Conserving Plant Biodiversity in a Changing World:

A View from Northwestern North America

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A View from Northwestern North America

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"Paintbrush and Sedge" by Louise Smith

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ABSTRACT

Gibble, W.J. and Combs, J.K., and Reichard, S.H., 2011. Conserving Plant Biodiversity in a Changing World: A View from Northwestern America. University of Washington Botanic Gardens. Conference Proceedings, 106 pp.

During March 13-14, 2012, a conference was held at the University of Washington Botanic Gardens, Seattle, WA, entitled "Conserving Plant Biodiversity in a Changing World: A View From Northwestern North America". The objective of the conference was to bring together practitioners, researchers, and managers to share our collective expertise on conservation practices for preserving plant biodiversity during this period of economic, political, and climatic instability and to brainstorm strategies to address current and future challenges. The conference comes at a time when plant conservation is at a critical juncture because of the changes that are already being observed in ecosystems and species interactions and the continuing erosion of financial resources and knowledgeable professionals. The tremendous challenges that plant conservationists face require us to act collaboratively, think eco-regionally, and consider innovative approaches to address climate change. The Conference included 55 presentations and 164 attendees belonging to 62 organizations. The geographic scope of the conference covered a broad region, from Alaska to Alberta, Montana, and south to Oregon, that shares a similar flora and whose climate is influenced by North Pacific weather systems. Presentations addressed three broad themes of climate change, ecology and biology of ecosystems, plant communities, and species; and policy and strategies, and were organized into seven sessions. Working groups were formed at the end of the conference based on these three themes to inspire collaborative work to address future challenges. A Botanical Art Exhibit and Contest was held in conjunction with the conference featuring 21 botanical illustrations and 21 photographs that captured the immense beauty of native plants and landscapes throughout northwestern North America.

KEYWORDS: climate change, conservation strategies and policy, plant community ecology, population ecology, rare plants, restoration, conservation management

***Astragalus columbianus* by Julie Combs**

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(in Alphabetical Order):

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***Calochortus longebarbatus* var. *longebarbatus* by Susan Saul**

ACKNOWLEDGMENTS

This conference was sponsored by USDA Forest Service; USDI Bureau of Land Management; Interagency Special Status Sensitive Species Program, Bureau of Land Management & USDA Forest Service; USDI U.S. Fish and Wildlife Service; and the USDI National Park Service. The conference was hosted by the University of Washington Botanic Gardens and the Rare Plant Care & Conservation Program. We would like to thank members of the Conference Steering Committee for their guidance during planning for the conference, their assistance with selection and organization of conference presentations, leading working group discussions, and reviewing manuscripts submitted for the conference proceedings. We would also like to thank staff members at the University of Washington and volunteers who assisted with conference logistics. Special thanks to Michael Hamel at USFS for assistance with the design and technical aspects of the conference proceedings. Also, to our keynote speakers, Dr. Peter Raven (President Emeritus of the Missouri Botanical Gardens) and Dr. Joshua Lawler (Associate Professor of the University of Washington) for identifying many of the challenges conservationists face today and providing concrete ways scientists, managers, and policy makers can work toward preserving native plant communities, rare plants and their habitats.

Wenatchee Mountains by Wendy Gibble

CONSERVING PLANT BIODIVERSITY IN A CHANGING WORLD: A VIEW FROM NORTHWESTERN NORTH AMERICA

CONFERENCE SYNTHESIS

Wendy J. Gibble, Julie K. Combs, and Sarah H. Reichard

More than 160 botanists, conservationists and land managers from across western North America participated in the 2012 conference "Conserving Plant Biodiversity in a Changing World: A View from Northwestern North America" hosted by the Rare Plant Care & Conservation Program of the University of Washington Botanic Gardens. The objective of the conference was to bring together practitioners, researchers, and managers to share our collective expertise on conservation practices for preserving plant biodiversity during this period of economic, political, and climatic instability and to brainstorm strategies to address current and future challenges. The timing for the conference comes at a time when plant conservation is at a critical juncture because of the changes that are already being observed in ecosystems and species interactions and the continuing erosion of financial resources and knowledgeable professionals. The tremendous challenges that plant conservationists face require us to act collaboratively, think eco-regionally, and consider innovative approaches to address climate change.

The two-day conference included 55 presentations, 164 attendees belonging to 62 organizations. The geographic scope of the conference covered a broad region from Alaska to Alberta, Montana, and south to Oregon that shares a similar flora and whose climate is influenced by North Pacific weather systems. Presentations addressed three broad themes of climate change; ecology and biology of ecosystems, plant communities, and individual species; and policy and strategies and were organized into seven sessions presented over the 2-day conference. The sessions included:

- **Session A - Climate Change: Observed Effects on Plants and Plant Communities:** This section focused on ways in which recent and past climate changes have affected individual species as well as plant assemblages. For example, sessions included discussions of recent changes in phenology, demography, and interspecific interactions associated with changes in climate. Studies examined rare as well as common or dominant species.

- **Session B - Climate Change: Predicted Effects on Plants and Plant Communities:** Vulnerability assessments, habitat suitability models, and scenario planning are some of the science-based tools that managers are using to develop management strategies and tactics to protect rare plants and biological diversity. In this session, we heard from managers and scientists who are evaluating the influence of climate on plant communities and specific challenges associated with rare plants and communities.

- **Session C - Climate Change: Adapting Management Strategies to Observed and Predicted Effects:** There is a great deal being written on the observed and potential effects of climate change but much less on how managers and managing agencies should respond. Nonetheless, this is where the rubber (science) hits the road (application). Presentations ranged from a philosophical nature to examples of specific actions based on sound science. Managing for increased resiliency, creating corridors, designing habitat-diverse preserves and translocations were some of the management strategies suggested to respond to the influence of climate change on plant diversity.

- **Session D - Disturbance Ecology and Plant Conservation:** Disturbance and changes in disturbance regimes may in some cases cause a loss of rare plants and biological diversity. In other situations disturbance is required to preserve species and communities. Invasive species and changing fire frequencies are examples of two types of disturbance discussed in this session. In addition, several presentations addressed "Indigenous landscape management" and the relationship between culture and ecological complexity.

- **Session E - Recovery of rare species and the restoration of their habitat:** Rare species, both plants and animals, require a properly functioning, healthy ecosystem for long-term survival and conservation. Agencies, universities, and NGOs, with the support of dedicated volunteers are planning recovery actions for imperiled species and implementing these projects on local landscapes. Through the commitment of many contributing parties we are attaining positive results on the recovery of imperiled species in this time of shrinking budgets for environmental protection. This session highlighted several regional recovery projects that have contributed to our improved understanding of ecological relations and the conservation of rare species.

- **Session F - Reintroduction in a Changing World: How well is it working, how can it be done better, and under what circumstances is it appropriate or not?:** Native plant species are increasingly being reintroduced to sites where they formerly occurred, and introduced to new sites within and outside their known ranges. Despite the apparent clarity, the lack of a universally accepted terminology slows progress in the field. The attempt to establish native species involves not only practical and scientific issues, but also those having to do with human value systems. Recent reviews differ on how well reintroduction appears to be working, and the jury is still out. Questions of its potential use as a tool in countering the effects of global climate change only make the situation more challenging. Contributors in this session discussed diverse aspects of reintroduction from empirical studies to more general discussions of the utility, risks, or proper application of the practice.

- **Session G - Strategies for implementing conservation: partnerships, outreach, and public engagement:** Especially in times of shrinking conservation budgets and expanding ecological change, a range of creative strategies are needed to achieve success in conserving botanical biodiversity. Strengthening connections among governmental agencies, academic institutions, conservation organizations, and committed individuals enables the scientific community to continue conservation work in more effective ways, and may broaden and deepen public support for these efforts. This session explored innovative strategies and highlighted case studies for funding and implementing projects and enhancing public support for plant conservation.

- **Session H - Taxonomy, ecology, and population dynamics of rare and endangered plants:** Rare plants are the subject of a wide variety of taxonomic, genetic, ecological, and population dynamics studies throughout the Pacific Northwest. Basic research, taxonomic and natural history information provides the foundation upon which rare plant conservation and recovery actions are built. This session gave an opportunity for researchers, students, agencies, and private organizations to share and learn about current developments in rare plant science.

The conference also included a Botanical Art Exhibit and Contest featuring 21 botanical illustrations and 21 photographs of plants and ecosystems of northwestern North America. The goal of the exhibit was to integrate art and scientific investigation that leads to a greater appreciation and understanding of native plants and plant communities by the public. The illustrations and photographs captured the immense beauty of native plants and landscapes throughout northwestern North America. Conference participants voted on their favorite artworks. Prizes and recognition were awarded to the top three in each category. First, second and third place for best illustrations were awarded to Louise Smith for "Paintbrush and Sedge", Daphne Morris for "*Carex macrocephala*", and Jan Hurd for "*Rosa nutkana*", respectively. First, second and third place for best photographs were awarded to Daniel Mosquin for "*Castilleja applegatei* var. *pinetorum"*, Michael Hannam for "*Veratrum viride*", and Morgan Turner for "*Blechnum spicant*", respectively. The exhibit remained on display through the month of March in the Elisabeth C. Miller Library at the University of Washington Botanic Gardens.

The opening plenary session of the conference laid out the challenges conservationists face today. The keynote speaker, Dr. Peter Raven, painted a stark picture of the looming biodiversity crises brought on by a myriad of factors: a world population of 7 billion and growing, consumption levels that are outpacing the earth's carrying capacity, the spread of invasive species, over-harvest of certain plants and animals, and climate change. Of particular concern is how the predicted changes in climate will increase the stress experienced by rare plants already under pressure by human's ecological footprint on the globe. Not only will many plant populations find themselves outside their optimal climate range within the next 100 years, but habitat loss will be accelerated by rising sea levels and changes in human land uses necessitated by decreased water availability and higher temperatures. And those populations who survive those threats may face novel predators expanding their ranges or the loss of pollinators whose migration timing no longer matches their flowering period. Dr. Raven noted that extinction rates are expected to increase dramatically compared to historic rates, perhaps reaching 10,000 species a year, approximately equating to half of all species within a century.

Given this ominous prediction, Dr. Raven provided attendees a path forward to slow down and even halt the loss of plant biodiversity. After all, more is resting on the hope of conservation than the ecosystems and species themselves: we look toward these species as sources for new foods and medicines, opportunities for sustainable energy, providing new ways to purify water and soil, and improved agricultural practices. Conservation strategies need to be robust and multi-pronged, including gathering information on species and disseminating it widely, expanding reserve areas with an eye to future climate changes, identifying key sites that offer unique or contiguous habitats, building *ex situ* collections, and conserving whole communities in nature to improve resiliency.

Dr. Joshua Lawler opened the second day of the conference with a presentation on "Anticipating the Impacts of Climate Change on Native Plants." Current climate model predications, such as those provided by the University of Washington Climate Impacts Group, provide predictions on precipitation, mean annual temperature, fire frequency, and snow pack that can be used to estimate future climate envelopes for species or to predict species vulnerability to climate change. For instance, niche models project future suitable ranges for species based on topographic and climatic features predicted 20 to 100 years in the future, thereby providing predictions about where the species distributions will expand and contract. Such models can be applied to a suite of species, or even estimated for an entire flora for a defined geographic area. When land use is superimposed on these models, key migration corridors can be identified to help determine where reserves are needed to facilitate species movement. Researchers have also modeled dispersal velocities to identify which species will not be able to keep pace with the projected rate of climate change, suggesting that these species may need assisted migration. Other models take a mechanistic approach that includes ecological and physiological processes to predict change in vegetation communities based on mortality and establishment. Such modeling highlights the fundamental questions we face about how fully mankind should intervene to shape ecological communities: Do we want to preserve and move entire plant communities? Are there species we should allow to go extinct? Do we want to move species outside their native range? Should native species that are expanding their range be considered invasive?

Over the course of two days, conference attendees pondered these questions and the extraordinary challenges that face conservationists and land managers in the coming decades. While we took inspiration from the dedicated and innovative work of our peers, we also agreed that, as a community, we need to proactively address some of the pressing issues identified in the conference. Three working groups met to identify the challenges and steps needed to start tackling them. Three topics addressed by these groups included: climate change, ecology and biology of rare plants, and policies and strategies for plant conservation (see Appendix A). We look forward to hearing about what these working groups accomplish when we next meet for a regional conference on plant biodiversity.

These proceedings consists of three manuscripts, eight extended abstracts, forty-six oral presentation abstracts and eighteen oral presentation abstracts. Authors were given the choice of submitting their original abstract, an extended abstract or a manuscript. The majority opted to submit their original abstract.

Carex stylosa **by Brenda Cunningham**

Rare Vascular Plant Distributions In Alaska: Evaluating Patterns Of Habitat Suitability In The Face Of Climate Change

Matthew L. Carlson[1] and Helen Cortés-Burns[2]

ABSTRACT

The high magnitude of projected climate change in northern latitudes represents a serious concern to the persistence of Alaskan plant species with limited geographic distributions or narrow habitat requirements. To address this potential vulnerability, we review the distribution patterns of Alaska's rare plants and initial results from current and future habitat suitability models for 34 rare plants. Hotspots of rare taxa in the state are concentrated in the Aleutian Islands, southeastern Alaska, interior Alaska and Brooks Ranges, and the Arctic Coastal Plain. Approximately 60% of Alaska's rare species are found at high elevations, islands, or adjacent to the Arctic Ocean and therefore appear to lack clear migration corridors to track their current climate envelopes under future scenarios. We used inductive habitat-suitability models to evaluate whether future suitable habitat locations would be reduced in size or shifted in location. Preliminary models for rare species with southwestern Alaska and montane distributions showed little change in suitable area. Model outputs for interior species were varied: some models suggest large shifts and others minor shifts in suitable habitat. Last, outputs for arctic endemics suggest a dramatic loss of suitable habitat in 50 years. Species did not have consistent responses to climate variables, but in general, annual precipitation appeared to be a more important driver than mean annual temperature or other variables. This modeling effort highlights the need to identify additional important variables that drive many of Alaska's rarest plants distributions, and the need for experimental approaches for the most at-risk species to understand the relationship of climate warming on population vital rates.

Keywords: Alaska, rare plants, climate change, climatic niche model

INTRODUCTION

Alaska is in the enviable position relative to states and provinces to the south in having very few vascular plants at risk of extirpation. Currently a single plant species is listed as Endangered by the USFWS (Federal Register 1988) and just 24 taxa are listed as globally imperiled to critically imperiled in the state (AKNHP 2012). This low number of species of conservation concern is not solely a function of lower total biodiversity. Total plant species richness of approximately 2,000 species (Hultén 1968) is comparable to other Pacific Northwest states and provinces. However with a significantly larger area, the number of

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rare species per unit area is dramatically less in Alaska relative to other states (e.g., 15.2 × less than Washington). While Alaska does not harbor a large number of globally rare species, it encompasses the limited North American distribution of a number of widespread Eurasian species, such as Oxygraphis glacialis (Fisch.) Bunge, Saussurea triangulata Trautvetter & C. A. Meyer, and Potentilla stipularis L., where the North American distribution of these taxa are limited to a few populations in western Alaska. Additionally, the circumpolar north may harbor numerous cryptic plant species and is suggested to be a region of rapid incipient speciation (Grundt et al. 2006). Thus, we argue that Alaska makes a significant contribution to the plant biodiversity in the North America.

The low number of species at risk of extirpation in Alaska can also be attributed to fewer threats from human development. The primary cause of species endangerment, habitat conversion (Meffe and Carroll 1997, Wilcove and Master 2008), has been considerably less in Alaska relative to other states (e.g., road density is approximately 30 × less in Alaska relative to Washington and 880,000 acres have been converted to agriculture in Alaska relative to 15,000,000 acres in Washington, USDA 2012). Current and proposed large-scale natural resource extraction activities (such as mining and oil and gas development) however are causing alterations to substrates and habitats more broadly, which are likely to increasingly threaten rare plant populations. Second, dramatic changes in climate cause a growing reason for concern. Increases in mean annual temperature are well accepted to be proceeding more dramatically at high latitudes (Serreze et al. 2000) and direct and indirect impacts of climate change have the potential to threaten the persistence of plant species at these latitudes. In just the last 30 years, there has been a +2 °C increase in mean annual temperature in the arctic biome (ACIA 2005) and temperature is predicted to continue to increase more rapidly than at lower latitudes (IPPC 2007). The growing season has nearly doubled in length the interior of Alaska in the last 100 years, from 90 to 170 days (Wendler and Shulski 2009). Species and communities appear to be responding to these changes. There are numerous examples of increases in shrub and tree expansion in arctic and alpine tundra habitats (Klein et al. 2005, Dial et al. 2007, Tape et al. 2006, Roland 2012). As the majority of rare vascular plant species in Alaska are associated with open, low-competition habitats, shrub and tree encroachment represents a serious threat to these rare plant populations. Additionally, climate change is influencing patterns and frequency of disturbances in northern systems, such as increasing the frequency and intensities of herbivorous insect outbreaks and wildfires (Soja et al. 2006, Chapin et al. 2008). Last the rate of non-native plant species introduction and establishment in natural systems is accelerating in Alaska and is likely exacerbated by increased temperatures, longer growing seasons, and more frequent and severe disturbances (Carlson and Shephard 2007). While indirect ecological impacts associated with climate change, such as disturbance and herbivory, are the most difficult to predict and quantify, they are likely to have impacts that are equal or greater than direct impacts (Davis et al. 1998, Klanderude 2005, Suttle et al. 2007, Adler et al. 2009).

Rare plant species in Alaska display pronounced biogeographic patterns. Some of these biogeographic associations are anticipated to experience more extreme climatic changes, and/or lack clear dispersal routes to future suitable climate and are therefore expected to be more vulnerable to climate change. Hierarchical cluster analysis of globally rare to imperiled species by 250,000 mi^2 grid cells and ecogeographic region (Nowacki et al. 2001) suggest these species can be grouped into an Aleutian, southeastern coastal, montane, interior, and Bering Strait, and Arctic Coastal Plain associations (fig. 1). Projected global circulation model average temperatures predict an approximately +2 °C increase over much of Alaska in 50 years, but with greater increases in northern Alaska and only modest increases in southwestern Alaska to the Aleutian Islands (SNAP 2012). Total precipitation is expected to remain relatively similar along the Arctic Coastal Plain, southeastern coast, and in the interior, while southwestern and western Alaska is projected to become significantly wetter. Specifically, we anticipate that Aleutian, montane, and Arctic Coastal Plain species associations are more vulnerable to reduced and geographically disparate future suitable habitats since these species would presumably have to move to the north and to higher elevations to track suitable climates and they are predicted to show the most dramatic changes in temperature or precipitation. Areas to the north and higher elevations for these groups of species are either bounded by the Chukchi, or Beaufort Seas, or are reduced in area for the montane species. The interior species associations tend to be dominated by species found on warmer and drier microsites and thus we expect that habitat suitability for this group of species will generally increase under future scenarios at least in the eastern interior.

In an attempt to evaluate the potential vulnerabilities of rare plant species in Alaska to climate change, we modeled the distribution of current and future climatic envelopes of 34 rare plant species. Specifically we address if predicted suitable habitat contracts in area and if the region of predicted suitability is different in 50 years. We anticipated that montane-associated species and species endemic to the Arctic Coastal Plain would be more vulnerable than species of other biogeographic affinities to climate change. Last, we examined the importance of temperature relative to other climate and geographic variables in the development of distribution models for these species.

METHODS

We modeled the current and future ecological niches using presence data for seven to ten species from each of four biogeographic regions in Alaska: Arctic Coastal Plain, interior, montane (primarily Alaska and Brooks Ranges), and a combined Aleutian and southeastern coastal region (Aleutian-south coastal, table 1). Aleutian and southeastern coast regions were combined because they share biogeographic affinities (fig. 1) and the small numbers of populations and incomplete data layers in the western Aleutians hampered our ability to treat that region independently. We included species considered rare to imperiled in the state for which there were approximately ten or more occurrences.

Population locations were obtained from the Alaska Natural Heritage Program's rare plant database (AKNHP 2012). The majority of these records are based on georeferenced vouchered specimens housed in herbaria such as the University of Alaska Museum and the University of Alaska Anchorage, as well as from the USDA Forest Service NRIS database. Species occurrences that were less than 1 km apart were eliminated from the analysis.

The predictor variables we used included current and projected climate data created for Alaska by the Scenarios Network for Alaska Planning (SNAP 2010, 1 km^2 grid cells). The future climate projection is based on the downscaled output from five of the International Panel on Climate Change's Global Circulation models. We used the climate projection for 2060 under the intermediate (A1B) emission scenarios. Climate variables used to develop the models included mean annual temperature, mean annual precipitation, and growing season length (number of frost-free days). Additionally, we included slope and elevation, which were extracted from the National Elevation Dataset for Alaska (Gesch 2007 and Gesch et al. 2002; approximately 60 meter resolution).

We used the maximum entropy modeling program MaxEnt version 3.3.1 (Phillips et al. 2006, Phillips and Dudik 2008) to produce the species distribution models. MaxEnt calculates expected levels of species presence using presence-only data, and has been shown to outperform more established modeling methods, such as GARP and BIOCLIM (Elith et al. 2006). When the number of data points available made it possible, runs were cross-validated. Occurrences were randomly split into a number of groups, and models were created omitting each group of occurrences in turn. Models run from previously omitted occurrences are then used for evaluation. We used area under the curve (AUC) statistics derived from receiver operating characteristics (ROC) analyses, which is automatically calculated by Maxent, to estimate model performance. AUC values range between 0.5 and 1, with values between 0.5 - 0.7 being relatively poor, those between 0.7 and 0.9 being useful, and those above 0.9 indicating relative high accuracy (Swets 1988). Finally, our knowledge of individual species and their habitat preferences was also incorporated to make final determinations on which models were useful and which ones were not as reliable.

We developed an index to compare the relative importance of the five predictor variables in determining suitability for the biogeographic groups of species. Percent variable contributions are generated from MaxEnt and we used the first two variables that contributed most to the model for each species were given scores of 1.0 or 0.5, for first and second variable contribution, respectively. The ratio of scores for each variable to the total for all species in the biogeographic group was then calculated. Thus the variable most important to the majority of species in the group received a higher score. We compared changes in predicted suitability over the 50 year time-step by visually comparing the mapped outputs.

RESULTS

In general, model performance was correlated with the number of occurrences used to develop the model. Species with greater than 15 known occurrences, and for which we could run cross-validation statistics with 5-10 replicates performed the best. Predicted habitat suitability models for 2010 and 2060 are shown in figure 2 for three species within each biogeographic group to demonstrate the range of responses.

Overall, species had varied responses to future climates, with predicted suitabilities increasing in some cases and decreasing in others. However, there were some consistent patterns within biogeographic groups. Consistent with expectations, all Arctic Coastal Plain species exhibited a decrease in suitable habitat as a result of climate change (albeit with poor model performance). Model results from the Aleutian-south coastal and montane biogeographic groups suggest that the area of suitable habitat shifts north as expected, but that the area of suitable habitat is roughly similar or increases under these future climate projections. Last, model results suggest a range of vulnerabilities of interior species under future climate predictions.

Arctic Coastal Plain Species

Model performance for most of the Arctic Coastal Plain species was poor. Many of the rare species we selected from this region have few known occurrences (3-20 per species), and even when cross-validated the model outputs were still either over-fitted (too constrained to the predictor variables and lack generality) or potentially lacking a variable that would have served as a stronger predictor. There was however a consistent trend among all arctic species analyzed: the area of suitable habitat shifted northward and declined in the 2060 models (fig. 2). The model obtained for the arctic grass ***Koeleria asiatica*** Domin, which is considered rare in the state and of long-term conservation concern globally, was well-supported (22 known locations, ten replicates, AUC 0.976). Predicted habitat for this species shows a general reduction in the area and degree of suitability by 2060, with particular reductions in the southern and western portions of its current range. We also retained the modeled outputs for ***Papaver gorodkovii*** Tolm. & Petrovsky (13 known locations, three replicates, AUC 0.964) and for ***Cardamine microphylla*** M.F. Adams (nine known locations, three replicates, AUC 0.919). Model runs for ***Draba subcapitata*** Simmons, ***Ranunculus sabinei*** R.Br., and ***Symphyotrichum falcatum*** ssp. ***falcatum*** (Lindl.) G.L. Nesom, which are all imperiled and restricted to the Arctic, could not be replicated due to the lack of distinct occurrences (three to six). Models for these species were highly over-fitted and discarded after an initial run. Although our confidence in the models for ***Mertensia drummondii*** (Lehm.) G. Don, ***Pleuropogon sabinei*** R.Br., ***Draba pauciflora*** R.Br., ***Symphyotrichum pygmaeum*** Brouillet & Sugirthini, ***Saxifraga rivularis*** ssp. ***arctolitoralis*** (Jurtzev & V.V. Petrovsky) M.H. Jørg. & Elven, and ***Poa hartzii*** ssp.

alaskana Soreng. was low, all of these species displayed similar constrictions of predicted suitable habitat. In many cases the declines were dramatic, for example no suitable habitat was identified for *Mertensia drummondii* under this scenario by 2060. Species models in this biogeographic group were driven primarily by mean annual temperature, followed by elevation and the other variables (fig. 3).

Montane Species

Unlike the Arctic Coastal Plain species, montane species all had more than 15 occurrences (most had more than 40 known presences), and models were consequently run with cross-validation (ten or sometimes three replicates per species). High AUC values (0.83 to 0.93) and the omission versus commission analyses indicated strong model performance across all species in this group.

