zeiss Sonnar 135mm T* F/2.8 1/500, Kodachrome 64, 15/5/2005.

Fig. b. 'Allt an Loch' westward from 'Creag an Fhir shaighde' (Callater Burn segment located 500 m upstream from Loch Callater); note the U-shaped valley characterised by moderate longitudinal gradient, crossed by a well-developed meandering reach imposed by the Loch Callater water level. Zeiss Sonnar 135mm T* F/2.8 1/500, Kodachrome 64, 15/5/2005.

Fig. c. Chest of Dee, 300 m upstream from the White Bridge; note the wide and deep pool occurring within this step pool reach. Zeiss Planar 85mm T* F/2 1/500, Kodachrome 64, 8/6/2003.

Fig. d. Linn of Dee (Braemar), narrow gorge excavated through hard bedrock; note the fast and turbulent flow associated to this straight reach. Zeiss Planar 50mm T* F/1.4 1/250, Kodachrome 64, 23/4/2005.

Fig. e. Glen Lee entering into the Loch Lee; note the meandering reach related to the low longitudinal gradient imposed by the loch water level. On the left side of the picture is visible the boat house (St. No. 297). Zeiss Sonnar 135mm T* F/2.8 1/250, Kodachrome 64, 8/5/2005.

Fig. f. Artificial pool created along the Brackley Burn, 800 m eastward from the House of Glenmuick, Ballater; this lentic habitat represents a rarity in a step pool reach, representing an important sites for amphibian breeding and for the successful establishment of molluscs species not adapted to fast currents (e.g. *Radix balthica).* Zeiss Sonnar 135mm T* F/4 1/500, Kodachrome 64, 30/1/2005.

Fig. g. Step pool reach along the Glenbeg Burn: upstream view from the suspension bridge, Ballochbuie Forest, Ballater. Zeiss Planar 85mm T* F/1.4 1/125, Kodachrome 64, 7/3/2004.

Fig. h. Water of Feugh, view from the Bridge of Feugh, Banchory; this riffle reach is located upstream from the major waterfall caused by the hard bedrock outcropping in the area. Zeiss Planar 85mm T* F/1.4 1/125, Kodachrome 64, 14/6/2003.