The overall trend for the montane species is that the distribution of predicted suitable habitat remains similar in extent or even increases within the next 50 years (fig. 2). In particular, for many of the montane species, increased habitat suitability is evident in the Brooks Range, while little reduction on the southern edge of their distribution is indicated. However, some reductions of current habitat suitability were evident in the model for *Aphragmus eschscholtzianus* Andrz. ex DC. in the southwestern portion of its range on the Alaska Peninsula. Montane species models were primarily driven by elevation and precipitation.

Aleutian-South Coastal Species

Models for Aleutian-south coastal species with greater than 15 occurrences were also reliable. However, *Oxygraphis glacialis* (Fisch.) Bunge and *Plagiobothrys orientalis* (L.) I.M. Johnst. were discarded because of poor model performance and over-fitting. Many of the Aleutian-coastal species models indicated increased future habitat suitability in the Bristol Bay region to the north of their current locations and some moderate decline in suitability in southeastern Alaska. Only modest declines in suitabilities in their current ranges in southwestern Alaska were indicated (fig. 2). It should be stressed that most of the species in this biogeographic group are associated with strongly maritime-influenced habitats and therefore, the increased suitabilities in the highlands of southwestern Alaska projected by many models are unlikely to be reflective of truly suitable habitat. Aleutian-south coastal species models were driven primarily by mean annual precipitation (fig. 3).

Interior Species

Interior species displayed the most diverse response to climate change. *Lupinus kuschei* Eastw. and *Physaria caldera* (G.A. Mulligan & A.E. Porsild) O'Kane & Al-Shehbaz were discarded for poor model performance. Some species showed large declines in the area of predicted suitable habitat by 2060 (e.g., *Campanula aurita* Greene, *Cerastium maximum* L., *Draba murrayi* G.A. Mulligan, *Erysimum asperum* var. *angustatum* (Rydb.) B. Boivin, *Eriogonum flavum* var. *aquilinum* Reveal, *Alyssum obovatum* (C.A. Mey.) Turcz., *Antennaria densifolia* A.E. Porsild; fig. 2). However, in almost all cases, predicted habitat suitability in 2060 remained high in the specific areas where populations are currently known. In addition, other taxa exhibited an increase and/or shift in their predicted suitable habitat (e.g. *Artemisia tanacetifolia* L. and *Corispermum ochotense* Ignatov; fig. 2). Precipitation was the most important variable driving the species models for the interior species model, while slope and the other variables were important predictors for a minority of species (fig. 3).

DISCUSSION

While the rare flora of Alaska is less threatened by anthropogenic factors than floras to the south, our modeling results suggest that some groups of species may have difficulties tracking suitable habitats and are vulnerable to climate change. In particular, models of the Arctic Coastal Plain endemics suggest a common pattern of dramatic decrease in the area of predicted suitable habitat. Although we restricted our analysis to Alaska, areas of future suitable climate for many of these species would be expected to occur in higher latitude polar regions, such as in the Canadian Archipelago. Migration corridors to these areas, however, would require long distance dispersal across the water or sea ice. Population genetic data from a number of arctic plant species does suggest high dispersal ability (Abbott and Brochmann 2003). Interestingly, modeling of the arctic tundra biome more broadly has suggested that this system may be less vulnerable to shifts than many other biomes, as shifts in other biomes are often sensitive to relatively small changes in temperature and precipitation (Murphy et al. 2010, Loarie et al. 2011). The arctic tundra habitat on the Seward Peninsula, which is much nearer to the margin of the arctic tundra biome climate envelope than the Arctic Coastal Plain, is anticipated to diminish dramatically in this time frame (Murphy et al. 2010). Therefore the Bering Strait associated rare species (which were not modeled here) could be at particular risk. While biological organization may not change dramatically at broader physiognomic levels (i.e., treeless tundra persists) on the Arctic Coastal Plain, the composition of communities within the biomes may change due to individual species responses. In particular, models of these rare species suggest that changes in their climate envelopes could be striking.

Rare species associated with the Aleutian-south coastal and montane regions appear more secure than the species of the Arctic Coastal Plain and interior regions. These species are found in the southern and central portion of the state and in areas with high topographic complexity. Thus future suitable climate envelopes are generally proximal to current climate envelopes. In regions to the south, alpine habitats and associated species have been recognized as sky islands that are particularly vulnerable to climate change (e.g., Kupfer et al. 2005, Gifford and Kozak 2012). In Alaska, the reduction in alpine habitats in response to climate change is likely substantially less than regions to the south since alpine habitats occur at much lower elevations and a relatively large area still remains at higher elevations. Future suitable habitat generally increased in the Brooks Range for the montane associates and for many species that are currently associated with the Alaska and Coastal Ranges there is no clear high elevation north-south dispersal route to the Brooks Range. Also, even though suitable habitat was predicted to remain similar in extent or increase for Aleutian-south coastal and montane-associated species, reductions in suitabilities at the southern margin of the ranges of some species were implied; thus local population decline at the edge of some species' ranges is a concern. Therefore, some caution should be taken in assuming with increasing area of suitable habitat modeled there is reduced threat. Due to lack of some adequate environmental data layers and few known locations, we did not model suitable habitats for the rarest Aleutian Island endemics. These species would likely face significant dispersal barriers assuming suitable climates shift from current locations. However, the only USFWS Listed plant taxon in the state is the Aleutian shield fern (***Polystichum aleuticum***) and of all vascular plant groups, ferns are generally not dispersal limited (Tryon 1966, 1970, Perrie et al. 2010).

Mean annual precipitation, rather than temperature, was the predictor variable that explained the most variation in suitable habitat across species models. The degree of uncertainty in patterns of future precipitation in general is quite high however, and thus constrains the confidence in models of future suitable habitat in cases where precipitation an important predictor variable (Lawler 2012). Second, plants are expected to respond to soil moisture rather than precipitation ***per se***, and soil moisture is a more complex variable involving temperature, evapotranspiration, etc. Despite these caveats, many of the rare species, particularly in interior Alaska, are clearly associated with unusually dry microsites (see Lipkin and Murray 1997) and therefore changes in precipitation (and temperature) would be expected to have large impacts on the size and distribution of suitable habitat. Even small decreases in precipitation and increases in temperature are expected to result in potentially large areas of conversion of forest habitats to open, steppe-bluff habitats (Lloyd et al. 2011), which could result in a greater area of suitable habitat for this group of rare species.

The lack of importance of temperature in explaining variation in the models is noteworthy. It is quite possible that many of these species occur in areas with relatively large variation in mean annual temperature and although they occur in a relatively narrow geographic region, it encompasses a range of elevations, aspects, and distances to coast. Thus variation in mean annual temperatures associated with known locations would be expected to be high and therefore have reduced predictive ability relative to other variables. Second, since we have only treated temperature in a very coarse manner (mean annual temperature) we are unlikely to capture many important climate niche parameters. For example, individual plant species would be expected to respond to finer-scale aspects of temperature, such as minimum winter temperatures or maximum summer temperatures, variables that may be only weakly correlated with mean annual temperature.

These model outputs are intended as a hypothesis generating exercise and should be viewed with caution and an awareness of their limitations (see Davis et al. 1998). First, we have no ***a priori*** information that the habitat of the species modeled is in fact related to the climate and topographic variables used. While mean annual temperature and precipitation are accepted in general to be the most important niche parameters for vascular plants (see Woodward 1987, Davis and Shaw 2001, Hughes 2000, McCarty 2001, Walther et al. 2002), it is possible that these variables are not important within the scope of the geographic region investigated. Populations of these rare plants may be more constrained by finer-scale variables. For example, soil moisture-holding capacity has been shown to be a major determinant of the distribution of three alpine tundra willow species (Dawson 1990) and the presence of mycorrhizal symbionts has been shown to be a major component determining species' distributions (McCormick et al. 2012). Second, with few known locations for many of the rarest species, there is greater uncertainty about the relationship of the species with the predictor variables, leading to poor or over-fitted models. Third, we have little ability to infer if the pattern of current and future suitable habitats of the most critically imperiled taxa (that were not modeled because of low sample size) would be similar to the model outputs associated with the species with more occurrences. Thus we restrict comments on climate vulnerabilities of our rarest species. Finally, the majority of rare plants in Alaska are associated with uncommon substrates (e.g., sand dunes, limestone outcrops, wet scree, etc.) and we were not able to include these as predictor variables because high resolution spatial data is not avaialable for the state. Thus the habitat suitability outputs produced in these models represent a coarse perspective based on a limited number of predictors with at least one of the major predictors (substrate type) omitted. Last, it should be emphasized that we are unaware of indirect impacts of climate change on rare plants. Changes in disturbance regimes and antagonistic and mutualistic interactions, herbivory, pathogens, etc. are likely to have equal or greater impacts on rare plant species than direct effects of climate (Davis et al. 1998, Klanderude 2005, Suttle et al. 2007, Adler et al. 2009).

This study does, however, provide a direction for future research on the impact of climate change on Alaska's rare plants. These initial findings suggest that natural resource managers in the state should give greater priority to inventorying, monitoring, and conducting experimental work on rare vascular plants in the Arctic. Even though these species are not currently listed as threatened or endangered, the lack of information we have on these plants severely limits our ability to understand their current rarity as well as predict how future changes in the state will affect them. Currently we have almost no information on baseline population trends or habitat changes of rare species in the state and monitoring efforts would be invaluable in gauging if populations of the identified vulnerable species are in fact showing signs of change. Second, we see a great value in studies to test the relationship of direct and indirect effects of climate on niche space by relating population vital rates to environmental parameters in natural populations or in newly established populations subjected to current and predicted future climates (McLean and Aitken 2012). Future modeling studies will include rare species from the Bering Strait and strictly southeastern maritime ecoregions, as well as including the westernmost Aleutian species, and by including more widespread arctic and Aleutian species.

ACKNOWLEDGMENTS

Dave Yokel with the Alaska Northern Region of the Bureau of Land Management and Michael Shephard and Amy Miller with the Southwest Alaska Network, National Park Service supported previous modeling efforts, integral in this study. Timm Nowacki, Erin Johnson, and Nancy Norvell with the Alaska Natural Heritage Program, University of Alaska Anchorage assisted in the modeling efforts. Amy Miller, Tracey Gotthardt, and Miles Spathelf offered valuable insights and edits on earlier versions of this manuscript.

LITERATURE CITED

Abbott, R.J; Brochmann, C. 2003. History and evolution of the arctic flora: In the footsteps of Eric Hultén. Molecular Ecology 12: 299-313.

Adler, P.B.; Leiker, J.; Levine, J.M. 2009. Direct and indirect effects of climate change on a prairie plant community. PLoS ONE 4(9): e6887. doi:10.1371/journal.pone.0006887.

ACIA. 2005. Arctic Climate Impact Assessment: Impacts of a warming climate. University of Cambridge Press, Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo.

AKNHP. 2012. Rare vascular plants of Alaska. Alaska Natural Heritage Program, University of Alaska Anchorage. http://aknhp.uaa.alaska.edu/botany/rare-plants-species-lists/2012-rare-vascular-plant-list. 10 March 2012.

Chapin, F.S.III; Trainor, S.F.; Huntington, O.; Lovecraft, A.L.; Zavaleta, E.; Natcher, D.C.; McGuire, A.D.; Nelson, J.A.; Ray, L. Calef, M.; Fresco, N.; Huntington, H.; Rupp, T.S.; DeWilde, L.; Naylor, R.L. 2008. Increasing wildfire in Alaska's boreal forest: pathways to potential solutions of a wicked problem. Bioscience 58:531-540.

Carlson, M.L.; Cortés-Burns, H.; Miller, A. 2007. Areas of plant radiation and migration in Alaska: Testing Hultén's ideas of elemental areas and rare plant diversity in Alaska. AAAS, Arctic Chapter Annual Meeting 24-26 September 2007, Anchorage.

Carlson, M.L.; Shephard, M. 2007. Is the spread of non-native plants in Alaska accelerating? In: Meeting the challenge: invasive plants in Pacific Northwest ecosystems, Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, En. Tech. Rep. PNW-GTR-694: 111-127.

Cortés-Burns, H.; Carlson, M.L.; Lipkin, R.; Flagstad, L.; Yokel, D. 2009. Rare vascular plants of the North Slope: a review of the taxonomy, distribution, and ecology of 31 rare plant taxa that occur in Alaska's North Slope región. BLM Alaska Technical Report 58. BLM/AK/GI-10/002+6518+F030. pp. 116.

Davis, A.J.; Jenkinson, L.S.; Lawton J.H.; Shorrocks, B.; Wood, S. 1998. Making mistakes when predicting shifts in species range in response to global warming. Nature 391: 783–786.

Davis, M.B. & Shaw, R.G. 2001. Range shifts and adaptive responses to Quaternary climate change. Science, 292, 673–679.

Dawson, T.E. 1990. Spatial and physiological overlap of three co-occurring alpine willows. Functional Ecology, 4, 13-25.

Dial, R.J.; Berg, E.E.; Timm, K.; McMahon, A.; Geck, J. 2007. Changes in the alpine forest-tundra ecotone commensurate with recent warming in southcentral Alaska: Evidence from orthophotos and field plots. Journal of Geophysial Research 112: G04015, doi:10.1029/2007JG000453.

Elith, J.; Kearney, M.; Phillips, S. 2010. The art of modelling range-shifting species. Methods in Ecology and Evolution 1:330-342.

Fielding, A.H.; Bell, J.F. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24:38-49.

Gesch, D.B. 2007. The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p. 99-118.

Gesch, D.; Oimoen, M.; Greenlee, S.; Nelson, C.; Steuck, M.; Tyler, D. 2002. The National Elevation Dataset: Photogrammetric Engineering and Remote Sensing 68: 5-11.

Gifford, M.E.; Kozak, K.H. 2012. Islands in the sky or squeezed at the top? Ecological causes of elevational range limits in montane salamanders. Ecography 35: 193-203.

Grundt, H.H.; Kjølner, S.; Borgen, L.; Rieseberg, L.H.; Brochmann, C. 2006. High biological species diversity in the arctic flora. Proceedings of the National Academy of Sciences 103: 972–975.

Hughes, L. 2000. Biological consequences of global warming: is the signal already apparent? Trends in Ecology and Evolution, 15, 56–61.

Hultén, E. 1968. Flora of Alaska and Neighboring Territories. Stanford University Press, Stanford, California.

IPCC 2007. Climate change 2007: impacts, adaptationand vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

Klanderud, K. 2005. Climate change effects on species interactions in an alpine plant community. J Ecology 93: 127–137.

Klein, D.; Berg, E.E.; Dial, R. 2005. Wetland drying and succession across the Kenai Peninsula Lowlands, south-central Alaska. Canadian Journal of Forestry Research 35: 1931–1941.

Kupfer, J.A.; Balmat, J.; Smith, J.L. 2005. Shifts in the potential distribution of sky island plant communities in response to climate change. USDA Forest Service Proceedings RMRS-P-36.

Lawler, J. 2012. Anticipating the impacts of climate change on native plants: models, forecasts, and implications. Conserving Plant Biodiversity in a Changing World: A View from NW North America. Seattle, Washington. 14 March 2012.

Lipkin, R.; Murray, D.F. 1997. Alaska rare plant field guide. U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Alaska Natural Heritage Program, and U.S. Forest Service.

Lloyd, A.H.; Duffy, P.; Mann, D.H.; Leonawicz, M.; Blumstein, M.; Pendall, E. 2011. Threshold Responses of Aspen and Spruce Growth to Temperature May Presage a Regime Shift in the Boreal Forest. American Geophysical Union, Fall Meeting 2011, abstract #U51C-05.

Loarie, S.R.; Duffy, P.B.; Hamilton, H.; Asner, G.P.; Field, C.B.; Ackerly, D.D. 2011. The velocity of climate change. Nature 462:1052-1056.

McCarty, J.P. 2001. Ecological consequences of recent climate change. Conservation Biology, 15, 320–331.

McCormick, M.K.; Taylor, D.E.; Juhaszova, K.; Burnett, R.K. Jr; Whigham, D.F.; O'Neill, JP. 2012. Limitations on orchid recruitment: not a simple picture. Molecular Ecology. doi: 10.1111/j.1365-294X.2012.05468.x

McLane, S.C.; Aitken, S.N. 2012. Whitebark pine (*Pinus albicaulis*) assisted migration potential: testing establishment north of the species range. Ecological Applications Vol??:142-153.

Meffe, G.K.; Carroll, C.R. 1997. Principles of Conservation Biology. Sinauer Associates, Inc., Sunderland, Massachusetts.

Murphy, K.; Huettmann, F.; Fresco, N.; Morton, J. 2010. Connecting Alaska landscapes into the future. Final Report. Scenarios Network for Alaska Planning, University of Alaska, Fairbanks, Alaska.

Nowacki, G.: Spencer, P.; Fleming, M.; Brock, T., Jorgenson, T. 2001. Ecoregions of Alaska: 2001. U.S. Geological Survey Open-File Report 02-297 (map).

Perrie, L.R.: Ohlsen, D.J.; Shepherd, L.D.; Garrett, M.; Brownsey, P.J., Bayly, M.J. 2010. Tasmanian and Victorian populations of the fern *Asplenium hookerianum* result from independent dispersal from New Zealand. Australian Systematic Botany 23: 387–392.

Phillips, S.J.; Anderson, R.P.; Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190:231-259.

Phillips, S.J.; Dudik, M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161-175.

Roland, C. 2012. Modeling the diversity of rare and endemic plants at the landscape scale in Denali National Park: implications of climate change for this unique natural heritage. Conserving Plant Biodiversity in a Changing World: A View from NW North America. Seattle, Washington. 14 March 2012.

Serreze, M.C.; Walsh, J.E.; Chapin, F.S. III; Osterkamp, T; Dyurgerov, M.; Romanovsky, V.; Oechel, W.C.; Morison, J.; Zhang, T.; Barry, R.G. 2000. Observational evidence of recent change in the northern high-latitude environment. Climate Change 46:159-207.

SNAP. 2010. Scenarios Network for Alaska Planning (http://www.snap.uaf.edu/gis-maps) Alaska Climate Datasets. University of Alaska Fairbanks, Fairbanks, Alaska

Soja, A.J.; Tchebakova, N.M.; French, N.H.F.; Flannigan, M.D.; Shugart, H.H.; Stocks, B.J.; Sukhinin, A.I.; Parfenova, E.I., Chapin, F.S.III; Stackhouse, P.W.Jr. 2006. Climate-induced boreal forest change: predictions versus current observations. Global and Planetary Change 56: 274–296.

Suttle, K.; Thomsen, M.; Power, M. 2007. Species interactions reverse grassland responses to changing climate. Science 315: 640–642.

Swets, J.A. 1988. Measuring the accuracy of diagnostic systems. Science 240:1285-1293.

Tape, K.; Sturm, M.; Racine, C. 2006. The evidence for shrub expansion in Northern Alaska and the Pan-Arctic. Global Change Biology 12:686-702.

Tryon, A.F. 1966. Origin of the fern flora of Tristan de Cunha. British Fern Gazette 9: 269–276.

Tryon, R.M. 1970. Development and evolution of fern floras of oceanic islands. Biotropica 2: 76–84.

USDA, Economic Research Service. 2012. State Fact Sheets. http://www.ers.usda.gov/StateFacts/. (12 June 2012).

USFWS Federal Registry. 1988. http://alaska.fws.gov/fisheries/fieldoffice/anchorage/endangered/pdf/factsheet_alsf.pdf. (9 June 2012).

Walther, G.R., Post, E., Convey, P., Menze, 1, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O. & Bairlein, F. 2002. Ecological responses to recent climate change. Nature, 416, 389–395.

Wendler, G.; Shulski, M. 2009. A century of climate change for Fairbanks, Alaska. Arctic 62: 295-300.

Wilcove, D.S.; Master, L. L. 2008. How Many Endangered Species are there in the United States? Frontiers in Ecology and the Environment 3: 414-420.

WNHP. 2012. List of Vascular Plants Tracked by the Washington Natural Heritage Program. http://www1.dnr.wa.gov/nhp/refdesk/lists/plantrnk.html. (10 March 2012).

Woodward, F.I. 1987. Climate and plant distribution. Cambridge University Press, Cambridge.

Table 1. Species used in the habitat modeling, biogeographic association, NatureServe global and current Alaska Natural Heritage Program state rarity ranks, and number of occurrences in Alaska. The Aleutian-south coastal association is abbreviated 'Aleutian-coastal' and the Arctic Coastal Plain is abbreviated 'Arctic'.

Species	Region	Global Rank	State Rank	Number of occurrences
Alyssum obovatum	Interior	G5	S2S3	12
Antennaria densifolia	Interior	G3	S2	9
Aphragmus eschscholtzianus	Montane	G3	S4	57
Arnica ovata	Montane	G5	S2S3Q	18
Artemisia tanacetifolia	Interior	GNR	S3	26
Atriplex gmelinii var. *alaskensis*	Aleutian-coastal	G3G4Q	S4	27
Campanula aurita	Interior	G4	S4	42
Cardamine microphylla	Arctic	G3G4	S2	9
Cerastium maximum	Interior	G4	S4	26
Corispermum ochotense	Interior	G3G4	S3	14
Douglasia alaskana	Aleutian-coastal	G3	S4	45
Draba macounii	Montane	G3G4	S3	21
Draba murrayi	Interior	G2	S2S3	22
Draba pauciflora	Arctic	G4	S2	9
Erigeron porsildii	Montane	G3G4	S3S4	21
Eriogonum flavum var. *aquilinum*	Interior	G5T2	S2	18
Erysimum asperum var. *angustatum*	Interior	G5T1	S2	19
Koeleria asiatica	Arctic	G4	S3	22
Lupinus kuschei	Interior	G3G4	S2	16
Mertensia drummondii	Arctic	G2G3	S2	16
Noccaea arctica	Montane	G3	S4	48
Oxygraphis glacialis	Aleutian-coastal	G4G5	S3	16
Papaver alboroseum	Montane	G3G4	S4	46
Papaver gorodkovii	Arctic	G3	S2S3	13
Physaria calderi	Interior	G3G4	S2	10
Plagiobothrys orientalis	Aleutian-coastal	G3G4	S3	11
Pleuropogon sabinei	Arctic	G4G5	S1	11
Poa hartzii spp. alaskana	Arctic	G3G4T1T2	S1S2	8
Ranunculus pacificus	Aleutian-coastal	G3	S3S4	25
Romanzoffia unalaschensis	Aleutian-coastal	G3	S3S4	39
Rumex beringensis	Aleutian-coastal	G3	S3	23
Salix setchelliana	Montane	G4	S4	50
Saxifraga rivularis ssp. *arctolitoralis*	Arctic	G5T2T3	S2	9
Symphyotrichum pygmaeum	Arctic	G2G4	S2	9

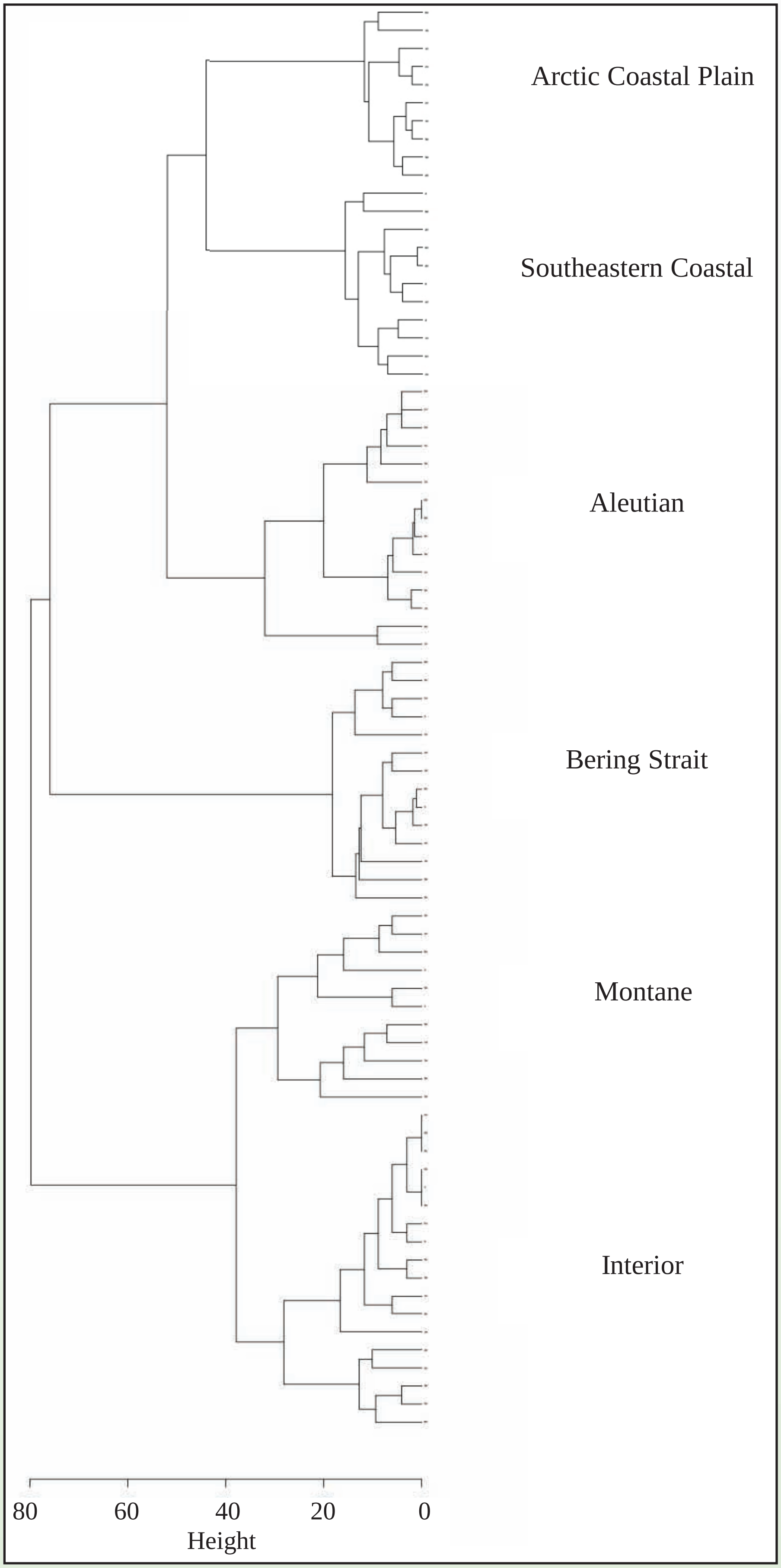
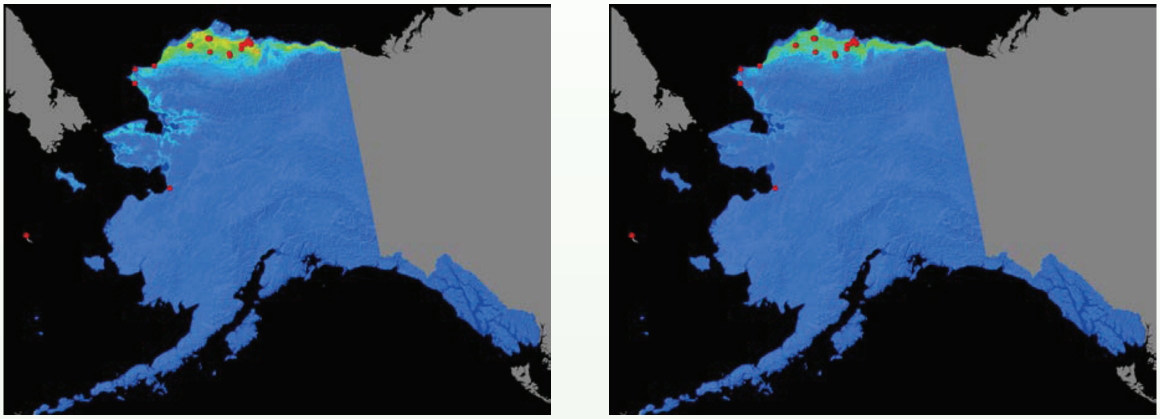


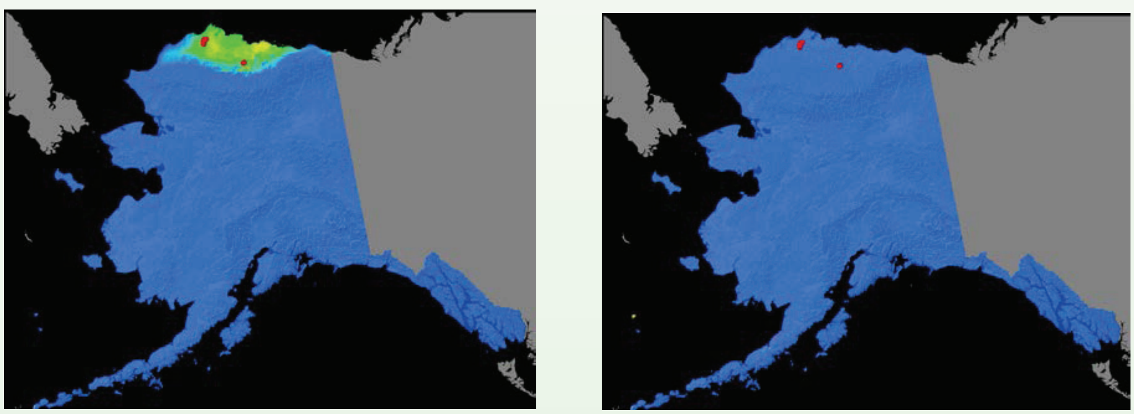
Figure 1. Hierarchical cluster analysis of 76 rare plant taxa occurring in more than one 1:250,000 mi² grid cells and ecoregions (Nowacki et al. 2001). Biogeographic groupings are indicated to the right of the boxes.

Figure 2. Current and future species habitat suitability for four biogeographic groups of rare species in Alaska (warm colors are used for pixels with potentially suitable habitat while cool colors indicate pixels or areas where the species is less likely to occur; the spectrum ranges from red to blue). Known occurrences are indicated as red dots.

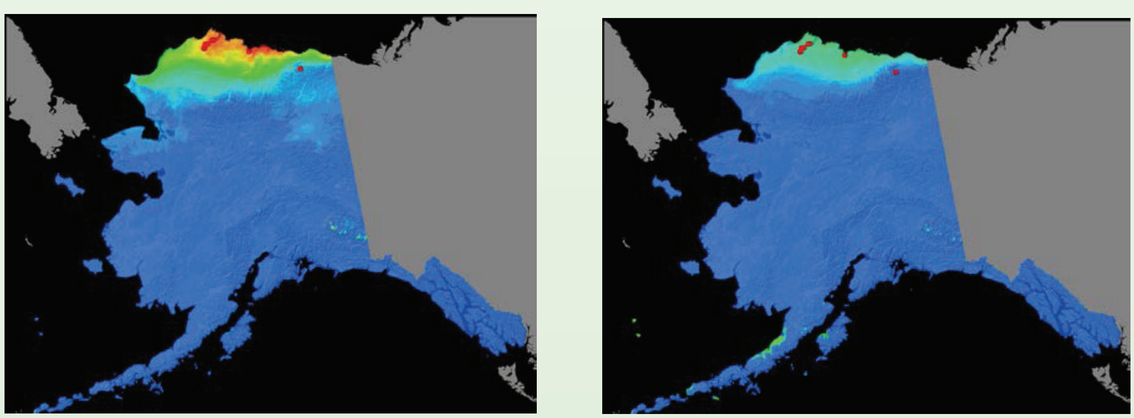
Arctic Coastal Plain species distributions



Present (2010) and future (2060) ecological niche models for *Koeleria asiatica*.

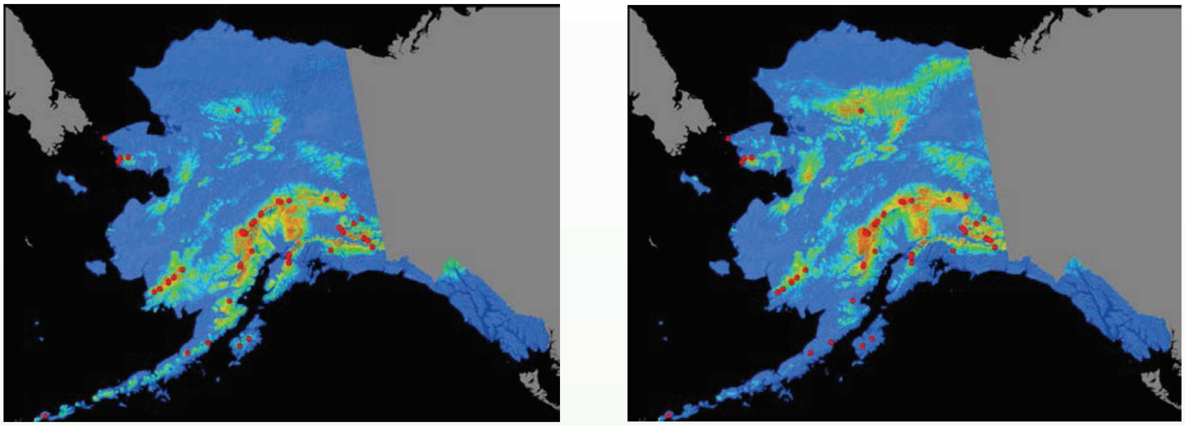


Present (2010) and future (2060) ecological niche models for *Mertensia drummondii*.

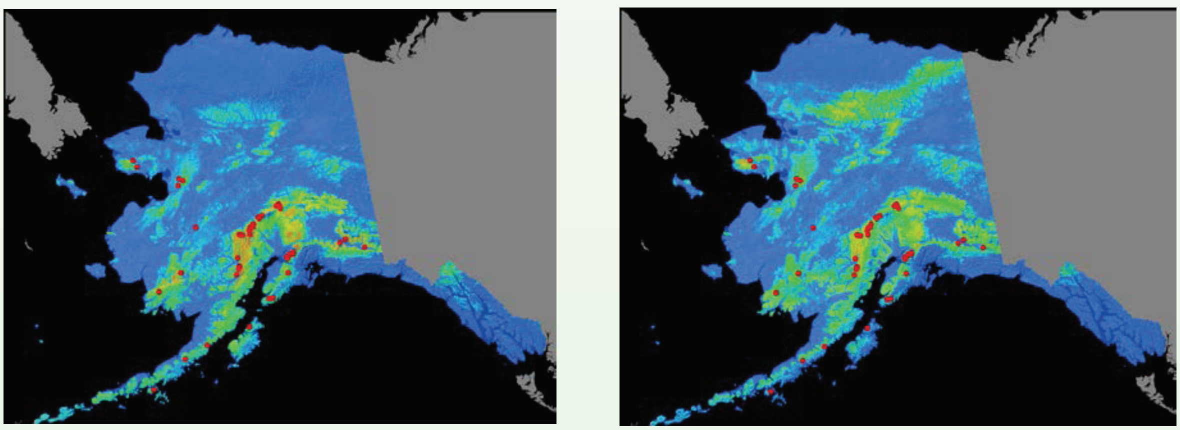


Present (2010) and future (2060) ecological niche models for *Poa hartzii* ssp. *alaskana*.

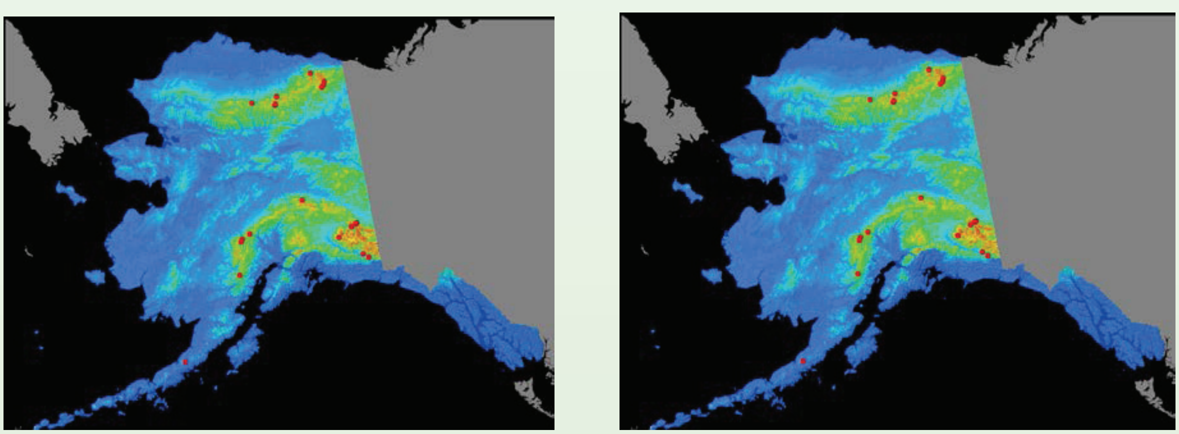
Montane species distributions



Present (2010) and future (2060) ecological niche models for *Aphragmus eschscholtzianus*.

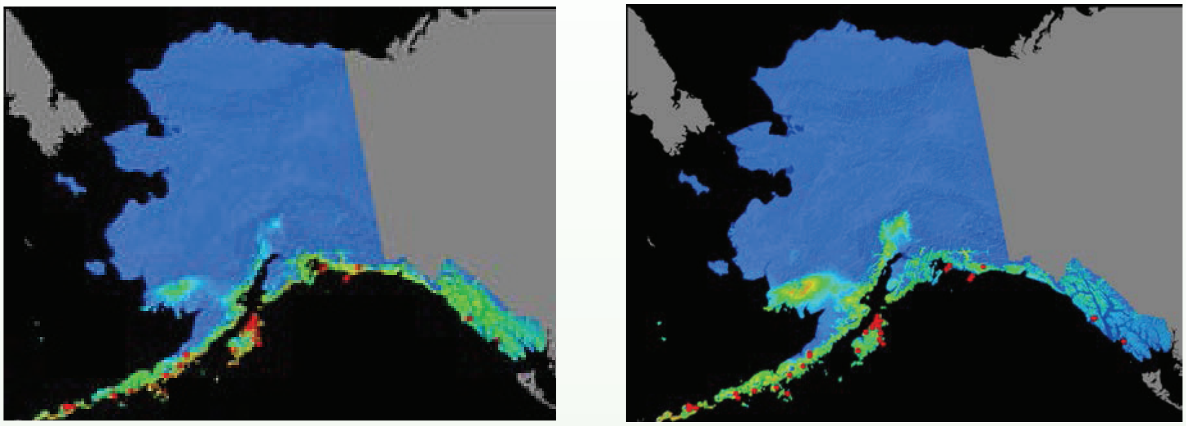


Present (2010) and future (2060) ecological niche models for *Douglasia alaskana*.

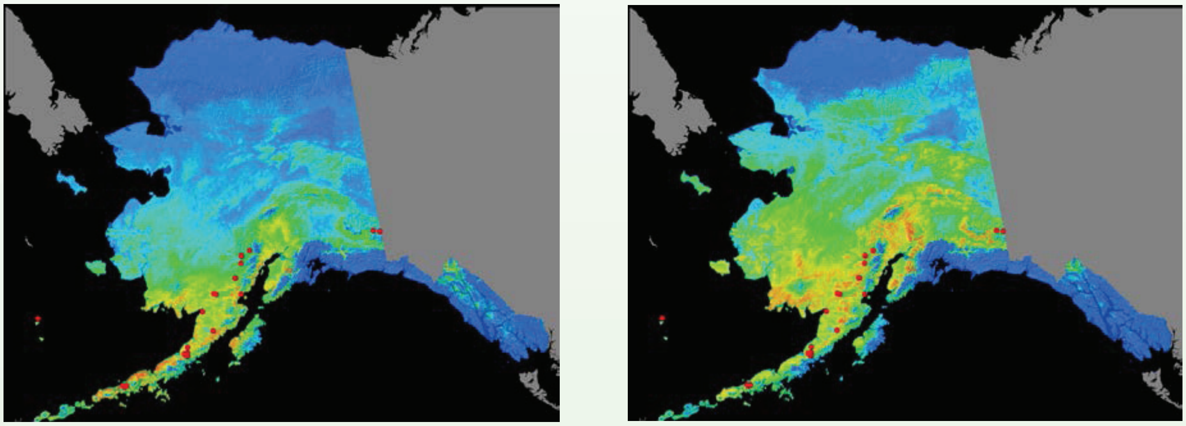


Present (2010) and future (2060) ecological niche models for *Draba macounii*.

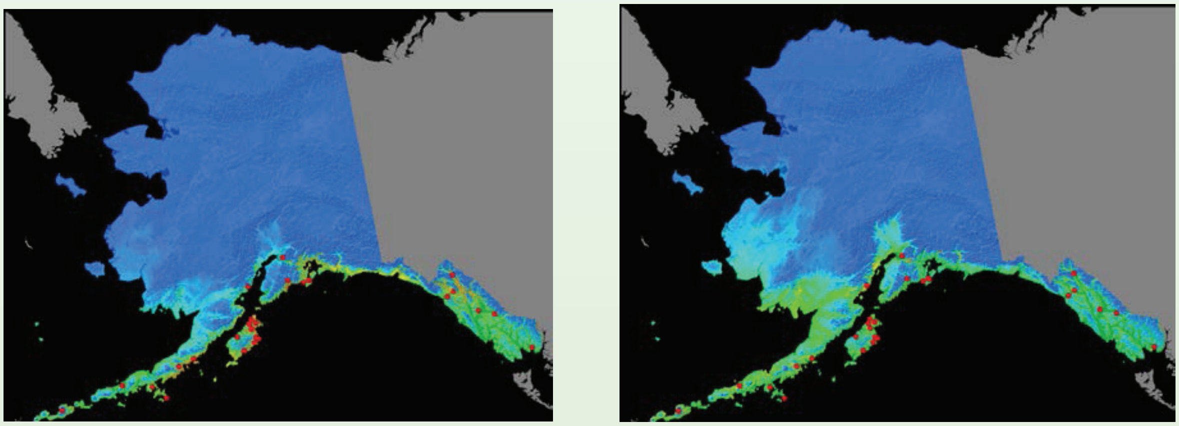
Aleutian-south coastal species distributions



Present (2010) and future (2060) ecological niche models for *Romanzoffia unalaschcensis*.

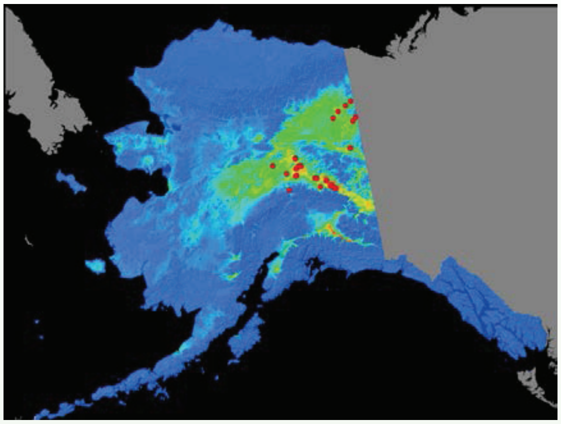
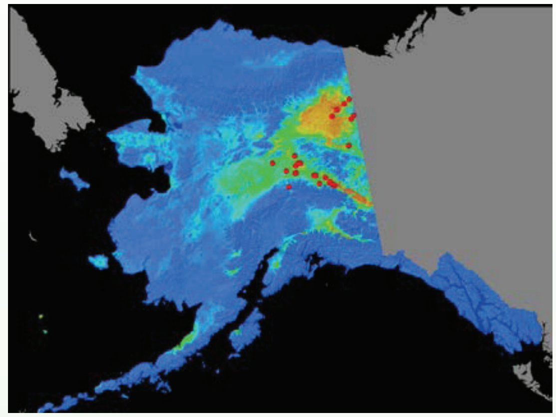


Present (2010) and future (2060) ecological niche models for *Rumex beringensis*.

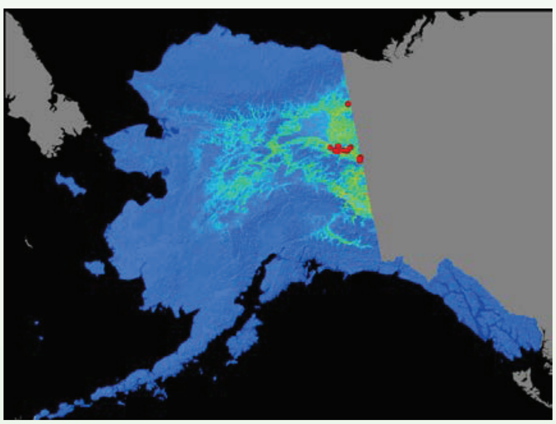
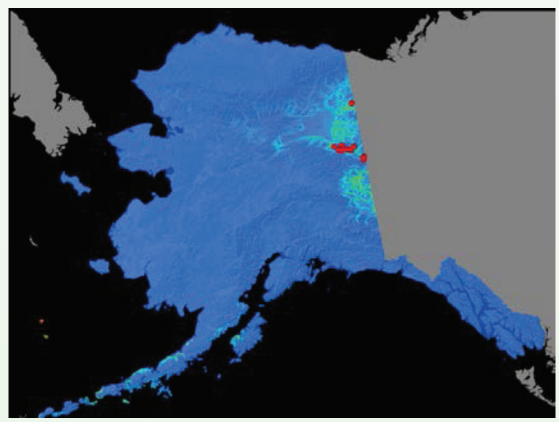


Present (2010) and future (2060) ecological niche models for *Atriplex gmelinii*.

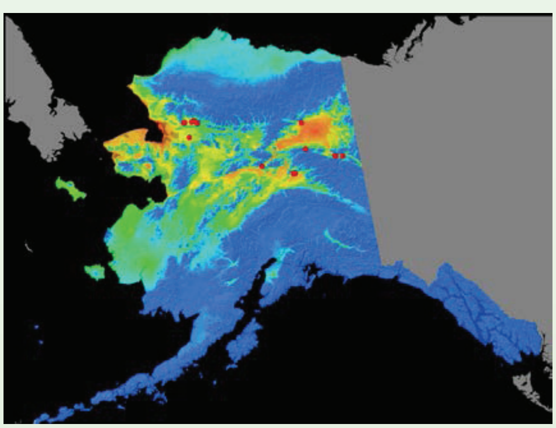
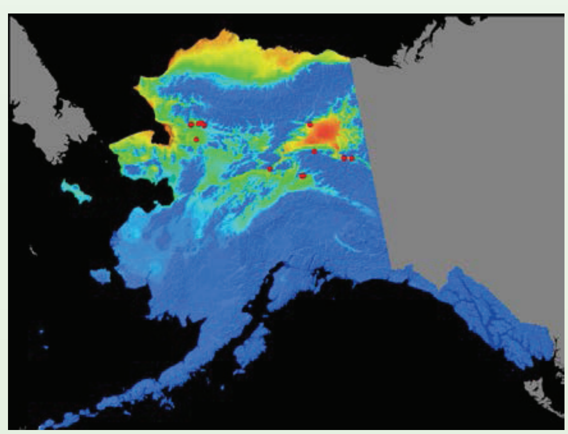
Interior species distributions

Present (2010) and future (2060) ecological niche models for *Artemisia tanacetifolia.*

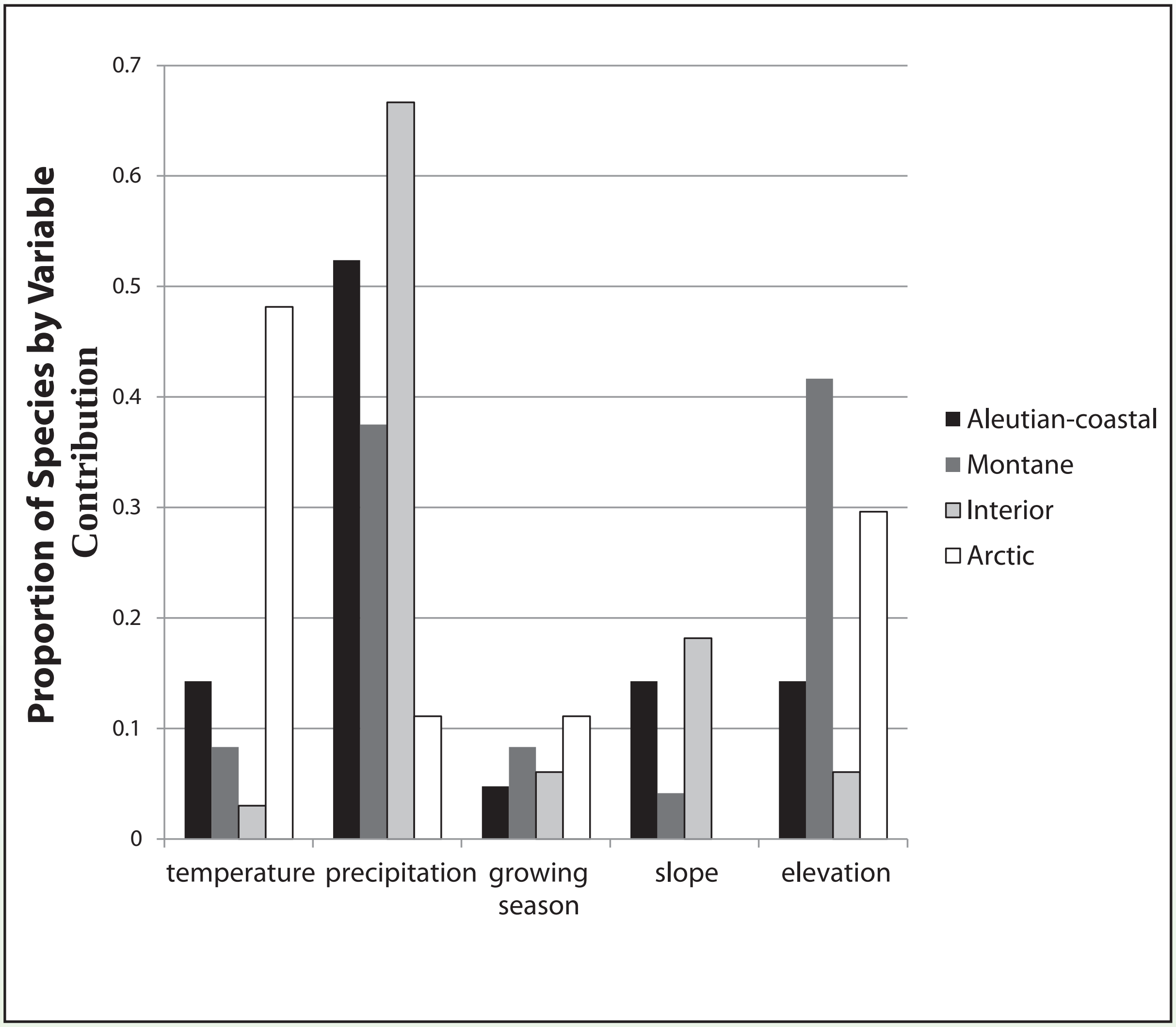



Present (2010) and future (2060) ecological niche models for *Erysimum asperum* var. *angustatum.*

Present (2010) and future (2060) ecological niche models for *Corispermum ochotense.*

Figure 3. Index of predictor variable contributions to species distribution models for four biogeographic groups. The Aleutian-south coastal association is abbreviated 'Aleutian-coastal' and the Arctic Coastal Plain is abbreviated 'Arctic'.