Pl. 35

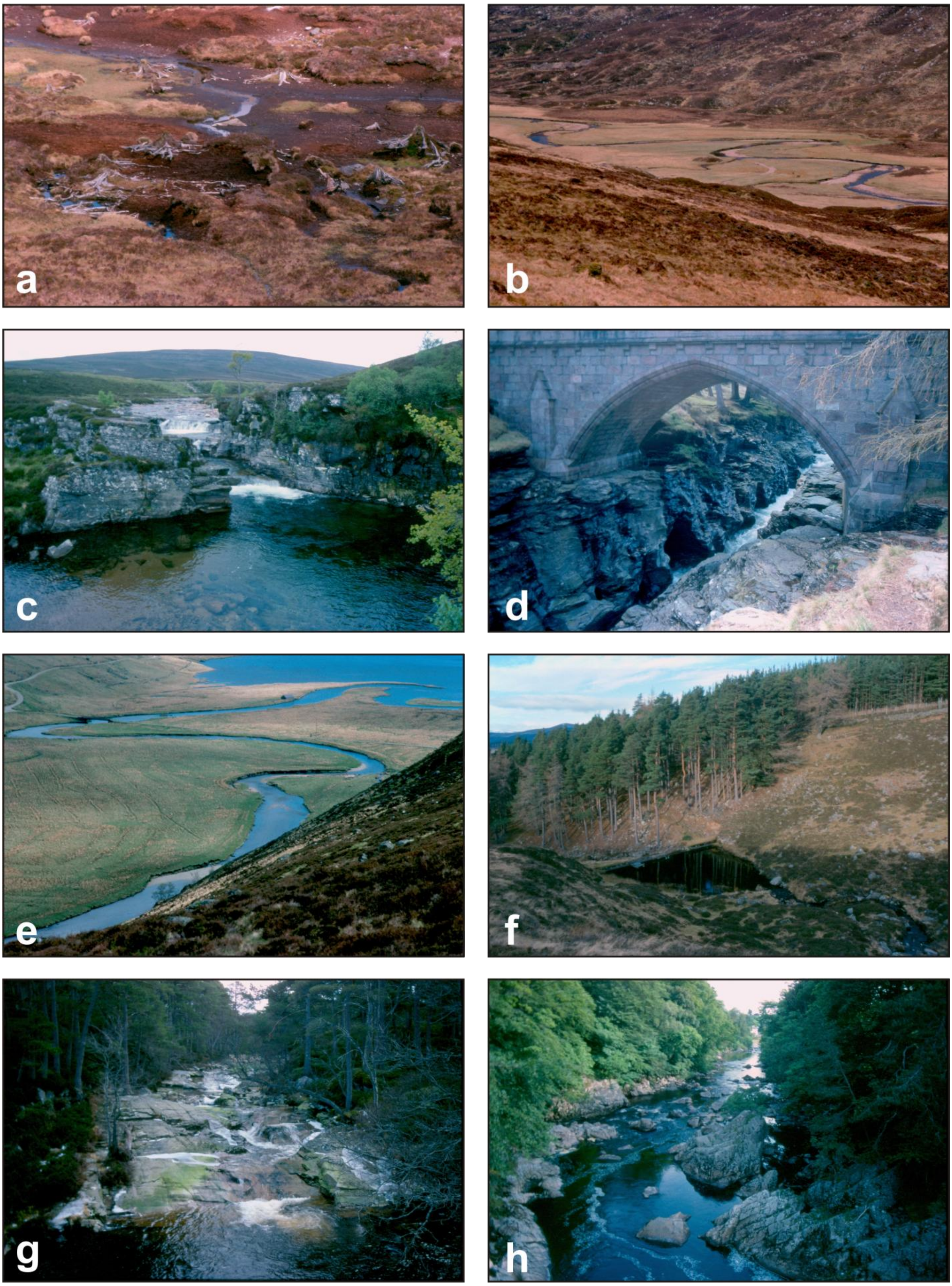


PLATE 36

Fig. a. River North Esk, Rocks of Solitude gorge; note the fast and turbulent flow associated with the small waterfalls. Zeiss Planar 50mm T* F/1.4 1/500, Kodachrome 64, 8/5/2005.

Fig. b. Burn o' Vat; the series of small waterfalls found along the Vat Burn (River Dee left tributary) before entering into the Loch Kinord, are the consequence of a strong post-glacial erosion, occurred after the ice retreat. Zeiss Distagon 28mm T* F/2.8 1/60, Kodachrome 64, 2/2/2005.

Fig. c. Tore Burn mouth, Cullykhan Bay, Pennan; note the shingle bar separating freshwater from the sea water during low tide. Zeiss Distagon 28mm T* F/2.8 1/500, Kodachrome 64, 4/4/2005;

Fig. d. River Don mouth, Aberdeen; note the longitudinal shingle bars splitting the river channel in independent branches. Zeiss Planar 50mm T* F/1.4 1/1000, Kodachrome 64, 29/2/2004;

Fig. e. Blanket bog located in a flat area north-westward from the col between Craig Vallich and Pannanich Hill, Ballater; note the dense moorland covering the area. Zeiss Planar 50mm T* F/1.4 1/1000, Kodachrome 64, 30/1/2005.

Fig. f. Loch nan Stuirteag, northern slope of the Monadh Mòr, Cairngorms; note the flooded and swampy area located to the western side. Zeiss Planar 50mm T* F/2 1/500, Kodachrome 64, 8/6/2003.

Fig. g. Loch Kander; note the typical cirque loch morphology with the steep slopes of the Carn an Tuirc plunging into the water. Also note the laminar flow associated with the Allt Loch Kander, the loch outlet. Zeiss Planar 50mm T* F/2.8 1/1000, Kodachrome 64, 15/5/2005.

Fig. h. Carlochy, a cirque loch located on the north-eastern slope of the Cairn Lick, within the Water of Lee drainage basin; note the mountain-ward side bounded by cliffs and steep slopes. Zeiss Planar 50mm T* F/2 1/250, Kodachrome 64, 8/5/2005.