Cultural and Ecological Relationship between the Nisqually Indian Tribe and the Plants of Mount Rainier National Park

David Hooper[1]

ABSTRACT

Throughout the history of the National Park Service the question of whether Native American's still have rights to traditionally use natural resources found within park land has been debated. This debate is largely held in political, legal and philosophical arenas. But there are ethnographic and ecological questions that need to be addressed in order for policy makers to make informed decisions. One of the parks that have been addressing this issue is Mount Rainier National Park, which has been working with the Nisqually Tribe to develop a collecting agreement that would allow members of the tribe to harvest twelve species of plants. For my dissertation research I am asking two questions: first, how do members of the Nisqually tribe traditionally harvest these plants? This ethnographic research is being accomplished through interviews, surveys, and observations of harvesting practices. My other question is: what are the biological effects of harvesting beargrass (*Xerophyllum tenax* (Pursh) Nutt.) and pipsissewa (*Chimaphila umbellata* (R. BR.) Spreng,), and peeling bark of western redcedar (*Thuja plicata* Donn. Ex D. Don)? For each of these species I am using different methods to measure the impact of harvesting. The impact of beargrass harvesting is done by estimating percent ground cover. Pipsissewa measurements are frequency, percent cover, and density. I am comparing the secondary growth rate of peeled and unpeeled cedar trees. The results of this research will help Mount Rainier managers and the Nisqually Tribe to develop policy that allows the tribe to utilize these plants according to treaty rights while not interfering with the park's mission.

Keywords: Nisqually Tribe, Mount Rainier National Park, traditional plant harvesting

INTRODUCTION

In the 1830's the painter George Catlin proposed the idea of establishing national parks in the United States. The parks he envisioned were wilderness areas that would preserve the fauna, flora, and Native Americans in their natural state (Spence 1999). Even though the idea of forcing people to remain the same is culturally insensitive, it clearly shows the early concept of wilderness included some groups of humanity. The view of wilderness in the early nineteenth century was a landscape that contained abundant wildlife, deep soils, and thick forests that were also occupied by noble savages who were living in ecological harmony (Buege 1996, Krech 1999).

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As the West was explored and opened up to settlement areas were discovered of such scenic beauty people wanted to protect them from becoming over-developed, as happened in Niagara Falls, while still making profit from tourism (Sellars 1997). The establishment of Yellowstone National Park, in 1872, was based on these goals. As the first national park, Yellowstone set the majority of trends in managing future national parks including the policies concerning Native Americans (Spence 1999). The removal of Native Americans and the exclusion of their use in Yellowstone established the policies that were applied to all future national parks in the lower forty-eight states.

This policy is based on several ideas. First was the desire to force Native Americans to be assimilated into white society. The second was a changing view of wilderness as land where people are absent. The last idea was that wilderness areas with special features needed to be protected and developed for recreation.

The Organic Act of 1916 states that the purpose of the National Park Service (NPS), "is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The removal of native populations from parklands ended ecological relationships between these people and the biotic community. The ending of these ecological relationships have changed the landscapes that NPS is supposed to conserve. One example is Yosemite National Park, where the oak savannahs where created through centuries of anthropogenic burning, harvesting and seed dispersal. With the cessation of Miwok and Yokut Native Americans management systems, coniferous trees are invading these savannahs (Anderson 2005). '

Mount Rainier National Park's influence on Native Americans

Mount Rainier at an elevation of 14,411 feet is the largest active volcano in the Cascade Mountain range. The height and breadth of this mountain and its position near the west coast of North America have created plant communities unmatched in scale to the surrounding region. It is these plant communities, especially its extensive subalpine parkland habitats, that attracted Native Americans to the slopes of Mount Rainier. The subalpine parklands and the alpine meadows contained plants (e.g. beargrass (***Xerophyllum tenax***) and huckleberry (***Vaccinium*** spp.)) and animals (e.g. mountain goats (***Oreamnos americanus***) that represented unique resources not found at lower elevations (Burtchard 1998; Carpenter 1994; Smith 2006).

The Nisqually are one of several tribes that have historically used resources found on Mount Rainier (Carpenter 1994, Schmoe 1926a, Schmoe 1926b, Schmoe 1926c, Smith 2006). The uses of these resources declined with the decimation of Native populations following introduction of European diseases. Use decreased further with the creation of the Nisqually reservation in the mid-1800s and Mount Rainier National Park (MORA) in 1899 (Burtchard 1998, Carpenter 1994, Carpenter 2002). The collection of some plant resources, however, never ended (Carpenter 1994, Schmoe 1926b). Recognizing long-standing traditional use, Mount Rainier National Park and the Nisqually Indian Tribe entered into a formal Memorandum of Understanding in November, 1998, permitting the hand collection of 12 plant species from park lands. In 2001, MORA's authority to enter into plant collecting agreements of this sort was challenged by the environmental protection group Public Employees for Environmental Responsibility on the grounds that such an agreement is a violation of the Organic Act of 1916.

In order to develop policies that balance the NPS needs, as a federal agency, to fulfill treaty obligations that allow plant harvesting on park lands, and its primary mission of conservation, three questions need to be addressed. First, what is traditional plant harvesting? Second, how does harvesting affect the plants ecology? Third, if there are any ecological effects, do they contribute to how tribal members harvest in the future. By addressing these questions NPS and Native American tribes can develop policies that are community and species specific.

The data from my dissertation will be used by MORA and the Nisqually Tribe to establish collecting protocols and monitoring programs, so that the collecting agreement best meets the cultural needs of the Nisqually and the policy needs of the park. Also, the ethnobotanical information from my research will further the understanding of how Native people used the natural resources found growing in the subalpine and alpine biomes in the Cascades.

METHODS AND RESULTS

Documentation of Nisqually traditional plant collecting practices and methods

Since the 2007 season, I have documented traditional harvesting practices and methods by working with Nisqually harvesters to conduct ethnographic research through two semi-directive interviews. Along with the interviews I have had three experiences as participant observer, first in 2007 and again in 2010 and 2011, to record harvest practices and plant knowledge (Bernard 2006, Huntington 2000, Martin 1995, Schensul, et al. 1999). I was able to interview one person who is considered (by the Nisqually natural resource office) to be currently one of the most active plant harvesters in the community, in 2007 and again in 2008. For the 2007 interview a list of the plants from the collecting agreement was used to stimulate discussion about traditionally harvested plants. Answers to direct questions provided information on characteristics used to select sites and plants for harvesting. This interview was not recorded, which lead to the 2008 interview, when I asked more questions that were focused on beargrass, such as how it is used and what characteristics of an area indicate that it will be a good place to harvest.

Monitoring beargrass harvesting

Beargrass has traditionally been used in basketry for decoration and structural integrity (Carpenter 1994, Gunther 1973). According to the interviews and field observations, beargrass harvesting is accomplished by individuals who grab and pull up two to seven leaves at a time. The leaves are not from the center, which are the youngest, nor farthest from the center of the plant, which are the oldest, but they are located in between. Preferred harvesting is on top of ridges and hills. The harvesting of beargrass used to be a community and family activity, but the commercial harvesting has removed the easily reachable patches, so beargrass is now harvested in areas that elders and children cannot easily get to, except for MORA. In 2008 I was told that up to 15 leaves are removed from each stem. The number of leaves harvested depends on the size of the plant. The smallest plants are not harvested in hopes that in the next few years they may be the right size. Individual leaves are selected based on the width and color of the leaf's base. Leaves with wide bases are preferred over narrower leaves. White bases are better at taking dye then the leaves with purple bases; therefore white is the preferred choice. In clumps of beargrass the center stems are harvested.

From 2001 to 2003, MORA's plant ecologists monitored the impact of traditional harvesting of beargrass (Kurth 2001, Kurth 2002, Kurth 2003, Kurth 2004). The monitoring effort was designed to provide information regarding the hypothesis that harvesting had no short or long term adverse environmental effects. Monitoring was accomplished by establishing six 10m by 10m plots. Three of the plots served as un-harvested controls, and the others were used for harvesting. In each plot 25 samples are selected and estimations of percent ground cover of all species are recorded. The members of the Nisqually Tribe harvested plants in 2001, 2002, and 2003. The preliminary conclusion of Kurth's monitoring effort was that harvesting had no adverse effects on the plants, because the number of leaves harvested in each plot was so low (Kurth 2001, Kurth 2002, Kurth 2003). During the 2007 season I reestablished and measured the plots following the methods that Kurth's crews had used. Since then I have continued to monitor the plots.

Analyzing the data has shown two trends; the first is that both the control and harvested plots have increased in the amount of beargrass present (fig. 1). Second, I used a student's T-test to determine if there was difference in the amount of beargrass between the two treatments. The only year that there was a difference was 2003, where harvested plots were significantly larger than the control (2003 two tail T-test=.038, $P<0.05$). With this method of estimating percent ground cover, differences of 20% or more are needed before the conclusion can be made that a change in treatments is biologically significant even if it is statically significant (Coulloudon, et al. 1999, Elzinga, et al. 1998). Because the difference between the plots in 2003 is 9.44%, which is statically significant, I cannot say it is biologically significant.

Pipsissewa monitoring

Pipsissewa is a low-to-the-ground evergreen shrub (Biek 2000, Mathews 1999, Pojar, et al. 2004). There are two closely related species in the Ericacea with the common name pipsissewa, ***Chimaphila menziesii*** and ***C. umbellata***. ***C. umbellata*** is a circumpolar species while ***C. menziesii*** is endemic to the Pacific Northwest (Mathews 1999). In both species of pipsissewa the main method of reproduction is through rhizomes (Tilford 1997). During the 2010 harvest of pipsissewa none of the harvesters ever remember harvesting ***C. menziesii***.

The traditional uses of the ***C. umbellata*** are medicinal. The leaves and roots were used to treat kidney and urinary issues and colds (Mathews 1999, Moerman 1998). When discussing the use of devil's club, Gunther (1973) reports that the Skagit boiled devil's club root and bark with pipsissewa and cascara to treat tuberculosis. One of the harvesters talked about their great grandmother making two quarts per week, and she would drink the tea throughout the week for general health and as a pick-me-up. Based upon my observations, the Nisqually harvest pipsissewa by pulling the stems out of the ground but trying to avoid pulling the plant's rhizome, so a few centimeters of the rhizome, if any, are removed. Some of the less experienced harvesters were just pulling leaves, until a more experienced harvester explained that the stem and leaves were collected.

There are two hypotheses concerning the effect harvesting has on pipsissewa. First; there is no change in pipsissewa abundance, and second; there is a change in abundance. If harvesting does not change pipsissewa then there should be no change in percent ground cover, stem density and frequency of pipsissewa in harvested plots when compared to control plots. If the alternative hypothesis is correct then I would predict a decrease or increase in stem density, frequency and percent ground cover between harvested and control plots.

I established a control and a harvested plot, each 30m by 20m. Several of the Nisqually commented on the abundance of pipsissewa in the monitoring plot. They said that the areas that supplied pipsissewa on or near the reservation have been developed, and the plant is harder to find there. Monitoring occurred before the harvest. Between 2010 and 2011 the markers for the control plot where lost and the plot had to be reestablished. Within each plot are 120 samples. Each one-meter by one-meter sample has three quadrats: 25cm X 25m (1), 50cm X 50cm (2), and 1M X 1M (3). Frequency data were recorded by marking the presence of all species that occurred in the smallest quadrat, then the next two sizes up (Coulloudon, et al. 1999). The nested quadrat frames used to record the frequency have four tines coming to a point. I measured ground cover by recording what these tines touched when laid on the ground (Coulloudon, et al. 1999). Stem density was measured by counting the number of pipsissewa stems in the smallest quadrat.

In this paper I am not going to address the frequency analysis. Comparing harvested and control treatments between 2010 and 2011 indicates no effect of harvesting on pipsissewa. The exception is that there is a statistically significant increase ($p<0.05$) in pipsissewa between years in the control plot ($p=0.02$, $P<0.05$; table 1). This result is possibly caused by the slight shift of the control plot since its markers were lost between years.

Western redcedar bark harvesting

Western redcedar has been called the tree of life for the Native Americans of the Pacific Northwest (Stewart 1984). To a greater extent than other evergreens, every part of western redcedar has a material use. The wood was harvested for housing, storage containers, canoes, and ceremonial and religious items. The withes (the small branches) in many coastal areas were made into ropes for whaling, and all along the Northwest coast it was used for bindings. The roots where also used for binding and in basketry. The bark of redcedar was harvested for basketry, clothing, and cordage (Lepofsky 2004, Mobley and Eldridge. 1992, Stewart 1984).

The focus of my study is on peeling cedar bark. Several tribal members have expressed interest in collecting cedar bark for making baskets. The methods for cedar bark harvesting are constant along the Northwest coast (Mobley and Eldridge 1992, Stewart 1984). During the spring, when the sap was running at a greater rate, the harvesters would select a tree where the bark did not twist around the trunk, make a cut at waist height, and then pull on the cut bark until it tapered to a point. The point where the bark was still connected to the tree required some twisting and pulling to break. The harvesters removed a section of the bark so as not to kill the tree (Lepofsky and Lyons 2003, Mobley and Eldridge. 1992, Stewart 1984). The amount of bark the Nisqually remove is either a quarter of the circumference of trunk or two hands width depending on the size of the tree. Though harvesting bark should not kill the tree it may affect the tree's performance.

The approach I have used to understand how bark peeling affects western redcedar's overall performance is to measure the secondary growth of the tree. Secondary growth is the process by which trees increase their girth. Bark peeling limits phloem transport, the movement of the sugars and other products from photosynthesis, which are used throughout the plant for metabolism. It also affects water transport by breaking the pressure required to maintain water flow from the roots to the leaves, through the sap wood that makes up the scar face, another factor that could influence secondary growth and reduce photosynthetic rates (Salisbury and Ross 1992). Either of these processes have the potential to reduce secondary growth.

By repeated measurements of the diameter of peeled and unpeeled trees throughout the year, I was able to see if bark removal affects secondary growth. If secondary growth is affected by bark harvesting, then the rate of change in girth would be different between peeled and unpeeled trees. Dendrometer bands were installed for the duration of the study to limit the error caused by using DBH tape (Cattelino, et al. 1986, Keeland and Young 2007). A dendrometer band is a stainless steel tape that is wrapped around the tree, so that the ends overlap. A collar is placed around the overlap which allows the ends to slide past each other. The band is held together with a stainless spring. At the start of the study, a mark is placed next to the collar. As the tree increases in girth, the spring allows the band to expand, pulling the mark away from the collar. By measuring the distance of the mark from the collar, it is possible to document the tree's growth rate (Cattelino, et al. 1986, Keeland and Young 2007).

In the last five years eight western redcedar trees have been peeled. These trees were paired with eight unpeeled trees of similar size. I took five measurements between July 29 and November 7, 2011. Peeled trees average growth rate was 0.015 mm/day, and 0.009 mm/day for the controlled trees (fig. 2). A two tailed paired t-test indicates that there is a significant difference between the two treatments ($p=0.025$, $p<0.05$).

DISCUSSION

For some members of the Nisqually tribe their approach to harvesting is a product of their knowledge about the target species' natural history, a belief that their use is not detrimental to the plants and a desire to strength their cultural identity as Nisqually through traditional practices. So far, the metrics I have measured reinforces their claim that harvesting does not reduce beargrass and pipsissewa abundance. If harvesting intensity increases it is unclear whether there will still be no measurable impact on these two species.

Future research is needed to address the mechanisms underlying the lack of impact from harvesting. One possibility is that the beargrass and pipsissewa have a high tolerance to damage caused by herbivory, including human harvesting. The other possibility is that from centuries of interactions between the Nisqually and these plants, sustainable approaches to gathering these species have developed. Traditionally the time to visit Mount Rainier was restricted to a few months of late summer and early fall (Smith 2006). This activity was further reduced by the need to participate in other tasks, for example, fishing fall salmon runs. Having known locations where abundance is high would have been desirable when dealing with time limitations. Therefore, practices that minimized decreases in plant populations could have been desirable.

I am not confident that peeled western redcedar trees are growing faster than unpeeled trees as indicated by my analysis, because the difference seems so small and so little time has passed since start of this study that the dendrometer bands may not have settled (Cattelino, et al. 1986). To address these concerns I am taking measurements throughout 2011 and 2012 and am going to take cores from the trees in the study to measure growth rates from tree ring widths. Making the study longer and comparing the dendrometer growth rates to rates determined by tree ring data should clarify how peeling bark affects secondary growth.

My results indicate that under the current conditions, harvesting beargrass and pipsissewa could continue without infringing on MORA's primary mission. If conditions were to change, then an understanding of the biological and cultural mechanisms that shape the current relationships between the Nisqually and these plants would be needed to develop a policy that could address future changes. Besides studies such as this one, there is a need to maintain open and honest dialogue between national parks, local tribal governments, and environmental groups if culturally important practices such as plant harvesting and plant conservation are to coexist.

ACKNOWLEDGMENTS

I need to express my gratitude to the Nisqually Tribe and Mount Rainier National Park in allowing me to conduct this research, the plant harvesters for sharing their knowledge, and MORA's vegetation branch for volunteering to help collect beargrass data.

REFERENCES

Anderson, M. K. 2005. Tending the wild: Native American knowledge and the management of California's natural resources. University of California Press. 526 p.

Bernard, H. R. 2006. Research methods in anthropology: qualitative and quantitative approaches. AltaMira Press. Oxford. 803 p.

Biek, D. 2000. Flora of Mount Rainier National Park. . Oregon State University Press. 506 p.

Buege, D. J. 1996. The ecologically noble savage revisited. Enviromental Ethics. 18: 71-88. p.

Burtchard, G. C. 1998. Environment, prehistory, and archaeology of Mount Rainier National Park, Washington. International Archaeological Research Institute, Inc. Honolulu, HI. p.

Carpenter, C. S. 1994. Where the waters begin: the traditional Nisqually Indian history of Mount Rainier. Northwest Interpretive Association. Seattle, WA. 108 p.

Carpenter, C. S. 2002. The Nisqually, my people: the traditional and transitional history of the Nisqually Indian people. Tahoma Research Service. Tacoma, Wash. 280 p.

Cattelino, P. J., Becker, C. A. and Leslie G. Fuller. 1986. Construction and Installation of Homemade Dendrometer Bands. Northern Journal of Applied Forestry. 3: 73-75. p.

Coulloudon, B., Eshelman, K., Gianola, J., Habich, N., Hughes, L., Johnson, C., Pellant, M., Podborny, P., Rasmussen, A., Robles, B., Shaver, P., Spehar, J. and Willoughby, J. 1999. Sampling Vegetation Attributes: Interagency Technical Reference. Bureau of Land Management's National Applied Resource Sciences Center. Denver, CO. 163 p.

Elzinga, C. L., Salzer, D. W. and Willoughby, J. W. 1998. Measuring & monitoring plant populations. Bureau of Land Management. Denver, CO. 477 p.

Gunther, E. J. J. R. 1973. Ethnobotany of western Washington : the knowledge and use of Indigenous plants by Native Americans. London. Seattle. 71 p.

Huntington, H. P. 2000. Using traditional ecological knowledge in science: Methods and applications. Ecological Applications. 10: 1270-1274. p.

Keeland, B. D. and Young, P. J. 2007. Construction and installation of dendrometer bands for periodic tree-growth measurements. http://www.nwrc.usgs.gov/Dendrometer/index.htm.

Krech, S. 1999. The ecological Indian: myth and history. W.W. Norton & Co. New York. 318 p.

Kurth, L. 2001. Native American gathering study in Mount Rainer National Park Plant Ecology Program final report. NPS. Ashford, WA. 16-17 p.

Kurth, L. 2002. Native American gathering study in Mount Rainer National Park Plant Ecology Program final report. NPS. Ashford, WA. 13 p.

Kurth, L. 2003. Native American gathering study in Mount Rainer National Park Plant Ecology Program final report. NPS. Ashford, WA. 8-9 p.

Kurth, L. 2004. Native American gathering study in Mount Rainer National Park Plant Ecology Program final report. NPS. Ashford, WA. 11 p.

Lepofsky, D. 2004. Peleoethnobotany in the Northwest. In: People and plants in ancient Western North America Washington, Smithsonian Institution Press. Washington. 367-464 p.

Lepofsky, D. and Lyons, N. 2003. Modeling ancient plant use on the Northwest Coast: towards an understanding of mobility and sedentism. Journal of Archaeological Science. 30: 1357. p.

Martin, G. J. 1995. Anthropology. In: Ethnobotany Chapman & Hall. London. 95-135 p.

Mathews, D. 1999. Cascade-Olympic natural history: a trailside reference. Raven Editions. Portland, Or. 623 p.

Mobley, C. M. and Eldridge., M. 1992. Culturally modified trees in the Pacific Northwest. Arctic Anthropology. 29: 91-110. p.

Moerman, D. E. 1998. Native American ethnobotany. Timber Press. Portland, Or. 927 p.

Pojar, J., Mackinnon, A. and Alaback, P. B. 2004. Plants of the Pacific Northwest coast : Washington, Oregon, British Columbia & Alaska. Lone Pine Pub. Vancouver. 528 p.

Salisbury, F. B. and Ross, C. W. 1992. Plant physiology. Wadsworth Pub. Co. Belmont, Calif. 682 p.

Schensul, S. L., Schensul, J. J. and Lecompte, M. D. 1999. Essential ethnographic methods: observations, interviews, and questionnaires. AltaMira Press. Walnut Creek, Calif. 318 p.

Schmoe,F . W. 1926a. Indians of Rainier. Mount Rainer Nature News Notes. 3: 1-2. p.

Schmoe,F . W. 1926b. Indians still visit park. Mount Rainer Nature News Notes. 3: 2-3. p.

Schmoe,F . W. 1926c. Two distinct types of people. Mount Rainer Nature News Notes. 3: 2-3. p.

Sellars, R. W. 1997. Preserving nature in the national parks : a history. Yale University Press. New Haven. 380 p.

Smith, A. H. 2006. Takhoma: ethnography of Mount Rainier National Park. Washington State University Press. Pullman, WA. 182 p.

Spence, M. D. 1999. Dispossessing the wilderness : Indian removal and the making of the national parks. Oxford University Press. 179 p.

Stewart, H. 1984. Cedar: tree of life to the Northwest Coast Indians. Douglas & McIntyre; University of Washington Press. Vancouver, B.C; Seattle. 192 p.

Tilford, G. L. 1997. Edible and medicinal plants of the West. Mountain Press Pub. Missoula, Mont. 239 p.

Table 1. Average pipsissewa stem density and percent cover. The percent cover of pipsissewa in the control plot significantly increased between 2010 and 2011. All of the other measurements show no significant difference.

	2010	2011	Paired T-test
Control stem density (#/m^2)	25.3	25.1	0.48
Harvested stem density (#/m^2)	26.2	29.3	0.21
Control percent cover	6.09	10.63	0.023
Harvested percent cover	8.95	10.21	0.40

Figure 1. Mean percent ground cover of beargrass. Members of the Nisqually Tribe harvested in 2001, 2002, 2003, 2010 and 2011. Overall there is no significant difference between the control and harvest plots. 2003 is the only year where there is a large difference between the control and harvested plots.