Pl. 36

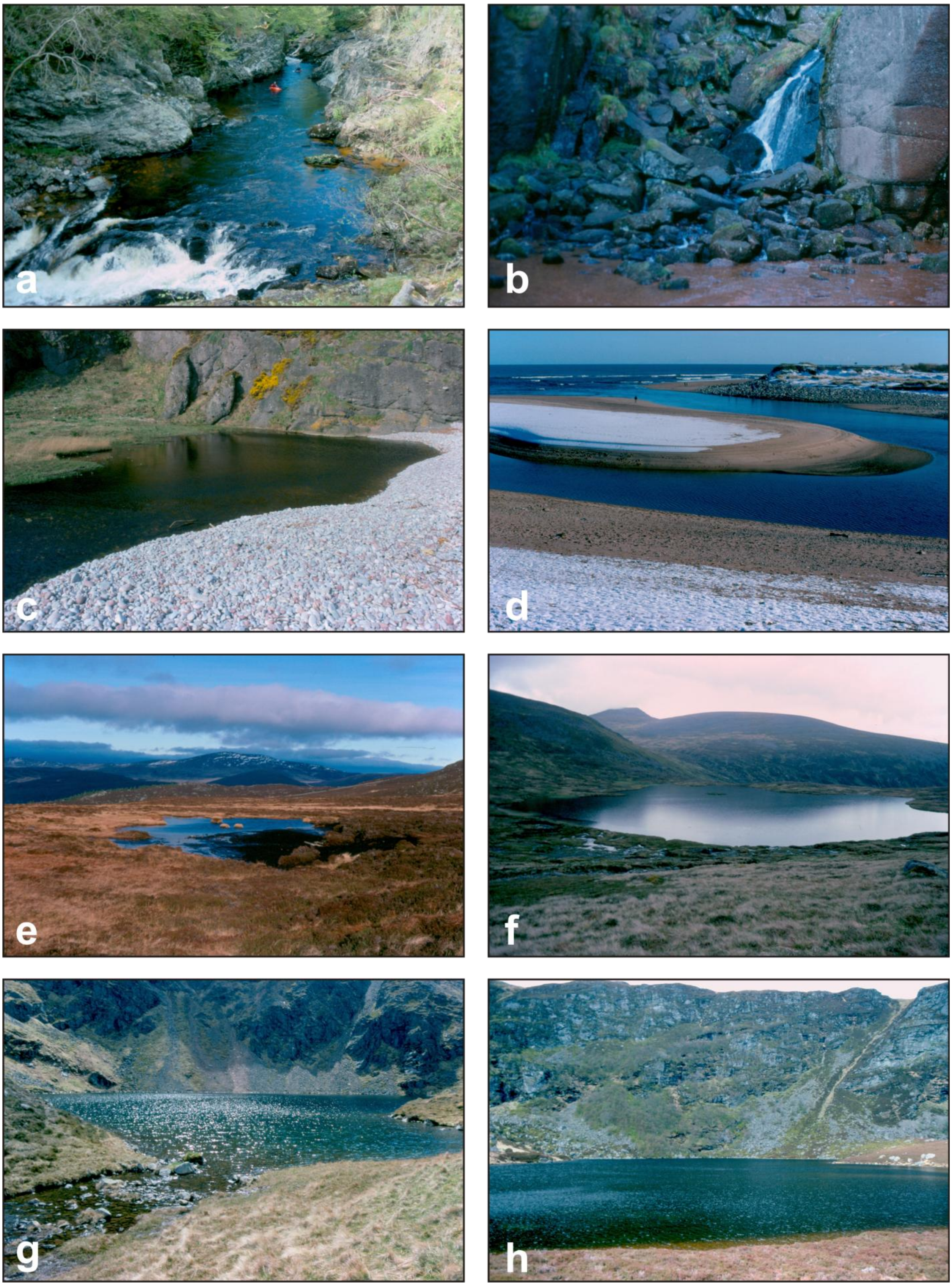


PLATE 37

Fig. a. Lochnagar, northern slopes of the Lochnagar Massif; note the asymmetric geometry of this cirque loch due to the rocky ridge located to the north-west (at the bottom of the picture). Zeiss Sonnar 135mm T* F/2.8 1/250, Kodachrome 64, 14/6/2003.

Fig. b. Late spring view of the western side of the Loch Callater, note the steep slope plunging into the water, leaving virtually no space to the development of shallow beaches with fine sediments. Zeiss Planar 50mm T* F/2 1/500, Kodachrome 64, 15/5/2005.

Fig. c. Winter view of the Dubh Loch, upper sector of the River Muick; note the thin ice layer covering the whole surface (highlighted by the reticular cracks) and the thicker ice packs sparsely floating on water. Minox GT-S 35mm F/2.8 1/30, Kodachrome 64, 11/1/2003.

Fig. d. Winter view of the Sandy Loch, Lochnagar Massif; note the fully iced surface covered by snow patches. Zeiss Planar 50mm T* F/1.4 1/30, Kodachrome 64, 7/3/2004.

Fig. e. Northern side of the Loch Lee, near the ruins of the church of Kirkton; note the wave exposed shore characterised by coarse sediments with sparse boulders. Zeiss Planar 50mm T* F/2 1/500, Kodachrome 64, 8/5/2005.

Fig. e. General view from the Morven eastern flank of the Muir of Dinnet, occupied by the lochs Davan and Kinord. Zeiss Sonnar 135mm T* F/2.8 1/250, Kodachrome 64, 13/12/2003.

Fig. g. Mill of Criggie lochan: a group of common toads *Bufo bufo* (Linnaeus, 1758) mating in a calm water pool protected by macrophytes. Zeiss Planar 50mm T* F/1.4 1/125, Kodachrome 64, 26/3/2005.

Fig. h. Western shore of the Loch of Strathbeg, Fraserburgh: sampling activities in station No. 161. Note the wide area densely colonised by reeds. Zeiss Sonnar 135mm T* F/2.8 1/250, Kodachrome 64, 28/3/2004.

Pl. 37