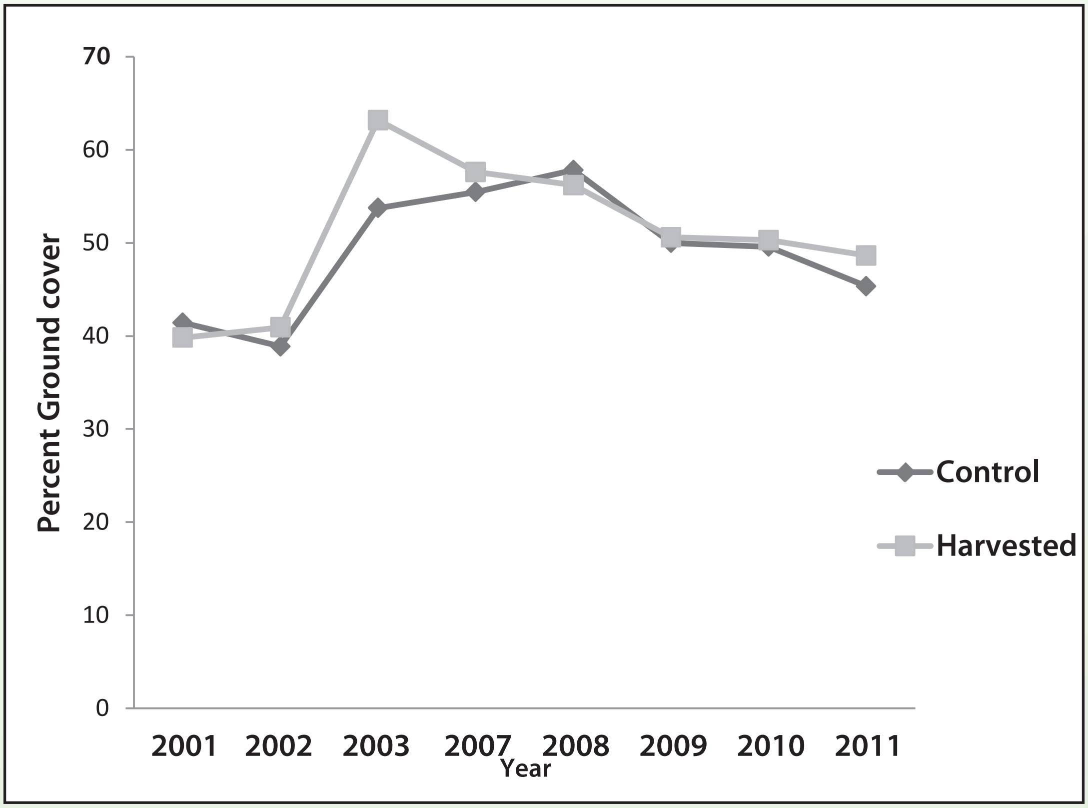
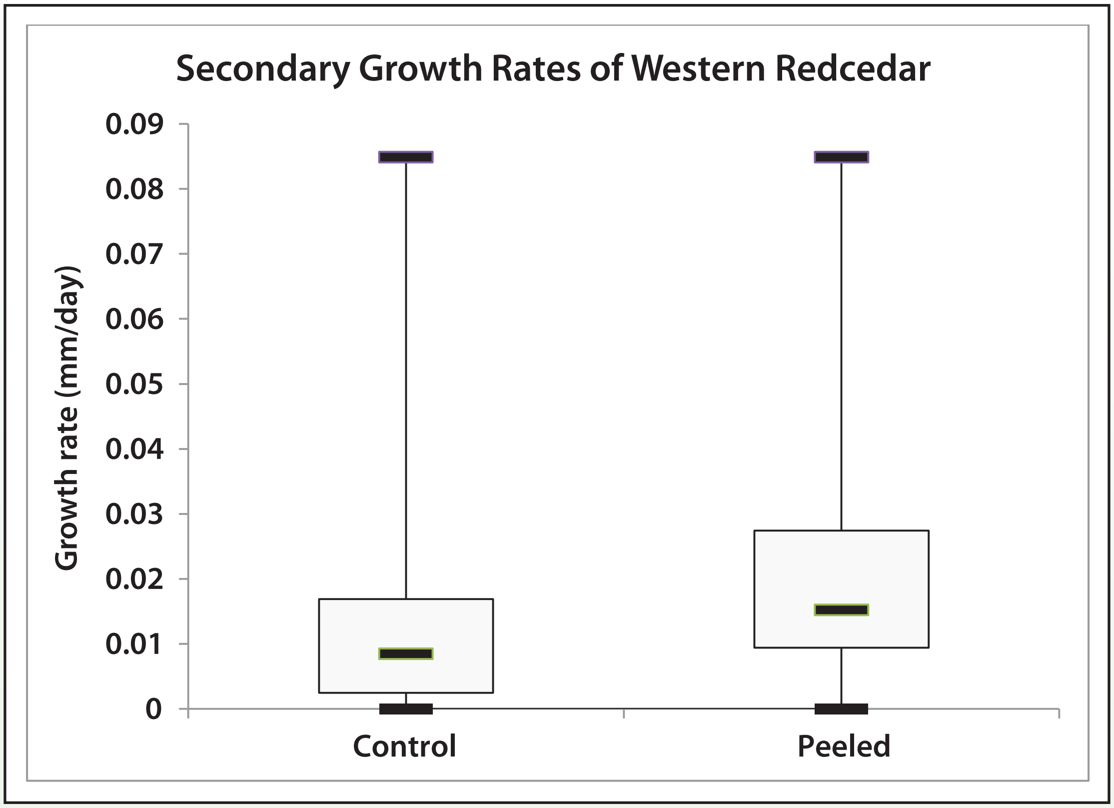


Figure 2. Growth rate (mm/day) of peeled and controlled western redcedar. Statistically, peeled trees are growing significantly faster than control trees ($p<0.05$).



Restoring Biodiversity In The Shrub-Steppe And Strategies To Increase Regulatory Recognition Of Tribally Significant Species

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ABSTRACT

Restoring full biodiversity to disturbed areas in semi-arid shrub-steppe is difficult. Because many species have ethnobotanical uses, reestablishing diverse plant communities is an important goal. We planted and seeded multiple species in disturbed areas in mid-elevation silt loam and in high elevation lithosol at the USDOE Hanford Site (Fitzner-Eberhardt Arid Lands Ecology Reserve) to increase biodiversity. We collected seed of 30 species for greenhouse germination and 31 species for field seeding tests. In the greenhouse, maximal germination was 78.4 percent for *Nestotus stenophyllus* with no germination for five species. Initial monitoring results showed that of 11 species seeded in silt loam, establishment ranged from zero percent for *Calochortus macrocarpus* to 5.4 percent for *Chaenactis douglasii*. Establishment of Washington state sensitive *Erigeron piperianus* was 0.085 percent. In lithosols, 16 species were seeded with establishment ranging from zero percent for 13 species to 0.67 percent for state watch-list Balsamorhiza rosea. In silt loam, seedlings of six species were planted with survivorship ranging from 31 percent for *Achnatherum thurberianum* to 92 percent for *Lupinus leucophyllus*. Survivorship of planted *Erigeron piperianus* seedlings was 90 percent. In lithosols, 14 species were planted with survivorship ranging from zero percent for three species to 44 percent for *Balsamorhiza rosea* seedlings and 87 percent for *Salvia dorrii*. Restoring high biodiversity to disturbed sites appears feasible, but species were highly variable in establishment and survival. Planting seedlings was more successful than seeding species. Using this information, restoration strategies can be optimized for success and for tribal importance.

Keywords: Plant biodiversity, plant reestablishment, shrub-steppe, tribally significant species

INTRODUCTION

Restoration of disturbed habitats to a condition similar to that of undisturbed habitat is difficult and can be limited by the availability of an appropriate seed mix (Pywell et al. 2002).

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With appropriate seed, Pywell et al. (2002) found that sowing a species-rich seed mixture representative of undisturbed habitats into disturbed areas in British arable lands resulted in a high degree of similarity with undisturbed habitats after four years. Community assembly by natural colonization was slow, unreliable, and was not enhanced by sowing species-poor grass-dominated seed (Pywell et al. 2002).

Lack of appropriate seed is a common limitation in ecological restoration. Lack of adequate seed is a characteristic of restoration at the Hanford Site in south-central Washington (Lindsey and Johnson 2010). Lindsey and Johnson (2010) report that in 33 sites restored since 2006 only eight grass species were seeded and three shrubs planted, which is very low compared with 55 native species observed at the same sites. In an effort to increase the number of tribally significant species, for the peoples of the Plateau Culture in the Columbia Basin, that can be used for restoration at Hanford we investigated the success of high species richness seeding and planted seedlings in disturbances. These disturbances were on silt loam and lithosol (weathered bedrock at the surface with silts in cracks and a discontinuous thin layer on the surface) soils at Hanford.

The objective of the study was to compare and order the species by percent survival of planted seedlings and the percent establishment of seeded species. This ranking allows us to evaluate relative success of each species and also will allow us to prioritize research efforts to improve percent survival of planted seedlings and/or percent establishment of seeded species. Species that have high success can be integrated into restoration plans after appropriate seed increase and/or greenhouse propagation. Further research can be done on species that have low success. We compare the percent survival of planted seedlings and the percent establishment of seeded species in each soil type and compare responses between soil types. These tests were done in two habitats: deep silt loam soil at 377 m.a.s.l and lithosol at 1092 m.a.s.l.

Finally, we present the tribal uses of the species used in the study with the purpose of increasing attention to these species as is done in state natural heritage programs for all sensitive native species. Tribal uses have been reviewed by many authors (e.g. Moerman 1998). Conserving and increasing the presence of tribally significant species in the landscape is inherently valuable. Another value of increasing the species richness of restoration plantings is increasing invasive species resistance (Tilman 1997).

These experiments were conducted on the Fitzner-Eberhardt Arid Lands Ecology Reserve in areas affected by decommissioning of buildings, infrastructure, and debris removal actions. We propagated 2600 selected native forb, grass, and shrub plants of 20 species in a greenhouse and applied seed of 27 species.

METHODS

Study area

The study areas are on the Fitzner-Eberhardt Arid Lands Ecology Reserve of the Hanford National Monument in south-central Washington. The average annual precipitation is 16 cm, occurring mostly in the autumn and winter (Stone et al. 1983). Soils are classified (Hajek 1966) as a Ritzville Silt Loam more than 1-m deep at the lower site (46° 23’30.66”N, 119° 32’12.19”W, 377 m.a.s.l.) and a Lickskillet Silt Loam Lithosol at the upper site (46° 23’42.26”N, 119° 35’45.15”W, 1092 m.a.s.l.).

Seed collection and processing

Seed were collected by hand in and near the restoration areas from 2005 through the summer of 2010. Seeds were placed in paper bags and stored at room temperature, dry, and in the dark until cleaned. Seeds that were being predated by insects or that may be predated were frozen before cleaning. Seed cleaning was done by hand separating debris from the seed. This was done using screens, tools to rub the flower heads and seed against the screens, fans, and tweezers.

Plant propagation

Twenty-six hundred seedlings were grown for planting in the late winter and early spring of 2011. Plants were grown in a climate-controlled glasshouse. Lighting was supplemented with 1000W metal halide grow lights. Seeds were sown in 164 ml Ray Leach Cone-tainer cells that were filled with a mixture of 46.1 percent potting soil with slow release fertilizer (Miracle Grow potting mix), 46.1 percent sand, 3.8 percent perlite, and 3.8 percent vermiculite. Seeds were sown between November 2, 2010 and January 31, 2011. Tubes filled with wetted soil were planted with seeds just below the surface. The number of seeds planted in each pot ranged from one to ten depending on the species and the amount of available seed. Each 98-cell rack was an experimental unit. There was one species in each experimental unit. The number of replicates or experimental units ranged from one to 10. Germinated seeds were counted in each experimental unit. The number of days until maximal germination was attained in each experimental unit ranged from 8 to 106 days depending on the species. Irrigation was automated with frequency and amount changed during the growth period to optimize germination and growth. Irrigation was more frequent during seed germination and less frequent during growth. Plants were further fertilized using Scott Miracle-Gro Nursery Select (20N-20P-20K). Fertilizer was dissolved as 10 ml solid in 7.6 l water and applied by pouring over about 800 cells. Fertilizer was applied four times from December 22, 2010 to January 27, 2011.

Plant installation and seeding

Plant installation occurred from March 7 to April 7, 2011 proceeding from low to high elevation. Six plots were established at low elevation and nine at high elevation. Plots were circular with a radius of five meters. Each plot was marked at the center with a numbered aluminum tag wired around a spike or rebar that was driven into the ground. Planting was done with dibbles and hand tools in the softer soils at the low elevation site. Planting was done with pry bars and dibbles in the lithosols at the high elevation site. The dibble was 91 cm long, the planting blade was 30 cm long, and the width of the planting was 7.6 cm. Plants were well watered just before installation. Planting was done by separating the seedling from the pot, immediately placing the seedling in the hole, and packing soil into the hole. Separation of the soil and plant from the pot was done by tapping on the top of the plastic tube. Care was taken to place the entire root system linearly in the hole without turning root tips up. Soils were packed around the seedlings to eliminate air pockets near roots. The upper soil surface of seedlings in tubes was placed a few millimeters below the surface of site soil upon planting and covered with site soil. In the lithosol, rocks were used to create a protected space for the seedlings. Rocks were circled around the plant especially on the upwind side of the seedling. Soils were wet throughout the planting profile. Plants were not given supplemental water. One hundred and fourteen plants were installed in each low elevation plot and 119 to 142 plants were installed in each of the high elevation plots.

Seeding occurred from January 19 through February 11, 2011 proceeding from low to high elevation sites. Seventeen plots were established at low elevation sites and nineteen at high elevation. Plots were circles with varying radii. Plots at low elevation had radii ranging from 1.96 to 2.6 m depending on the number of seeds (7400 to 9890) sown into the plot. Plots at higher elevation had radii ranging from 1.39 to 0.544 m depending on the number of seeds (450 to 750) sown into the plot. Each plot was marked at the center with a numbered aluminum tag wired around a spike or rebar that was driven into the ground. Seeding was done by roughing the surface with shoes, hand broadcasting the seed, covering the seed with soil, and walking on the surface to push in the seed.

Monitoring

Field monitoring occurred between June 17 and July 14, 2011. In each planted plot all live individuals of all planted species were counted. In the seeded plots all live seedlings of seeded species were counted. Enumeration was facilitated by partitioning plots into small sections.

Tribal uses review

We conducted an extensive review of the uses of Hanford flora by Native Americans. This was done by searching the Internet using Google and by reviewing 49 books (citations available upon request).

Data analysis

Percent germination in the greenhouse was computed by dividing the number of live seedlings by the number of seeds sown and multiplying by 100. Survivorship in the field was determined by counting the number of live seedlings within each plot and computing percent survival based the number of individuals planted in each plot. Percent establishment for seeded species was determined by dividing the observed number of individuals of each species by the number of seed applied. Percent data (covering a wide range of values) for survivorship were transformed (normalized) by

$$arcSin\sqrt{\frac{percent}{100}} \quad (1)$$

and percent data (small values) for establishment were transformed by

$$\sqrt{percent+0.5} \quad (2)$$

before statistical analysis (Steele and Torrie 1960). Data were analyzed using JMP software (SAS Institute 2002). Percent data are presented using untransformed data with error bars based on untransformed data for interpretation. Multiple range comparisons were done using the Tukey-Kramer HSD test. Error terms are one standard error of the mean. Statistical significance is set at $\alpha = 0.05$.

RESULTS

Percent germination ranged from zero for five species to 78 for two species (Table 1). Based on the mean maximal germination values in table one, mean maximal germination for all species was 24 ± 4.5 percent.

Percent survival of *Achnatherum thurberianum* seedlings in the silt plots was significantly lower than that of the other five species (Fig. 1). Percent survival of *Astragalus caricinus* was significantly lower than for *Lupinus leucophyllus*. There were no differences among the other three species (Fig. 1).

There was no establishment from seed of *Calochortus macrocarpus* or *Erigeron filifolius* in the silt soils (Fig. 1). Small numbers of *Erigeron piperianus, Ericameria nauseosa*, and *Crepis atribarba* established, but means were not significantly different from zero. Percent establishment of *E. nauseosa, C. atribarba*, and *Helianthus cusickii* were not significantly different. Percent establishment of *H. cusickii, Astragalus succumbens*, and *L. leucophyllus* were not significantly different. Percent establishment of *A. succumbens, L. leucophyllus,* and *Machaeranthera canescens* were not significantly different. Percent establishment of *L. leucophyllus, M. canescens,* and *Chaenactis douglasii* were not significantly different. No conclusions can be drawn for *A. caricinus* (Fig. 1).

In lithosol, mean percent survival of three species was zero and *Phemeranthus spinescens* survival was 6.7%, but the differences among these four species were not significant (Fig. 2). The mean percent survival of the remaining species was above 40 percent and did not differ significantly among these species (Fig. 2).

There was no establishment from seed for 13 of 16 species (Fig. 2). Only *Astragalus purshii, Salvia dorrii,* and *B. rosea* established from seed, but at very low rates that were not significantly different from zero (Fig. 2).

Responses in silt and lithosol were compared by lumping species in each plot. Percent survival of planted seedlings in silt (73 ± 2.0) was significantly ($p = 0.0009$) greater than in lithosol (51 ± 3.5). Percent establishment from seed in silt (1.7 ± 0.23) was significantly ($p < 0.0001$) greater than in lithosol (0.045 ± 0.023), which was not significantly different from zero. Survival of planted seedlings was much greater than establishment from seed in both soil types.

Thirty-four of the 39 native species (Table 1) used in this study are used by tribes with 76 percent being used for food, 38 percent for fiber, 91 percent for medicine, and 18 percent for dye. Seventy-four percent of species used by tribes are used for more than one purpose (Table 1).

DISCUSSION

The survival of the planted seedlings was significantly higher at the low elevation silt site than at the high elevation lithosol site. The high elevation site has very high wind speeds (Stone et al. 1983), which may account for some of the losses. While we did surround the seedlings at the upper site with rocks the seedlings were still subjected to severe wind speeds that may have desiccated some of the seedlings. We observed a coarse ordering of the species by percent survival at the two elevations. The high variability of percent survival does not allow us to distinguish differences in survival among many of the species. We anticipate that as percent survival declines some species will become significantly different from others. We have noted declines in survival at another other shrub-steppe site and a more defined ordering of survival after three years (Link et al. 2011).

Seedling emergence in the shrub-steppe is often low (Pyke 1990) and was only 2 percent in a variety of soil surface conditions in Wyoming (Chambers 2000). A test of high diversity seeding with native species on a decommissioned roadbed in Montana failed because many species did not establish from seed (Grant et al. 2011). Grant et al. (2011) suggest that lack of endomycorrhizae after soil disturbance and low seed viability may contribute to the lack of establishment. While it is recognized that low germination rates and slow establishment are typical characteristics of native perennial plants (Schartz and Janke 1999) we did observe significantly greater establishment from seed in the silt loam soil than in the high elevation lithosol. The primary differences between our two sites were the elevation, rocky substrate, and wind speed. The high winds at the high elevation site may have blown away shallow planted seed, desiccated the upper soil surface preventing germination, or desiccated many germinated seedlings. The lower site is not subjected to such severe winds.

Many of the tribally significant species used in this study survived or established at varying levels. A number of tribally significant species failed including the two *Lomatium* species, *Tetradymia canescens, Phoenicaulis cheiranthoides, Calochortus macrocarpus,* and *Leymus cinereus*. The *Lomatium* species and *Calochortus* require a physiological cold stratification (Tilley et al. 2012, Blanke and Woodruff 2011) that we did not attempt. The seed of *T. canescens* were not filled and failed. Seed of *L. cinereus* did not germinate even though it does not need pretreatment and germination starts after seven days (Skinner 2005). There were many other tribally significant species that we were not able to investigate because we had not collected the seed. A strategy to increase recognition of tribally significant species may increase the attention that many other species will need to determine efficient propagation and re-establishment methods. Such increased knowledge for the full array of native species will be useful in attempts to re-establish highly diverse plant populations in disturbed ecosystems. Increasing recognition may be promoted by creating a tribal regulatory structure similar to a state natural heritage program that provides a ranking and status for tribally significant species.

In conclusion, we were able to establish a high diversity of native species after disturbance. Planting seedlings was much more successful than seeding after a few months. We will continue monitoring to determine the long-term success of these restoration efforts and anticipate that we will recognize those species that are likely to sustain themselves and those species that may require more investigation to improve success. Increasing the recognition of tribally significant species may result in more research to improve restoration success and efforts to re-establish tribal sensitive species at risk.

ACKNOWLEDGMENTS

Janice Jones, Titto Moses, and Beverly Penny are acknowledged for help with seed collection, seed processing, greenhouse propagation, planting, seeding, and monitoring. Funding was provided by the US Department of Energy.

LITERATURE CITED

Blanke, T.; Woodruff, H. 2011. Propagation protocol for production of *Calochortus nuttallii* plants; Upper Colorado Environmental Plant Center, Meeker , Colorado. In: Native Plant Network. URL: http://www.nativeplantnetwork.org (accessed 8 October 2012). Moscow (ID): University of Idaho, College of Natural Resources, Forest Research Nursery.

Chambers, J.C. 2000. Seed movements and seedling fates in disturbed sagebrush steppe ecosystems: Implications for restoration. Ecological Applications 10:1400-1413.

Grant, A.S.; Nelson, C.R.; Switalski, T.S.; Rinehart, S.M. 2011. Restoration of native plant communities after road decommissioning in the Rocky Mountains: effect of seed-mix composition on vegetative establishment. Restoration Ecology 19:160-169.

Hajek, B.F. 1966. Soil survey, Hanford Project in Benton County, Washington. Richland, Washington, Pacific Northwest Laboratory, BNWL-243.

Lindsey, C.T.; Johnson, A.L. 2010. 2010 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report, Washington Closure Hanford, Richland, WCH-428 Rev. 0. pp. 82.

Link, S.O.; Cruz, R.O.; Harper, B.L.; Jones, J.D.; Penney, B.L. 2011. Shrub-steppe species survival after outplanting on bare soils. In: Riley LE, Haase DL, Pinto JR, technical coordinators. National Proceedings: Forest and Conservation Nursery Associations—2010. Proc. RMRS-P-65. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station: 159-167.

Moerman D.E. 1998. Native American Ethnobotany. Timber Press, Portland, Oregon.

Pyke D. 1990. Comparative demography of co-occurring introduced and native tussock grasses: persistence and potential expansion. Oecologia 82:537-543.

Pywell R.F.; Bullock J.M.; Hopkins A.; Walker K.J.; Sparks T.H.; Burk M.J.W.; Peel S. 2002. Restoration of species-rich grassland on arable land: assessing the limiting processes using a multi-site experiment. Journal of Applied Ecology 39: 294-309.

SAS Institute. 2002. JMP Statistics and Graphics Guide, Version 5. Cary, NC

Schartz R.J.; Janke R.R. 1999. Evaluation of Native Legumes for Use as Cover Crops. Journal of Sustainable Agriculture 15:45-59.

Skinner, D. M. 2005. Propagation protocol for production of container *Leymus cinereus* (Scrib. & Merr.) A. Love plants; USDA NRCS - Pullman Plant Materials Center, Pullman, Washington. In: Native Plant Network. URL: http://www.nativeplantnetwork.org (accessed 8 October 2012). Moscow (ID): University of Idaho, College of Natural Resources, Forest Research Nursery.

Steele, R.B.D,; Torrie, J.H. 1960. Principals and procedures of statistics. New York, McGraw-Hill.

Stone, W.A.; Thorp, J.M.; Gifford O.P.; Hoitink D.J. 1983. Climatological Summary for the Hanford Area. Richland, Washington, Pacific Northwest Laboratory, PNL-4622.

Tilley, D.; St. John, L.; Ogle, D.; Shaw, N. 2012. Propagation protocol for production of *Lomatium grayi* (J.M. Coult. & Rose.) J.M. Coult. & Rose seeds; USDA NRCS - Aberdeen Plant Materials Center, Aberdeen, Idaho. In: Native Plant Network. URL: http://www.nativeplantnetwork.org (accessed 8 October 2012). Moscow (ID): University of Idaho, College of Natural Resources, Forest Research Nursery.

Tilman, D. 1997. Community invasibility, recruitment limitation, and grassland biodiversity. Ecology 78:81-92.

Table 1. Species used for seeding and seedling propagation with mean maximal greenhouse germination (± 1 standard error of the mean (sem), n). Tribal uses are food (f), fiber (fi), drug (d), and dye (dy)

Family Species	Common Name	Tribal uses	Mean maximum germination (percent)	1 sem	n
Apiaceae					
Lomatium grayi	Gray's lomantium	f			
Lomatium tritenatum	nine-leaf lomatium	f,d			
Asteraceae					
Agoseris grandiflora	large-flowered agoseris	f,d	26	7.9	6
Artemisia tridentata	big sagebrush	f,fi,d	6.0	3.0	5
Balsamorhiza rosea	rosy balsamroot	f,d	6.1	1.0	3
Chaenactis douglasii	false yarrow	d			
Crepis atribarba	slender hawksbeard	f,d			
Crepis modocensis	low hawksbeard	f,d	31		1
Ericameria nauseosa	Gray rabbitbrush	f,fi,d,dy	1.0		1
Erigeron filifolius	threadleaf fleabane	f,fi,d			
Erigeron linearis	desert yellow daisy	f,fi,d	21	1.1	3
Erigeron piperianus	Piper's daisy	f,fi,d	56	9.7	10
Erigeron poliospermus	cushion fleabane	f,fi,d	4.4	2.0	2
Eriophyllum lanatum var. *integrifolum*	woolly sunflower	d	0		1
Helianthus cusickii	Cusick's sunflower	f,d			
Machaeranthera canescens	hoary aster				
Nestotus stenophyllus	narrowleaf mockgoldenweed		78		1
Tetradymia canescens	gray horsebrush	d	0		1
Chenopodiaceae					
Grayia spinosa	hopsage	f	35	2.0	3
Brassicaceae					
Phoenicaulis cheiranthoides	daggerpod	d	0		1
Crassulaceae					
Sedum leibergii	Leiberg's sedum		18		1
Fabaceae					
Astragalus caricinus	buckwheat milkvetch	f,d	64	3.3	5
Astragalus conjunctus var. rickardii	Dr. Bill's locoweed	f,d	0		1
Astragalus purshii	woolly-pod milkvetch	f,d	62	8.7	5
Astragalus succumbens	Columbia milkvetch	f,d			
Lupinus leucophyllus	velvet lupine	f,fi,d	31	4.3	4
Grossulariaceae					
Ribes cereum	squaw currant	f,d	0		1
Laminaceae					

Family Species	Common Name	Tribal uses	Mean maximum germination (percent)	1 sem	n
Agastache occidentalis	western horsemint		58		1
Salvia dorrii	purple sage	d	13	4.4	3
Liliaceae					
Calochortus macrocarpus	mariposa lily	f,d			
Poaceae					
Achnatherum thurberianum	Thurber's needlegrass	fi	62		1
Leymus cinereus	giant wildrye	f,fi,d,dy	0		1
Polemoniaceae					
Phlox hoodii	Hood's phlox	d,dy	5.6		1
Phlox longifolia	longleaf phlox	d	56		1
Polygonaceae					
Eriogonum sphaerocephalum	rock buckwheat	f,fi,d,dy	11	6.5	3
Eriogonum thymoides	thyme buckwheat	f,fi,d,dy	10	1.7	4
Portulacaceae					
Phemeranthus spinescens	spiny fameflower		78		1
Ranunculaceae					
Clematis ligusticifolia	western white clematis	f,fi,d	13		1
Scrophulariaceae					
Penstemon speciosus	showy beardtongue	f,fi,d,dy	5.4		1

Figure 1. Mean ± one standard error of the mean survival of seedlings and establishment of seeded species in silt (46° 23'30.66"N, 119° 32'12.19"W, 377 m.a.s.l.) about four months after planting. Means with differing letters are significantly different ($p < 0.05$).

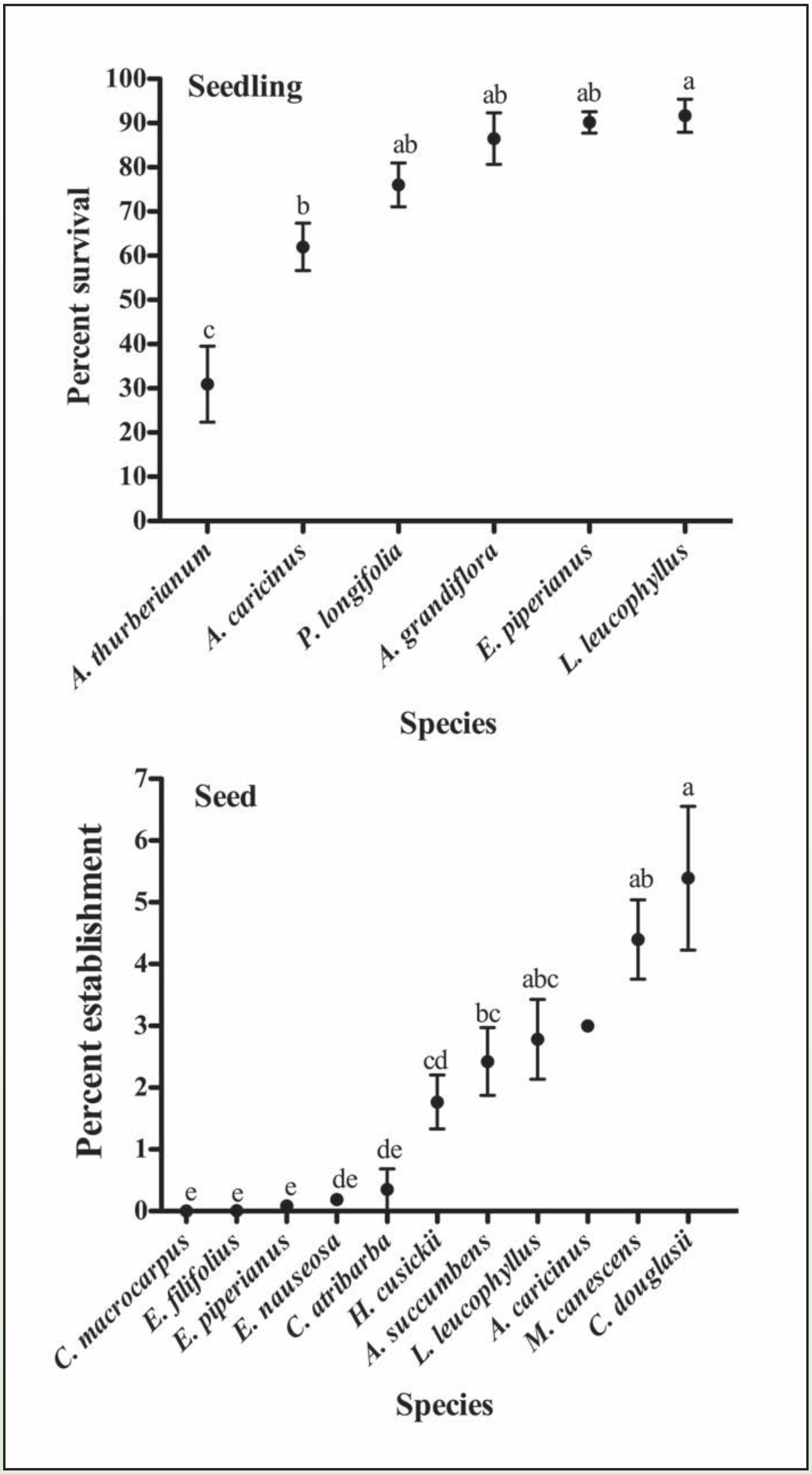
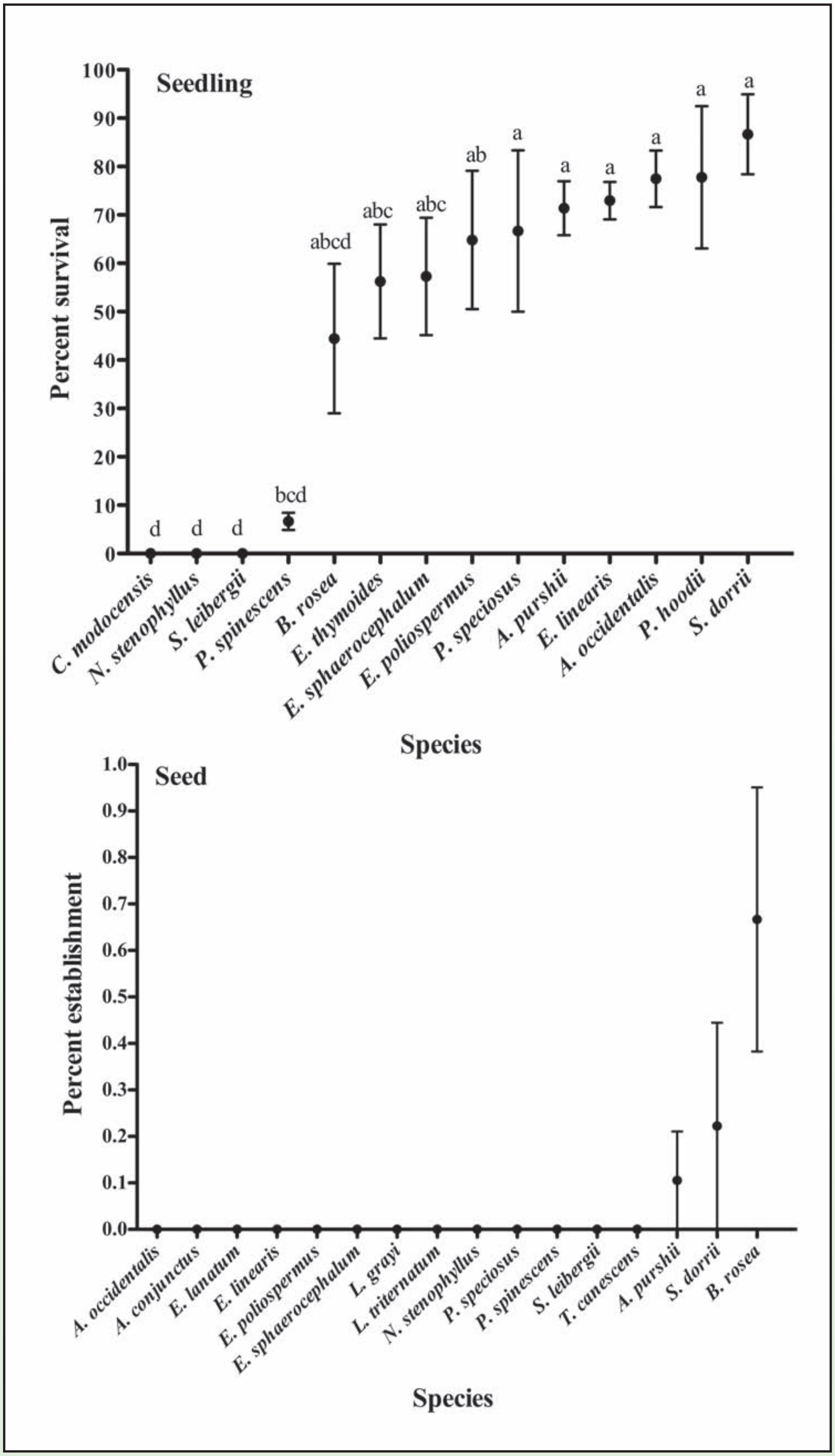


Figure 2. Mean ± one standard error of the mean survival of seedlings and establishment of seeded species in lithosol (46° 23′42.26″N, 119° 35′45.15″W, 1092 m.a.s.l.) about four months after planting. Means with differing letters are significantly different ($p < 0.05$).



Castilleja cryptantha **by Jeff Thorson**

Competition, Seed Predation And Predicted Effects Of Climate Change Influence The Survival Of A Rare Plant Species In Eastern Washington: What Are The Management Options?

Julie K. Combs[1]

The conservation of rare plant populations often relies on our understanding of the factors that limit rare species in order to successfully manage vulnerable populations. Theory on rarity suggests that rare plants may be more susceptible to ecological pressures, such as, competition, herbivory, or a lack of pollinators compared to abundant widespread species. This study summarizes five years of research examining factors that limit the growth and reproduction of Astragalus sinuatus L (Whited's milkvetch), a narrow endemic restricted to eight populations within a 10-km2 area in Chelan County, Washington. Observational and experimental studies documented interactions between A. sinuatus and an invasive grass species (Bromus tectorum L.), native predispersal seed predators and pollinators. Astragalus sinuatus seedling recruitment was higher in B. tectorum removal plots compared to plots with B. tectorum present. Seed predators consumed 65-82% of seeds produced. Seed predation was higher for A. sinuatus compared to two sympatric, common congeners (A. leibergii and A. purshii). Experimental reduction of predispersal seed predators significantly increased per capita seed set of A. sinuatus (164-345%) at two experimental sites. Concurrently, two seed addition experiments demonstrated the effect of seed loss and presence of B. tectorum on seedling recruitment and establishment of A. sinuatus over four growing seasons. In the first seed addition experiment, we found no difference in recruitment and establishment between low (40) and high (120) seed addition levels. In the second addition experiment (one level of addition; 40 seeds), we found that recruitment and survivorship increased 200% in plots where B. tectorum was removed compared to plots where B. tectorum was present. Trait comparisons suggest that high seed predation rates in the rare species reflect a combination of factors, such as, plant phenology, seed predator identity and phenology, plant vigor, and plant dispersal ability. A diverse pollinator community was found to visit flowers of A. sinuatus, suggesting that A. sinuatus may be an important resource for shrub-steppe pollinator communities. Primary findings suggest that competition with B. tectorum and seed predation are two of the most important factors limiting A. sinuatus.

Short-term and long-term management strategies are needed in order to ensure the survival of ***A. sinuatus*** with special attention to the predicted effects of climate change. Because conservation action is often limited by time and resources, it is important to identify which mechanisms limit species and

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under what circumstances. Based on our results we recommend small-scale reductions of ***B. tectorum***, either by hand-pulling or using grass-specific herbicides around the perimeter of mature ***A. sinuatus*** individuals.

Trials using different herbicides should be performed to ensure non-target effects on ***A. sinuatus*** and other native species in the community. Since A. ***sinuatus*** disperses seed close to the parent plant, short-term suppression of ***B. tectorum*** may enable seedlings to recruit and survive to a stage where they can coexist with ***B. tectorum***. In addition, in populations where ***B. tectorum*** density is low (currently no known populations meet this criterion), short-term reduction of predispersal insect seed predators also may be an effective management approach. Manual removal of insects or short-term targeted uses of insecticides are two methods of insect reduction. Again, if insecticides are used, trials should be conducted to ensure non-target effects.

There has been some disagreement in the literature concerning the use of insecticides to conserve rare plant. However, researchers on both sides of this debate agree that under certain circumstances, insecticides may be an appropriate management tool for threatened and endangered species, if care is taken to avoid non-target effects on pollinators and other community members. This study supports theory on rarity that suggests competition and predispersal seed predation are important mechanisms influencing both reproductive and population-level fitness of a rare plant species. Managers should consider how climate changes may create feedbacks that could intensify predation and competition factors. For example, it is predicted that the Columbia Basin will experience milder, wetter winters and dryer spring–summer seasons. Since ***B. tectorum*** is a winter annual, it will most likely have a competitive edge compared to many species, such as ***A. sinuatus***, that germinate or emerge later in the season. Additionally, the combination of drier spring–summer seasons and the presence of ***B. tectorum*** will likely increase fire events that can further stimulate ***B. tectorum*** invasion. Similarly, milder winters may lead to an increase in the survivorship of overwintering predispersal insects, which in turn may lead to higher rates of predation. Thus, conservation managers developing adaptive management and research plans should consider how factors such as competition and predation may change in a climate altered future and plan accordingly.

Citizen scientists conducting rare plant surveys by Beverly Linde

Will A Changing Climate Increase Interaction Between Rare And Non-Native Plant Species In Alaska?

Lindsey Flagstad[1], Matthew L. Carlson[2], Helen Cortés-Burns[3], Catherine Jarnevich[4], and Tracy Holcombe[4]

Non-native species represent a significant threat to rare plant species in North America (Wilcove et al. 1998), in Alaska however, very few rare plant populations are immediately threatened by non-native plant populations. Less than one percent of the documented critically-imperiled (G1) to vulnerable (G3)[5] plant populations occur within one kilometer of a documented non-native plant population. Despite the low area of overlap between rare and non-native plants, the increasing introduction and spread of invasive species is concerning, particularly in the context of climate change. Approximately 13 species and 7,000 populations of non-native plants are added to state records annually, and the rate of introductions is accelerating (Carlson and Shephard 2007). Additionally, the increases in temperature and changes in precipitation patterns predicted for Alaska are likely to expand the area of overlap between globally-rare and non-native plant species, thereby increasing the probability of ecological interactions.

To assess the potential for increased interaction between rare and non-native plant species in Alaska, we modeled current and future habitat envelopes for a rare species, a non-native species, and a species indicative of steppe-bluff habitats. In Alaska, steppe bluffs are considered an ecosystem of conservation concern and suggested to be particularly susceptible to colonization by non-native species (Roland 1996). These habitats are sagebrush-graminoid dominated and typically occur on south-facing slopes adjacent to large river systems in interior Alaska. The species included here are: the rare species ***Cryptantha shackletteana*** L.C. Higgins, a critically-imperiled species that is narrowly endemic to steppe bluffs along the upper Yukon and Nabesna Rivers; the non-native species ***Melilotus albus*** Medik., which is an extremely invasive colonizer of open habitats, particularly along river systems and roadsides in Alaska; and the native sagebrush, ***Artemisia frigida*** Willd., whose presence can be used as an indicator of steppe-bluff habitat in Alaska.

Several attributes of steppe-bluff ecosystems render them appropriate for the study of potential interactions between rare and non-native flora. First, the warm and arid microclimates of steppe bluffs reflect conditions of more temperate and/or continental regions and for this reason foster a distinctive, azonal flora, which is thought to be vulnerable to invasion and is predicted to increase in extent in a warming climate. Second, the natural geomorphic disturbances and aridity that is thought to exclude colonization by trees, holds steppe bluffs in an early successional state, favoring the establishment and

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[5]NatureServe Conservation Status; see http://www.natureserve.org/explorer/ranking.htm for more information

growth of all ruderals, including non-native plants. Last, steppe bluffs are typically linked by river systems that are likely to facilitate the movement of non-native species such as ***Melilotus albus*** (Conn et al. 2008).

The native and non-native plant locations used in this modeling exercise were taken from Alaska Natural Heritage Program (AKNHP) and Alaska Exotic Plant Information Clearinghouse (AKEPIC) records, as well as collections housed at the University of Alaska Fairbanks and Tongass National Forest Herbaria. The study area is defined as the Intermontane Boreal Division of Alaska (Nowacki et al. 2001). Habitat suitability was modeled using MaxEnt (Phillips 2006), which integrated the WorldClim bioclimatic variables of mean annual temperature, temperature seasonality, precipitation seasonality, and precipitation of warmest quarter across a two kilometer grid. Current climate was replicated by averaging conditions from 1980 to 2010; future climate was replicated by averaging conditions from 2020 to 2030 under the A1B midrange emission scenario.

The results generated here indicate that suitable habitat for the rare species (***Cryptantha shackletteana***) is predicted to increase in extent, while suitable habitat is predicted to shift towards the northeast for both the invasive species (***Melilotus albus***) and the steppe bluff indicator (***Artemisia frigida***). Thus, the potential for interaction between rare and non-native species will likely be similar in the near future (circa 20 years); however, assuming no dispersal limitations, these interactions may occur in a location more interior to the continent. In the changing climate modeled here, neither the rare plant species nor its endemic steppe-bluff habitat appear to be at immediate risk of ecological degradation due to the impacts of non-native plants. Regardless of potential changes in future interaction between rare and invasive plant species, invasive species with large current and future potential ranges, such as ***Melilotus albus*** remain poor candidates for eradication. Limited resources should instead be focused towards preventing their spread to ecosystems of conservation concern, such as steppe bluffs, where rare plant populations could be adversely impacted.

LITERATURE CITED

Carlson, M.L; Shephard, M. 2007. The spread of invasive exotic plants in Alaska: is establishment of exotics accelerating? In: Harrington T.B.; Reichard, S.H., eds. Meeting the Challenge: Invasive Plants in Pacific Northwestern Ecosystems. Gen. Tech. Rep. PNW-GTR-694. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 175 p.

Conn, J.S.; Beattie, K.L.; Shephard, M.A.; Carlson, M.L.; Lapina, I.; Hebert, M.; Gronquist, R.;

Densmore, R.; Rasy, M. 2008. Alaska Melilotus Invasions: Distribution, Origin, and Susceptibility of Plant Communities. Arctic, Antarctic, and Alpine Research. 40(2): 298-308.

Nowacki, G.; Spencer, P.; Brock, T.; Fleming, M.; Jorgenson, T. 2001. Unified ecoregions of Alaska and Neighboring Territories. U.S. Geological Survey Open-File Report 02–297. U.S. Geological Survey, Anchorage, Alaska, USA.

Phillips, S.J.; Anderson, R.P.; Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling. 190: 231-259.

Roland, C.A. 1996. The Floristics and Community Ecology of Extrazonal Steppe in the Yukon and Kolyma River Drainages. University of Alaska Fairbanks, 205 p.

Wilcove, D.S.; Rothstein, D.; Dubow, J.; Phillips, A.; Losos, E. 1998. Quantifying Threats to Imperiled Species in the United States. BioScience. 48(8): 607-615.

Monitoring Plant Biodiversity Through Citizen Science: A Tool To Complement Traditional Scientific Inquiry

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The coinciding pressures of environmental change and declining public funding for basic inventory has led many to conclude that citizen science will play an increasingly important role in monitoring biodiversity. Researchers have used data collected by citizen science projects to document the impacts of changing environments on species abundance and distribution, particularly for animal taxa. Projects for monitoring plant biodiversity can similarly fill a number of information gaps, but the degree to which they can provide reliable data to detect changes in plant biodiversity over time and space is less clear.

Washington Rare Plant Care and Conservation's (Rare Care's) rare plant monitoring project provides a case study to evaluate the applicability of citizen science for mapping and tracking plant biodiversity. In particular, we consider whether the data produced since the project's inception 11 years ago can be used to detect changes in abundance and distribution for rare plant species, whether trends in population sizes can be inferred from the data, and whether citizen-science can provide consistent quality data useful for species management and protection. The goal of the rare plant monitoring project is to revisit known occurrences of rare plants tracked by the Washington Natural Heritage Program (WNHP) in order to document the status of these species across Washington State and identify potential threats to known populations. Specific objectives include providing up-to-date information to land managers on status of and threats to rare plant populations, producing consistent quality data, revisiting populations every 5 to 10 years, identifying population trends, and engaging the public in the appreciation and conservation of rare native plants.

Since the project's inception in 2001, volunteers have submitted 1,180 reports on 750 rare plant occurrences. These represent 20 percent of the occurrences tracked by the Washington Natural Heritage Program, and 30 percent of the occurrences on public lands in the state. Over three hundred and fifty volunteers have participated in the project, contributing 24,800 hours. Volunteer recruitment and training are key components of the project to ensure that consistent, high quality data are collected.

The success of volunteers to relocate documented occurrences depended on the date of the last observation recorded in the WNHP database. Occurrences observed within the last 30 years were successfully relocated 78% of the time, whereas older recorders were successfully relocated only 41% of the time. In many cases, the older records were more difficult to find because of imprecise mapping provided by the original sighting record. Sites that were not found were subsequently revisited at least 2 more times before they were considered to have failed. To date, only 13 sites meet this criterion; however, more sites are still under review and pending further site visits. Volunteers also documented 97 new populations that were not previously recorded in WNHP's database; 56 of which were completely new occurrences and the remaining 41 populations were added to existing occurrences.

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One of the benefits of a citizen science project is the opportunity it provides to revisit a majority of the known occurrences for selected species and invest the time to make population estimates. Volunteers in this project provided population estimates for 482 populations over the 11-year period of the project and in 119 instances, the estimates were the first recorded for the occurrence. For occurrences that had previous estimates on record, Rare Care volunteers' estimates were larger than the older estimates 57% of the time, which is higher than would be expected if population sizes were not changing ($\chi^2 = 3.58$, $P = 0.06$). The frequency of larger population estimates is attributed to the increased time volunteers were able to spend detecting outliers and conducting a systematic sampling. Except for small discrete populations in which a count of individuals could be made, population trends could not be determined for populations because of the inconsistent sampling methods between surveys, large interval of time between population estimates, and lack of precise information on the limits of surveys.

Land managers participating in this project were surveyed in 2009 to evaluate whether the goals of the project were being met and the data provided were of acceptable quality and being used for land management purposes. All 19 respondents indicated that the data quality met or exceeded their expectations and found the information to be useful ($\bar{x}$ =3.2 on scale of 1 to 4), and found the mapping and verification of species persistence to be very useful. Seventy-eight of the surveyed managers reported using the data to evaluate current and future land use actions and to evaluate population status.

In summary, this project illustrates a successful application of citizen-science projects monitoring native plant biodiversity. Two of the key benefits they provide are the ability to intensively monitor a suite of species across multiple jurisdictional boundaries and over long time periods, and the increased opportunity they provide for detecting previously undocumented populations by familiarizing the public with these species. Therefore, these datasets provide critically-needed information about the distribution, abundance and persistence of rare plant populations that is not currently being met by other approaches. However, population trends are more difficult to infer from the data produced at this time because of inconsistencies between methodologies with previous surveys, incompleteness of mapping for many populations, and infrequency of monitoring. We expect that, once we complete revisits of old records, our ability to detect population trends will improve because of increased monitoring frequency and better population mapping.

The Conservation Value Of Rare Plant Reintroduction

Edward O. Guerrant Jr.[1]

Three recent reviews of reintroduction, drawing on sizeable and largely non-overlapping data sets, have come to starkly different conclusions. One (Godefroid, Piazza et al. 2011) concludes that "reintroduction is generally unlikely to be a successful conservation strategy as currently conducted." Another (Dalrymple, Stewart et al. 2011; Dalrymple, Banks et al. 2012) states "…this review cannot conclusively comment on the effectiveness of re-introductions…" A third (Guerrant Jr 2012) finds there is "strong evidence in support of the notion that reintroduction, especially in combination with ex situ conservation, is a tool that can go a long way toward meeting the need it was intended to address.": supporting species survival prospects in the wild. The contradictory conclusions of the three reviews are explained in part by the authors using different data sets, definitions of success, and time scales.

Godefroid et al.'s (2011) dismal opinion of follows in part from a gulf between their definition of success and the metric they use to evaluate it. They state "Success is defined here as the ability of the population to persist and reproduce. To assess the success of a reintroduction, we focused on the survival, flowering and fruiting rates of the reintroduced plants." They go on to assert "…the declining trends in vital rates over the first few years of projects strengthens the conclusion that reintroduction is generally unlikely to be a successful strategy as currently conducted."

Dalrymple et al. (2011) state that their "…review cannot conclusively comment on the effectiveness of re-introductions…" This appears due largely to a high proportion of projects for which the fates were unknown at the time of writing. Despite their modest summary judgment, they were able to glean many important insights into how reintroduction is being practiced and provide a number of valuable suggestions for improvement.

All three share some findings, including an apparent bias in the published literature favoring successful projects. Beyond the common human impulse to favor good news over bad, another factor contributing to a potential bias is the relatively short period of time over which monitoring data are available. Godefroid et al (2011) note that there is "Insufficient monitoring following reintroduction (usually ceasing after 4 years)". Dalrymple et al (2011) report "the average monitoring time prior to publishing the outcome of a study is about 3 years." Note the subtle difference in the way each group reports the duration of monitoring data. Godefroid et al (2011) appear to suggest that monitoring is typically done for four years at which time monitoring efforts cease. Dalrymple et al (2011) are explicitly neutral with respect to whether projects were monitored or not after publication, thus their caution.

In a response to Godefroid et al (2011), Albrecht et al (2011) question the value of short term survivorship data of founding individuals as a reliable measure of reintroduction success, contending that initial decline in survivorship after outplanting is to be expected. Indeed, this demographic cost of reintroduction is sufficiently substantial and widespread to warrant explicit consideration both during initial propagule collection and when planning a reintroduction (Guerrant and Fiedler 2004; Guerrant,

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Fiedler et al. 2004). Albrecht et al (2011) base their criticism on empirical data in combination with simulation modeling results by Guerrant and Fielder (2004. Figure 17.4). The take home message is that low early survival rates in founding populations is not necessarily a reliable indicator of later success.

In contrast to Godefroid, Dalrymple et al's (2011) caution in taking a strong a stand on whether reintroduction is an effective conservation tool is based in large part on the high proportion of reintroduction projects for which the status in 2009 was not known. Compared with the results of Guerrant (2011, plus unpublished data gathered since), the relative proportions of projects either known to be extant in 2009 or whose status in 2009 is unknown are strikingly different. While Dalrymple et al (2011, 2012) report that the proportion of projects at five and ten years whose status is unknown are 75 and 78 percent, Guerrant's figures are much lower (11 and 14 percent respectively). Thus Guerrant has a greater ability to draw stronger conclusions regarding levels of survivorship than do Dalrymple et al. (2011, 2012).

In using survivorship rate of founders as their measure of reintroduction success, Godefroid et al (2001) noted that while seed production and recruitment are also important metrics for measuring success of a reintroduction, such data were rarely available in the studies they review. In contrast, Guerrant was able to obtain data on the reproductive status of founders, production of a next generation, and reproductive status of individuals from the next generation on many projects.

Success in reintroduction has been defined in various ways often with reference to some particular result or series of thresholds, which once attained, indicate success. This has the implicit effect of turning reintroduction outcomes into a categorical variable having one two states: success or failure. Alternatively, it may be more useful to develop a consensus on what constitutes a minimally necessary and sufficient set of baseline descriptors to characterize the progress of a reintroduction.

A thorough discussion of the propriety of reintroduction is beyond the scope of this piece, but there are two particularly problematic areas: the removal of naturally occurring individuals to other locations, and attempts to establish populations outside their naturally occurring range. Neither practice is categorically inappropriate, and both should perhaps only be used when there are no other suitable alternatives.

***Delphinium viridescens* by Wendy Gibble**

LITERATURE CITED

Albrecht, M. A., E. O. Guerrant Jr, J. Maschinski, and K. Kennedy. 2011. A long-term view of rare plant reintroduction. Biological Conservation 144(11): 2557-2558.

Dalrymple, S.A.; Banks, E.; Stewart, G.B.; Pullin, A.S. 2012. A meta-analysis of threatened plant reintroductions from across the globe. Plant Reintroduction in a Changing Climate: Promises and Perils. J. Maschinski and E. H. Haskins. Washington, DC., Island Press: 31 - 50.

Dalrymple, S. A.; Stewart, G.B.; Pullin, A.S. 2011. Are reintroductions an effective way of mitigating against plant extinctions? CEE review 07-008 (SR 32), Collaboration for Environmental Evidence. 63 p.

Godefroid, S.; Piazza, C.; Rossi, G.; Buord, S.; Stevens, A.-D.; Aguraiuja, R.; Cowell, C.; Weekley, C. W.; Vogg, G.; Iriondo, J. M.; Johnson, I.; Dixon, B.; Gordon, D.; Magnanon, S.; Valentin, B.; Bjureke, K.; Koopman, R.; Vicens, M.; Virevaire, M.; Vanderborght, T. 2011. How successful are plant species reintroductions? Biological Conservation 144(2): 672-682.

Guerrant, E. O.; Jr.; Fiedler P. L. 2004. Accounting for sample decline during ex situ storage and reintroduction. Ex Situ Plant Conservation: Supporting Species Survival in the Wild. E. O. J. Guerrant, K. Havens and M. Maunder. Covelo, CA, Island Press: 365 - 385.

Guerrant, E. O.; Jr.; Fiedler P. L.; Havens, K.; Maunder, M. 2004. Revised genetic sampling guidelies for conservation Collections of rare and endangered plants. Ex Situ Plant Conservation: Supporting Species Survival in the Wild. E. O. Guerrant, Jr., K. Havens and M. Maunder. Washington, Island Press: 419 - 441.

Guerrant Jr, E. O. 2012. Characterizing two decades of rare plant reintroductions. Plant Reintroduction in a Changing Climate: Promises and Perils. J. Maschinski and K. E. Haskins. Washington, DC, Island Press: 9 - 29.

Fritillaria camschatcensis by Holly Zox

Modeling Ecological Niches Of Two Closely Related Utah Endemic Plants: U.S. Federally Threatened Townsendia Aprica *And Its Close Congener,* T. Jonesii *Var.* Lutea *(Asteraceae)*

Christopher Lee[1], Linda Jennings[2], and Jeannette Whitton[3]

Native to the Rocky Mountain region of North America and Mexico, Townsendia is a genus of charismatic composites in the tribe Astereae. Of the 27 taxa that comprise Townsendia, only seven are present in the Pacific Northwest, while 14 taxa are found in the state of Utah alone. Townsendia is thought to have an affinity for rare and unusual edaphic soil conditions. In Utah, the confluence of the Great Basin and Colorado Plateau has created ideal edaphic conditions for the rapid diversification of Townsendia. Two such plants are T. aprica S.L. Welsh & Reveal and T. jonesii var. lutea S.L.Welsh, herbaceous perennials endemic to central Utah. Described in 1968 and 1983, respectively, both taxa bear distinctive yellow-apricot coloured ray petals, a trait thought to be rare in the genus. Because of morphological similarity and geographic proximity, these taxa are combined as T. aprica in the updated Flora of North America. This change in taxonomic treatment of T. aprica and T. jonesii var. lutea potentially affects policy. Currently T. aprica is federally listed as threatened, while T. jonesii var. lutea is not, and joining the taxa may boost population numbers in such a way to warrant delisting T. aprica. Conservation concerns aside, past and current work examining isozyme variation, soil characteristics and molecular phylogenetics, suggest significant differences between these taxa. To further test the uniqueness of these taxa, we used ecological niche models (ENMs) to estimate niche overlap and to compare climatic niche profiles for 19 precipitation and temperature variables collected from WorldClim.org. We selected the 10 most influential variables using principal component analysis. With these key variables, we utilized Maxent to predict ENMs, and then estimated niche overlap and identity statistics with ENMTools. We found that six of our variables were temperature related, and four were precipitation related, with the most important variables being mean diurnal range, isothermality and precipitation seasonality. Climatic niche profiles and their weighted means were then calculated and compared for both taxa and were found to be significantly different in all but two of the least important variables. Despite geographic proximity, the niche overlap statistics indicate that both taxa inhabit only marginally overlapping niches. Furthermore, a random resampling procedure and niche identity tests support the robustness and statistical significance of these ecological niche differences. Taken together with other lines of evidence, these results suggest that the two taxa have distinct climate preferences with non-overlapping ENMs, and should be considered separate taxa. While this ENM methodology has been applied to Utah endemics, it can easily be transposed to systems in the Pacific Northwest and beyond. In addition to the identification of rare, cryptic species, ENMs also have the ability to identify potential habitat and predict the fate of species in uncertain climatic times.

Keywords: Townsendia, ecological niche modeling, cryptic species discrimination, Utah

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Gentiana glauca by Brenda Cunningham

Rarity, Reintroduction, And Dynamic Environments: Case Studies In Northwest Camassia *And* Silene

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Plant genera that include both rare and common species in the Pacific Northwest provide a unique opportunity to not only explore variability in the potential causes of rarity, but to assess the value and success of diverse reintroduction strategies. We linked experimental reintroductions of seeds, juveniles, and bulbs with assessment and monitoring of their survival and reproduction in both natural and restored habitats in two genera, ***Camassia*** and ***Silene***.

Camassia (Agavaceae) is an important spring-flowering perennial in wet prairies and oak savannas; it is increasingly being used in restoration. The six species and 10 subspecies include rare and common taxa that exhibit ecological differentiation and span a broad geographic range, with the highest diversity centered in Oregon. Both seeds and transplanted bulbs of ***C. leichtlinii*** and ***C. quamash*** were introduced in 2004 into Fairview Mitigated Wetlands, Salem, Oregon by scientists and volunteers. Of over 1500 young bulb transplants, 93 percent survived in the first season, of which 66 percent produced at least one reproductive stem. Survival and reproductive status varied by both species and habitat; values for ***C. quamash*** plants exceeded those for ***C. leichtlinii,*** particularly in mesic relative to wet habitats, and suggest a broader habitat tolerance for ***C. quamash***. Successful recruitment of seedlings occurred from seed produced by both species in subsequent years. Reproductive plants from the original bulb transplants are still present on site.

In ***Silene douglasii,*** we monitored seedling establishment and survival from seed reintroductions, as well as juvenile densities in multiple natural sites for three varieties differing in rarity. Despite similar seed germination rates, surveys of the rarest var. ***oraria*** (known from three coastal populations) revealed significantly fewer juveniles than for the more common varieties ***douglasii***, (widespread in the Pacific Northwest) and ***rupinae*** (endemic to Columbia River Gorge). Seedling survival also declined more rapidly than transplanted bulbs at Cascade Head, a UNESCO Biosphere Reserve; at that site, we reintroduced 1-2 year old juveniles of var. ***oraria*** into a formerly grazed area of the coastal headland in 1998. The juveniles were progeny of earlier, ***in situ*** crossing studies in an adjacent natural population that had been historically protected from grazing. Outbred progeny from the ungrazed site showed 8.5-15.2 % higher survival than progeny of selfed or open-pollinated plants in the initial reintroduction; the majority of newly recruited seedlings arose near outbred progeny. All ***oraria*** transplants showed varying rates of maladaptation, with significantly reduced fruit and seed production relative to natural populations. Overall, data thus far suggest that inbreeding limits initial seedling survival and establishment success in this rare plant. However, recent observations, nearly 15 years after the juvenile reintroductions, suggest that encroaching vegetation has strongly impacted the success of all progeny types of rare var. ***oraria***. Only in one of three macroplots, with less than half the vegetative cover height of the other two macroplots, were we able to detect budding or flowering plants in June 2012.

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Reproductive stems of these plants ranged from 3 to 32 stems, but plant canopy areas were small suggesting continued maladaptation.

In summary, we evaluated populations of northwestern ***Camassia*** (Agavaceae) and ***Silene*** (Caryophyllaceae) in multiple years in Oregon across diverse habitats from coastal to montane prairies and wetlands. In all, the results of our research imply that effective strategies for reintroduction that yield positive short and long-term outcomes remain challenging and are influenced greatly by diverse factors: plot and study design, the genetic makeup of source populations, control of invasives and encroaching vegetation, and species variability and rarity.

Erigeron basalticus **by Richard Ramsden**

Influence Of Invasive White Sweetclover On Plant-Pollinator Community Interactions In Interior Alaska

Laura C. Schneller[1], Matthew L. Carlson[2], Christa P. H. Mulder[3], and Katie V. Spellman[4]

Pollination is a critical ecosystem service that is often required for fruit set in angiosperms, which can be disrupted when establishment of non-native plant species alters the plant-pollinator network. Boreal Alaska is currently experiencing an invasion of ***Melilotus albus*** Medik., a highly rewarding plant to pollinators that is spreading along floodplains that support numerous rare plant populations, as well as along roadsides and burned areas (Conn et al. 2008). Alterations to plant-pollinator interactions may result in impacts to plant recruitment and community composition. Non-native plant species that are particularly attractive to pollinating insects are well-known to impact plant-pollinator networks, visitation rates, and fruit and seed production in co-occurring native plants (Bartomeus et al. 2008, Padrón et al. 2009). We used plant-pollinator observations in manipulated and non-manipulated sites to determine whether the plant-pollinator community structure differs with and without ***M. albus*** and to determine whether the visitation rates and fruit set of native plants differs in communities with and without ***M. albus***.

A 1 m diameter patch of 40 greenhouse-grown ***M. albus*** was added to 11 manipulated sites; six additional sites in similar habitat without ***M. albus*** addition were included as control sites. Approximately one week after addition, we observed pollinator interactions at randomly chosen 4 m^2 focal plots of various distances from the patch of ***M. albus***. These plots were arranged in concentric rings at distances of 1-2 m, 3-5 m, 8-10 m, 15-20 m, and 25-40 m from the center of the site. We observed plant-pollinator interactions at each site for 75 minutes total, with one observation per distance from the ***M. albus*** patch. We recorded plant-pollinator interactions by plant species and pollinator guild. After pollinator observations were complete, ***M. albus*** plants were removed from the sites. At the end of the season, fruit set was measured on two species of focal native plants (***Vaccinium uliginosum*** L. and ***Vaccinium vitis-idaea*** L.).

An additional 20 unmanipulated sites were chosen in pairs along the roadside on the Dalton Highway in interior Alaska, with and without ***M. albus***. Sites without ***M. albus*** were a minimum distance of 300 m away from the nearest ***M. albus*** patch. Each site was 10 m × 20 m, with the long edge perpendicular to the roadway. Observations were made in eight randomly chosen 4 m^2 subplots. During July 2011, we observed each site for 120 minutes total. Plant-pollinator interactions observed were recorded by plant species and pollinator guilds that could be identified in the field.

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Mean network connectance, the ratio of observed plant-pollinator connections to the total number of possible plant-pollinator connections in the network, was more than 1.5 times higher in sites with the invasive ***M. albus*** present for both manipulated and unmanipulated sites than sites without ***M. albus***. Visitation rates to native plants in manipulated sites followed a similar trend, with native plants in sites with ***M. albus*** receiving approximately twice as many visits by pollinators as native plants in control sites.

The plant-pollinator network structure at unmanipulated sites was dramatically different at sites with and without ***M. albus.*** The plant-pollinator network had lower visitation to native plants and fewer connections to all plants in sites without ***M. albus***.

Preliminary fruit set data suggests that fruit set of native ***V. uliginosum*** L. and ***V. vitis-idaea*** L. varied with distance to added ***M. albus*** at manipulated sites. Relative to control site means, ***V. uliginosum and V. vitis-idaea*** plants closest to ***M. albus*** had higher fruit set than control sites without ***M. albus***, but reduced fruit set at intermediate distances of 8-20 m (***V. vitis-idaea***) or all orbits beyond 5 m (***V. uliginosum***).

The presence of ***M. albus*** in these boreal communities impacts native plant-pollinator interactions. These impacts are reflected in increased connectance, visitation rates, and complexity of the plant-pollinator interaction network. In the short term, these relationships between ***M. albus***, native plants, and pollinators may have the potential to increase seed production in some co-occurring native plants. However, pollen quality of native plants may be reduced by mixing with ***M. albus*** pollen (Spellman unpublished data) and increased seedling mortality for native plants is expected due to severe vegetative competition in ***M. albus*** stands (Spellman and Wurtz 2011). In addition, the increase in pollinator visitation suggests that ***M. albus*** has the potential to draw pollinators from nearby areas, potentially reducing visitation and pollination services to native plants in surrounding areas.

LITERATURE CITED

Conn, J.S.; Beattie, K.L.; Shephard, M.A.; Carlson, M.L.; Lapina, I.; Hebert, M.; Gronquist, R.; Densmore, R.; Rasy, M. 2008. Alaska *Melilotus* invasions: distribution, origin, and susceptibility of plant communities. Arctic, Antarctic, and Alpine Research. 40: 298-308.

Bartomeus, I.; Montserrat, V.; Santamaría, L. 2008. Contrasting effects of invasive plants in plant-pollinator networks. Oecologia. 155: 761-770.

Padrón B.; Traveset A.; Biedenweg, T.; Díaz, D.; Nogales, M.; Olesen, J.M. 2009. Impact of alien plant invaders on pollination networks in two archipelagos. PLoS Biol. 4: e6275.

Spellman, B.T., Wurtz, T.L. 2011. Invasive sweetclover (Melilotus alba) impacts native seedling recruitment along floodplains of interior Alaska. Biological Invasions. 13: 1779-1790.

Rare Plant Rescue: Conserving Rare Plant Populations Through Voluntary Stewardship

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Rare Plant Rescue (RPR) is a voluntary land stewardship program that partners with private landowners to conserve prairie habitat for plant species at risk and other prairie species in Saskatchewan, Canada. Because the prairie landscape is one of Canada's most endangered areas, the plant diversity in southern Saskatchewan is at risk of being severely degraded. Specifically, as of 2001, only 21 percent of the prairie ecoregion in Saskatchewan remained as native grassland, and in highly arable areas, only two percent remained (Hammermeister et al. 2001). Both habitat loss (historically through cultivation) and degradation are major factors contributing to the decline of prairie species abundance. Landowner involvement in plant species conservation is crucial in southern Saskatchewan, since 40 percent of the remaining native grasslands are privately owned, while 60 percent are owned by the provincial government but are often privately managed by local landowners through lease agreements (Michalsky and Saunders 2009).

Rare Plant Rescue uses 16 ambassador plant species at risk to garner support for habitat conservation in southern Saskatchewan by engaging private landowners and land managers in their conservation. While the program focuses on a small number of species, ultimately an array of other prairie species benefit from RPR's habitat conservation activities. The program covers 100 percent of the provincial range of seven plant species at risk that are federally listed as either endangered, threatened, or special concern. Target areas include historical and extant locations (and surrounding areas) of these rare plants where habitat still exists.

The RPR search and monitoring methodology is consistent with the Canadian Wildlife Service's (a branch of Environment Canada) methodology. Rare Plant Rescue staff also work in close partnership with a number of other conservation and government agencies to ensure the program is not duplicating others' efforts. Searches are conducted using cardinal direction transects and census sweeps through appropriate habitat. While searches allow for the collection of species' life history, microhabitat, and distribution data, new locations also serve an important role as the basis for new landowner contact and involvement in the RPR stewardship program. Monitoring efforts compliment searches by allowing staff to revisit known sites and collect information on changes to plant numbers, habitat, management, or threats. Further, monitoring allows relationships with landowner stewards to be strengthened over time through ongoing contact.

For the stewardship component of the program to be successful, it is necessary to work closely with landowners. Staff usually initiate contact with a landowner through a phone call, after which they follow up with a one-on-one visit in the landowner's home. This provides staff with a chance to bring knowledge and information to the landowner, but also provides a venue for them to listen to the

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landowner's experiences and input, facilitating the building of a trusting relationship. Receptiveness to the program can vary, but it is important for staff to remain in contact with a landowner if the landowner is at all receptive, as he or she may become more involved once becoming more comfortable with the idea of joining the program, and after building a relationship with program staff.

Landowners join the RPR program and commit to habitat conservation by signing a voluntary stewardship agreement. These agreements are an effective, non-threatening way to engage landowners in conservation because they have no legal standing; however, by signing a document, landowners do make a commitment in front of program staff and family members. Even though landowners would remain in control of the land and their operations regardless of whether or not they sign up for the program, the non-binding agreement reinforces their feelings of security and control over their operations. Voluntary agreements can also serve as a step towards legally-binding agreements such as conservation easements.

There are incentives for a landowner to join the RPR program. Stewards become part of a conservation-minded community, which includes benefits such as having access to resources, free workshops, a rewards program, and access to habitat enhancement funding programs. Having a species at risk on one's land increases biodiversity, which contributes to a healthier and more productive landscape on which to run a farm or ranch operation. Being a part of such a stewardship program reinforces landowners' commitment to good management of the land, and acknowledges that they are contributing to species at risk conservation while continuing to use the land as they always have (e.g., for cattle grazing).

Voluntary stewardship programs are an effective means of habitat conservation for a number of reasons. Firstly, informed landowners are less likely to inadvertently destroy habitat or rare species. Secondly, program staff and agrologists are available to work with stewards to make suggestions on how they can improve their operation, and how they can make better management decisions that will benefit the species at risk as well as their bottom line. Thirdly, stewardship focuses on the root of the problem of habitat loss and destruction and addresses some of the human activities that cause it. Most importantly, RPR involves and engages those who are making the land management decisions, rather than forcing management restrictions on them.

These claims are supported by a 2004 study of Operation Burrowing Owl (OBO), a sister program to RPR, and the program after which RPR was modelled. The study showed that sites which were enrolled in the OBO program had significantly higher retention of grassland habitat than sites that were not enrolled (Warnock and Skeel 2004). In addition, habitat and rare plant populations have been maintained on RPR sites; 81 percent of the sites monitored by RPR since 2008 still support their rare plant populations, and native prairie habitat has been retained on all sites.[3] The RPR program also continues to grow steadily, showing good uptake with the producer community. In only ten years of RPR's existence, the program has gained 68 landowner stewards who are conserving over 67,000 acres (27,114 hectares) of native prairie for plant species at risk, and these numbers increase every year.

There are a number of challenges of which to be mindful to ensure the success of a program like RPR. While the searches and monitoring tasks for plant species at risk are very time and labour intensive, and it becomes easy to be consumed by those tasks, it is extremely important to remember that it is the stewards who are the backbone of the program and they must remain a priority. Communication with those stewards is also a key component of the program; some form of contact is made with them every

[3]Suitable habitat remained at the other 19 percent of sites; however, the plant species of interest were annuals or biennials and it is suspected that they had either not germinated that year, or existed only as basal rosettes and could not be found or were unidentifiable. No specific monitoring program existed prior to 2008.

year, even through something as simple as a newsletter, and face-to-face contact should be made every five years or earlier if possible. Landowners also have a great deal of important and relevant knowledge regarding their land and its management, so it is also important to ensure that communication with them remains two-way and that staff listen as well as teach. This is also an important component in building a trusting relationship between program staff and stewards. Patience is a necessary component to building those relationships; it is important to allow landowners time to feel comfortable with signing up for a stewardship program, and to not aggressively seek their commitment. Resistance to conservation programs is occasionally encountered, usually due to the prevalence of certain myths about what it means in Canada if a landowner has a species at risk on his or her land. Dispelling myths and disseminating accurate information is an important component of a stewardship program. Engaging youth is also important because they can influence their parents' decisions, and will grow up to be the next generation of land managers.

We suggest that this sort of stewardship program can be successful in any ecozone where land is privately owned or managed, as long as all parties involved can benefit.

LITERATURE CITED

Hammermeister, A.M.; Gautheir D.; McGovern K. 2001. Saskatchewan's native prairie: statistics of a vanishing ecosystem and dwindling resource. Saskatoon, SK: Native Plant Society of Saskatchewan Inc. 17 p.

Michalsky, S.; Saunders, E. 2009. At home on the range: living with Saskatchewan's prairie species at risk. Regina, SK: Nature Saskatchewan Special Publication No. 28. 47 p.

Warnock, R.; Skeel, M. 2004. The effectiveness of voluntary habitat stewardship in conserving grassland: case of Operation Burrowing Owl in Saskatchewan. Environmental Management. 33: 306-317.


Tauschia hooveri **by Betty Swift**

***Lycopodium dendroideum* by Wendy Gibble**

ORAL PRESENTATION ABSTRACTS

**Contact and affiliation information is listed for presenter and/or first author only*

SESSION A
CLIMATE CHANGE: OBSERVED EFFECTS ON PLANTS AND PLANT COMMUNITIES

Testing The Limits: Effects Of Climate And Competition On Conifer Distributions In Mount Rainier National Park

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Global climate change is expected to cause warming and reduced snowpack in the Pacific Northwest. These changes are likely to impact the species' distributions and therefore affect natural resource management and biodiversity conservation. We ask how important climate is in determining range limits of Pacific Northwestern conifers by quantifying relationships between climatic variables (e.g. snow, temperature) and growth across altitudinal ranges of six conifers on Mt. Rainier. We investigate growth-climate relationships at multiple life history stages (seeds, seedlings, adult trees) and find that growth-climate relationships vary by species, elevation, and life history stage. We also examine effects of competition on conifer growth and survival across their altitudinal ranges, and find that competition limits growth at low elevations. Our results suggest that, as temperature increases over the next century, conifers will likely show increased growth at treeline, but responses in low-elevation forests will be more idiosyncratic. These upward range shifts may lead to decreases in alpine and subalpine plant populations.

Arctic And Boreal Plants Decline At The Southern Margin Of Their Range In Montana

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Plant ecologists unanimously agree that climatic warming occurring now and predicted to continue will alter the distribution of plants. Biogeographic theory predicts that species will be most sensitive to environmental change at the periphery of their range. Warming should affect populations at the southern (warm) margin of a species' range before central populations. Numerous arctic and boreal species reach the southern margin of their range in alpine and peatland habitats of western Montana. I

monitored the density of 20 peripheral populations of 12 arctic and boreal species in permanent plots in Glacier National Park and The Nature Conservancy's Pine Butte Preserve over the past two decades, a period of dramatic climate warming. Of the boreal peatland species, three declined, while two remained stable. Four species of arctic plants declined, two species were stable, and one species increased at one site but declined at the other. Overall, of the 20 populations of 12 species, ten populations showed a significant decline; nine were stable; and only one increased. Thirty-three percent (n=6) of monocots declined, but 83% of dicots (n=6) declined. These results support the hypothesis that northern species are declining at the southern margins of their geographic ranges.

***Oxytropis campestris* var. *wanapum* by Wendy Gibble**

SESSION B
CLIMATE CHANGE: PREDICTED EFFECTS ON PLANTS AND PLANT COMMUNITIES

Climate Change Impacts On Biodiversity In The San Francisco Bay Area: Models, Monitoring And The Management/Research Interface

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Climate change is expected to profoundly impact terrestrial vegetation. Understanding spatial variability of these impacts is critical to development of conservation strategies and projections of ecosystem services under future climates. We present a novel probabilistic modeling strategy to examine projected impacts of climate change on major vegetation types in the San Francisco Bay Area. The model predicts that vegetation patches near the edge of the climatic envelope for a particular vegetation type are particularly vulnerable to change; there are weak but significant trends towards greater sensitivity for vegetation patches on cool, north-facing slopes and in valley bottoms, conflicting with commonly held conviction that cool environments will act as in-situ refugia. To test these projections, and associated challenges related to climate change, land management and biodiversity conservation, we have initiated the Terrestrial Biodiversity Climate Change Consortium (TBC3), in association with the Bay Area Ecosystems Climate Change Consortium (BAECCC). TBC3 brings together researchers from universities, NGOs, federal and state agencies to 1) develop and disseminate enhanced down-scaled climate layers for the Bay Area; 2) synthesize climate adaptation strategies and their application to regional conservation goals; 3) develop biotic monitoring and mapping protocols as a baseline to study long-term change; and 4) develop and implement citizen-science reporting systems to engage a broad audience in biodiversity observation and monitoring. The Bay Area provides great opportunities to develop regional climate adaptation strategies, and to integrate research, policy and land management to enhance conservation and ecosystem services in a major metropolitan area.

Spatial Heterogeneity In Ecologically Relevant Climate Variables At Coarse And Fine Scales

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Climate plays an important role in determining the geographic ranges of plant species. Given the rapid rates of climate change forecasted for the coming decades, many ecologists have predicted that widespread species extinctions will occur as the climate shifts faster than species can migrate. However,

the vast majority of quantitative range shift assessments are based on climate models with coarse spatial scale that ignore fine-scale climatic heterogeneity. This fine-scale heterogeneity can be critical to species persistence because it has the potential to provide cool microrefugia in a warming world. If climate varies dramatically over short distances, plants may only need to disperse tens of meters between microhabitats to track their climate as opposed to hundreds of meters upwards in elevation or hundreds of kilometers poleward. Thus, if fine-scale heterogeneity is great, range shift assessments based on coarse-scale climatic data could lead to overestimation of range shift magnitudes and extinction risks. To determine whether coarse-scale climate heterogeneity is greater than fine-scale climate heterogeneity, as assumed in many models, we measured climatic variables important to plant species distributions (snow disappearance date and soil temperature) at coarse and fine scales at Mount Rainier National Park in Washington State, USA. We found that locations separated by small distances (~10-20m horizontally) but differing by vegetation structure or topographic position often experienced differences in climate as great as locations separated by large distances (1km or more). This large degree of fine-scale heterogeneity could provide an important buffer for species against the negative effects of climate change.

Forecasting The Effects Of Climate Change On Rare Plant Populations

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Changes in global climate could cause shifts in species distributions and therefore affect the long-term dynamics of rare and endangered plant populations. Linking climate change models to demographic models may provide useful insights into the potential effects of environmental changes on rare plants, and therefore aid in their current and future conservation. We used demographic models to project population sizes of several rare plant species into future climate scenarios. Population growth rates were calculated from demographic data sets of 7-10 years for five rare, native Oregon plant species populations (***Astragalus tyghensis***, ***Pyrrocoma radiata***, ***Horkelia congesta***, ***Lomatium bradshawii*** and ***Lomatium cookii***) at multiple sites. We developed models to predict population growth from environmental variables using nonlinear, nonparametric regression with observed data. Climate variables included total precipitation, average dew point, minimum, and maximum temperature, and average evapotranspiration rates during specific growing seasons. Next, we simulated future population trajectories based on 1) GCM predicted climate conditions and 2) IID conditions of our data sets without climate predictors. Climate was a strong predictor of most species population growth, however this was confounded by site variation as predictors were not equally strong across all populations among species. Environmental factors explained some variation in population growth rates in all five species and may be useful in stochastic demographic models in general. Forecasts of population growth under climate change scenarios are more pessimistic in some plant species (***P. radiata***) than forecasts based on past conditions or IID, suggesting negative effects of climate change on these rare species.

Modeling The Diversity Of Rare And Endemic Plants At The Landscape Scale In Denali National Park: Implications Of Climate Change For This Unique Natural Heritage

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We used field plant species occurrence data recorded at 3063 sites to build probability of occurrence models for the vascular flora (>600 species) occurring within a 1.28 million hectare study area in Denali National Park. We then used a 100 m prediction raster grid to extrapolate these species models over the study area, which yielded spatially explicit, high resolution probability of occurrence models at a landscape scale for the vascular flora. We aggregated individual species probabilities at each raster cell to generate spatially-explicit estimates of rare and endemic species richness across the study area. Our work predicts that diversity of rare and endemic flora is conspicuously concentrated in tundra and other treeless areas of the alpine zone in Denali National Park. We discuss the results of our vascular plant diversity models in the context of the changing landscape of interior Alaska, using the results from our long term vegetation monitoring program and a large set of matched historic/modern photo pairs to consider the implications of a warming climate on the rare and endemic flora of Denali National Park specifically, and eastern Beringia more generally. We conclude that an expansion of woody vegetation, apparently already underway, may pose important conservation challenges for maintaining rare and endemic plant biodiversity in Alaska and adjacent areas of northwestern North America.

Lilies At The Limit: A Story Of Range Limits, Pollen Limitation, And Conservation In A Changing World

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What are the biological impacts of climate change? Climate envelope models predict that with climate warming, many species may expand their ranges towards the poles or towards mountain-tops. However, species range limits are also determined by biotic factors not considered in climate envelope models, complicating their forecasts. For example, if low seed production due to low pollinator visitation rates constrains population growth at a range limit, it is doubtful that a plant will expand its range to occupy newly available habitat unless pollinator visitation is also altered. We were interested in investigating plant-pollinator dynamics of ***Erythronium montanum*** (Liliaceae) to ask whether pollen transfer limits fruit set and whether the degree of limitation changes as we approach the range limits of the species. ***E. montanum*** is a particularly interesting species because it is one of the first flowers to bloom in the spring on the south side of Mount Rainier. As such, there is reason to suspect that this species will be among the most sensitive to a changing climate. We found that fruit set is lowest at the lower elevational limit and that fruit set is significantly pollen limited at the upper elevational range. This suggests that pollen limitation determines the upper range limit of this species but that something else, perhaps resource limitation, sets the lower range limit. These findings imply that as we consider the biological implications of climate change, it is essential to understand the complicated plant-pollinator interactions that are foundational to plant biodiversity and distribution.

SESSION C
CLIMATE CHANGE: ADAPTING MANAGEMENT STRATEGIES TO OBSERVED AND PREDICTED EFFECTS

Generalized Provisional Seed Zones For Native Plants

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Deploying vigorous, well adapted, and ecologically appropriate plant materials is a core component of a successful restoration project. The key to identifying appropriate plant materials (e.g. seeds) lies in understanding the genetics of adaptation through common garden studies. However, restoration practitioners often deploy plant species on the landscape for which no seed transfer guidelines have been established through genetic research. So what are practitioners to do when no seed transfer guidelines have been established for a species of interest? We have developed generalized provisional seed zones that can be applied to any plant to help guide seed movement. These seed zones area based on the intersection of high resolution (800m x 800m cell size) observed climatic data. The intersection of winter minimum temperature and annual precipitation delineates zones for trees, shrubs, and woody plants, while the intersection of average maximum temperature and precipitation is used for zones for grasses and herbaceous plants. The resulting seed zones represent areas of relative climatic similarity, and movement of seed within these zones should help to minimize maladaptation. Superimposing Omernick's level III ecoregions over these seed zones helps to distinguish areas that are similar climatically yet different ecologically. These provisional seed zones should be considered a starting point as guidelines for seed transfer, and should be utilized in conjunction with appropriate species specific information as well as local knowledge of microsite differences.

Patterns Of Rarity In Alaska Lichens: How Vulnerable Are These Species To Predicted Changes In Climate?

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Recent studies in Alaska have revealed dramatically higher lichen biodiversity than previously considered and are challenging ideas of reduced biodiversity at high latitudes. One such study conducted in a 5300 ha area reported 4 lichens new to science, 17 as new to North America, 196 taxa new to Alaska, and the largest number of lichens per unit area ever reported. Current and future changes in climate at high latitudes in particular emphasize the need for documentation, protection,

and management of lichen biodiversity in Alaska and neighboring territories. To address this need we calculated and assigned State Rarity Ranks of lichens in Alaska, with information gathered from research publications, herbaria, federal land managers, and lichen experts. A total of 62 species were ranked as rare or imperiled. The majority of rare species are locally uncommon, but widely distributed and therefore do not appear to be in immediate risk. Additional targeted surveys are required to confirm the rarity ranks for this under-sampled group. Relying on atmospheric moisture and nutrients, however, lichens are vulnerable to environmental changes driven by climate warming and drying. In particular, growth rates are expected to decline if summer warming does not correspond with increases in precipitation; conditions that ultimately may threaten abundance and diversity of lichens. The following presentation provides a review of the attributes of Alaska rare lichens, with emphasis on state and global distributions and environmental specificities, and discusses the implications of these patterns for future conservation planning.

Genetic Considerations For Plant Material Policies In The Context Of Climate Change: A Forest Service Perspective

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The USDA Forest Service (USFS) native plant policy calls for 'genetically appropriate' native plant materials for revegetation of USFS lands. Movement guidelines for these materials have historically been defined by 'seed zones' derived from common garden studies. These seed zones are designed to restrict seed movement to ensure 'locally adapted' materials are deployed in restoration/reforestation/rehabilitation efforts. However, 'local is best' may not be the optimal strategy given the variety and uncertainty of predicted future climate conditions. Consequently, USFS geneticists and others are using the best available science to explore how current strategies might be modified to better adapt to uncertain future climate conditions. This presentation will discuss the types of species and populations that are most at risk. Moreover, this presentation will describe genetic considerations and recommendations that may be incorporated into a plant materials policy to possibly mitigate some of the effects of predicted climate change scenarios.

Shifting Paradigms: Results Of An International Survey On Restoration And Climate Change

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Climate change may be the defining challenge to the field of restoration ecology this century. How does the wider restoration community currently approach the challenges of habitat and species restoration, and how is this approach likely to shift if the climate changes locally and globally?

Understanding how people conduct or support restoration is crucial to engaging in discussions that move our field forward in the face of changing environments. We conducted an international survey of over 1000 restoration practitioners and ecologists in 2010-11 to gather information on their perspectives about these issues. We asked twenty questions focused on the restoration process and obtaining organisms for restoration, climate change, and moving species in response to climate change. A strong majority of respondents (75%) believed that the practice of restoration should be modified to anticipate climate change. For example, the practice of setting restoration goals to match historic conditions may become infrequent or discarded (65%). Many practitioners were cautious about moving species in response to climate change. Moving species beyond their historic range was unpopular but moving species within their historic range was generally acceptable. Also, respondents were somewhat (42%) or very (55%) concerned that species moved in response to climate change could become invasive. These survey results suggest many commonalities among restorationists regarding the major issues they face while conducting restoration, obtaining organisms, and responding to climate change. In particular, there is widespread agreement that restoration should respond to shifting climates but exactly how to respond remains controversial.

Integrating Prairie Habitat Components Into Trails Crossing Urban Environments To Assist Dispersal

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Urbanization in the northern Willamette Valley forms a nearly continuous band stretching from the Coast Range to the Cascade Range, and recent urban planning is closing the last north-south gap in the urban growth boundary. The urban matrix is not entirely inhospitable to native wildlife and plants; many species appear to fare well in the urban environment. However, prairie species are generally not supported there and are relegated to surrounding farmlands and reserves. As the east-west urban barrier solidifies, climate change is expected to create conditions that will force many organisms to shift their ranges northward and/or to higher elevations. The network of urban riparian corridors, parks and natural areas will help many species begin those movements and range shifts. Unfortunately, the lack of contiguous open habitat stretching northward through the UGB may block successful dispersal by organisms that require it. One potential remedy is to improve habitat in linear open areas such as power line corridors. We are pursuing this strategy as we plan the Westside Trail project, which follows a north-south power line corridor for approximately 19 km from the Tualatin River south of the urban area to the Willamette River and Sauvie Island north of it. The power line corridor varies from about 46 m to 76 m in width and provides an opportunity for integrating prairie plants into trail design. We intend to provide habitat for grassland wildlife, pollinators and the plants they depend upon. Our work will be in partnership with other trail planners, landscape architects, scientists, local park providers and neighbors along the trail corridor.

SESSION D
DISTURBANCE ECOLOGY AND PLANT CONSERVATION

Biocultural Diversity: The Relationship Between Cultural Complexity And Ecological Diversity On The Northwest Coast Of North America

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How might a better understanding of pre-settlement indigenous land management practices inform the work of biodiversity conservation on the Northwest Coast? Prior to Euro-American settlement, Northwest Coast First Peoples actively tended meadows and prairies from the coast to the mountains in order to enhance the production of culturally important plants. The use of fire and other management practices likely played an important role in shaping the biocultural diversity that Euro-American settlers observed when they first arrived. This presentation summarizes recent scholarship on the linkages between biocultural diversity and pre-settlement indigenous management practices amongst the Coast Salish of Washington State, using specific plants and habitats as examples. The presentation will also discuss the role that these anthropogenic disturbances, as well as the cessation of them, have played in shaping ecological diversity and landscape heterogeneity.

Early Effects Of White Pine Blister Rust (*Cronartium ribicola*) On White Pines In Arizona And New Mexico

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White pine blister rust (*Cronartium ribicola*; WPBR) is an invasive fungal pathogen causing widespread mortality in North American five-needled pines. WPBR was first detected in most white pine species in the early 1900's, limiting research in unaffected ecosystems and reducing the potential for proactive management. The Southwest provides a unique opportunity to document the initial impacts of the disease on understudied white pine species. We documented WPBR distribution and white pine forest structure throughout Arizona and New Mexico. In addition, we investigated the effects of WPBR on white pine growth rate and vigor. We randomly installed 50x20 m permanent plots in stands containing white pine basal area exceeding 6.9 m2 ha-1. We recorded species, diameter at breast height (DBH), WPBR presence and severity, height, crown dimensions, and Hegyi's competition index for white pines >12.7 cm DBH. White pine faces heavy competition, and WPBR distribution is localized. We will present results related to growth impacts of WPBR, environmental and community influences on white pine forest structure and overall white pine competiveness. Our results will help inform the conservation of

white pines across the West through better understanding white pines' ecological roles in the absence of WPBR, and the early effects of WPBR on tree growth. Growth decreases may negatively affect the ability of trees to compete successfully, further affecting white pine population fitness and complicating conservation efforts.

Rare Plants Colonize Disturbed Habitat At Rocky Point, British Columbia

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At Rocky Point, Vancouver Island, BC, ***Limnanthes macounii*** and ***Epilobium densiflorum*** have recently been discovered growing in a fire break that is tilled twice each year. Both of these are annual plants that are usually associated with vernal pools and both are rare species, protected under the Species at Risk Act. The highly disturbed fire break appears to provide a largely competitor-free environment where these species are thriving. Populations in the fire break are orders of magnitude larger than any other known Canadian populations. The presence of these listed species in such a disturbed habitat raises questions about how these species should be managed, how natural and manipulated populations should be weighted in conservation planning, and what kind of sites should be selected for reintroduction or recovery efforts.

Indigenous Landscape Management, Recent Government Policy, And Restoration Efforts In Mountainous Landscapes In Washington And Sichuan

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The Yakama of Washington and Nuosu Yi of Sichuan are indigenous peoples living in mountain environments. For millennia they lived free of governmental authority, managing landscapes of forests and meadows to yield sustainable supplies of food, medicine, fuel, construction materials, and other subsistence goods. In recent decades the Yakama and Nuosu have lost their political autonomy to government control, including environmental regulation: in Washington most importantly fire suppression and management for timber yields; in Sichuan forest clearings to expand agriculture and to fuel construction. This has resulted in biodiversity loss of both woody and herbaceous plants, changes in species composition (from predominantly ***Pinus ponderosa*** to ***Pseudostuga Menziesii*** in Washington, and from mixed conifer and broadleaf to primarily ***Pinus yunnanensis*** in Sichuan), and changes in patch

structure. We examine effects on biodiversity, species composition, and patch diversity from 1) The traditional landscape management practices of the Yakama and Nuosu; 2) governmental regulation in the last 150 years in Washington and the last 60 years in Sichuan, and 3) current efforts at landscape restoration undertaken with active participation and leadership by Yakama and Nuosu.

Managing Hydrology For Native Wetland Plants

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The conditions predicted by many climate models may cause early drying of some Pacific Northwest wetland systems, providing inhospitable conditions for late-season native emergent plants and favoring reed canarygrass (***Phalaris arundinacea***) and other non-natives. Water level management has been used to control invasive reed canarygrass in floodplain wetlands by holding water from winter storms to flood and suppress it during spring and early summer. As water is subsequently drawn down, warm-season native plants emerge and grow. Using this strategy, wetland managers can maintain native wetland plant communities, at least temporarily, despite disrupted precipitation and flooding patterns. Research at Smith and Bybee Wetlands in Portland, Oregon, is providing cues to the phenology of native emergent plants and their relationships to hydrology. We conducted intensive vegetation and hydrological monitoring in 2003 (prior to structure installation), 2004, 2008 and 2009. We randomly established 26 permanent transects (cumulative length of 2.4 km) within the elevation zone that would be most influenced by the managed flooding and estimated the percent cover of all vegetation along the transects at 10 cm intervals. Results show increased cover of native plant communities and reduced cover of reed canarygrass. Native Columbia sedge (***Carex aperta***), water-smartweed (***Polygonum*** spp.), and Pacific willow (***Salix lucida*** ssp. ***lasiandra***) cover increased. We will show the relationships of selected native plants to timing, depth and duration of flooding and discuss the potential for hydrologic management to sustain native communities when water availability is uncertain and water control structures are available.

Ecology And Human Use Of Montane Meadows: Connecting The Conservation Of Cultural Landscapes In Sichuan, China To Northwestern North America

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Over the past decades there has been increased recognition throughout northwestern North America and elsewhere that traditional land-use has played a key role in shaping patterns of biodiversity.

Simultaneously, traditional land-use has declined globally; memory of traditional practices resides largely in older generations. There is, a strong need to understand the role that human land-use has played in shaping patterns of plant biodiversity in order to develop solutions for managing cultural landscapes before knowledge of these systems is gone. Jiuzhaigou National Park is an UNESCO World Heritage Site and Biosphere Reserve located on the eastern rim of the Tibetan Plateau in Sichuan Province, China. 1154 Tibetans reside within 4 villages in the park; traditionally agro-pastoralists, their lifestyle is restricted based on an assumption that traditional land-use negatively alters "natural" Park landscapes. An alternative view suggests traditional land-use may have been important for maintaining meadows and other disturbance adapted habitats. We use Jiuzhaigou as a case study examining the role of traditional land-use in maintaining landscape heterogeneity in a largely forested montane ecosystem. We combine time-series analysis of satellite images, vegetation sampling, repeat photography, GPS mapping, and interviews with local elders and Park staff to document rates of meadow encroachment, meadow species composition, and the cultural value of meadow species. Through this analysis we gain an understanding of the cultural-ecological processes that maintain floristic diversity in meadow habitats over time. We relate our findings to biodiversity conservation in cultural landscapes of northwestern North America.

There Goes The Neighborhood: Invasion Affects Foraging By Multiple Pollinators, Causing Floral Neighborhood-Contingent Reproductive Success In Native Plants

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Invasive plants can either compete with or facilitate pollinator visitation to natives, thereby influencing native seed production and ultimately, local biodiversity. To explore the indirect effects of invasion on native fitness, we compared pollinator visitation and seedset of two native Pacific Northwest prairie forbs ***(Microseris laciniata*** and ***Eriophyllum lanatum)*** and an exotic forb ***(Hypochaeris radicata)*** in three floral neighborhoods: (i) naturally occurring high native floral density with concomitant low floral density of exotic ***H. radicata***, (ii) naturally occurring high floral density of exotic ***H. radicata***, and (iii) manipulated low ***H. radicata*** floral density produced by clipping inflorescences. High exotic density neighborhoods reduced visitation and seedset for native ***M. laciniata***, but facilitated visitation and seedset for native ***E. lanatum*** and ***H. radicata***. Total pollinator visitation varied by floral neighborhood for each plant species, and major pollinator groups (eusocial bees, solitary bees, and flies) differed in their responses to neighborhood. Consequently, pollinator groups contributed differing proportions of total visitation to a plant species depending upon neighborhood. Our results show that (1) floral neighborhood affects the number and composition of pollinators visiting a plant; (2) the importance of a given pollinator group to reproduction of a given plant can be contingent on floral neighborhood; and (3) the effects of invaded floral neighborhood on foraging by different pollinator groups can lead to either competitive or facilitative effects on native plants. Management plans for invaded plant communities should consider pollinator-mediated interactions and how invasion may influence native fitness through pollinator-mediated effects.

Using Prescribed Fire And Glyphosate To Manage The Invasion Of Native Prairie By Indigenous Trees, Shrubs, And The Exotic Invasive Grass, Smooth Brome, (Bromus Inermis), In Saskatchewan, Canada

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A long-term study to develop a best management practice (BMP) for controlling the invasion of indigenous trees (trembling aspen, balsam poplar, and white spruce) and snowberry, and an exotic invasive grass (smooth brome) into remnant native grasslands was initiated in three provincial parks in Saskatchewan in the early 1990s. Suppression of the natural fire regime has allowed the encroachment of indigenous trees and shrubs into native grasslands in these parks. Several prescribed fires were undertaken between 1994 and 2008, to control woody species invasion into these remnant grasslands. A wicked application of glyphosate to smooth brome (***Bromus inermis***), a vigorous and invasive exotic grass, was incorporated into the control program in 2008. Prescribed fires are successfully controlling native tree and shrub invasion but the combination of burning and glyphosate wicking seems to be more effective for smooth brome control than either fire or glyphosate alone. Height differentials between the invasive exotic grass and native plants is essential for effective, low-risk wicking with herbicide but three years of monitoring indicates that sufficient height differentials may only occur early in the first summer following spring prescribed burning. Multiple disturbance types and a long time frame are essential for the development of the best management practices (BMPs) needed to restore these native grasslands.

***Silene seelyi* by Rod Gilbert**

SESSION E
RECOVERY OF RARE SPECIES AND THE RESTORATION OF THEIR HABITAT

Investigating The Role Of Host Plants In Recovering Golden Paintbrush

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The prairies of western Washington are one of the most endangered ecosystems in the United States. Several rare and endangered species are associated with this habitat, including ***Castilleja levisecta*** (golden paintbrush), a federally threatened hemiparasite. The recovery of rare, parasitic plants such as ***C. levisecta*** is a challenge for restoration practitioners as the species may be limited by their host plant requirements in addition to the usual issues such as small population size. There is currently limited information on the host requirements of ***C. levisecta***. Furthermore, we do not know whether the importance of host plants varies with the size of the ***C. levisecta*** plant. We tested the effects of host plant (none, ***Festuca roemeri***, or ***Eriophyllum lanatum***) and pot size (49 or 393 ml) on the performance of ***C. levisecta*** ouplanted in a tilled field. Preliminary results indicate that host plants positively affected survival and fecundity compared to controls, and that ***C. levisecta*** performance varied with host plant identity. Pot size had no effect on first-year performance. To date, recovery efforts have focused exclusively on restoring ***C. levisecta*** to extant prairies. Our research provides a new approach to recovery of ***C. levisecta*** by demonstrating that it can be outplanted in severely degraded sites with no native component present. We are continuing to track plant performance in this experiment and are replicating it to confirm the generality of these results under different climatic conditions. Further research should examine the performance of ***C. levisecta*** when growing with other potential host plants.

A Decade Of Restoring Golden Paintbrush (*Castilleja levisecta*) In Washington: Where Are We, And What Have We Learned?

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Golden paintbrush was listed as a threatened species in 1997. Since development of a species recovery plan in 2000, recovery actions have addressed a diversity of inventory, monitoring, research, protection, and restoration efforts. Restoration objectives have specifically focused on increasing the number, size, and geographic distribution of golden paintbrush populations using three primary strategies: 1) Enhancing the viability of extant populations by increasing the number of flowering individuals through augmentation planting, 2) Establishing new populations, and 3) Enhancing the suitability of habitats for sustaining viable populations. Of the ten extant populations in Washington, augmentation plantings have been carried out in four, and three of these are increasing significantly. At 14 sites, both outplanting and seeding have been used to establish new paintbrush populations. The future of six of these remains uncertain, with significant mortality and little new recruitment; three others are small but growing, one is increasing rapidly, and four have been abandoned. Habitat enhancement in extant and new populations (via burning, cutting, herbiciding, and mowing) has reduced competing vegetation at many sites, as well as reduced grazing damage (via fencing, caging, and prescribed burning). Overall, success appears to be dependent upon a combination of identifying suitable sites, locating and enhancing appropriate microsites within appropriate habitat, establishing sufficient numbers of flowering plants to ensure abundant propagule production and dispersal, and reducing the impacts of key threats. Progress has been hindered particularly by continued uncertainty regarding the characteristics of suitable sites, microsites, and host plants

Risk Tolerance And Rare Plant Conservation In Pacific Canada

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Risk tolerance in rare plant conservation may range from very low (based on worst case scenarios) to moderate (based on the precautionary principle) to high (based on evidentiary approaches). Conservation documents relating to rare plants of Pacific Canada show wide variations in implicit risk-tolerance. Examples will be drawn from work dealing with species assessment, goal-setting for recovery, and protection for critical habitat. Particular attention will be paid to plant species that are addressed by the Garry Oak Ecosystems Recovery Team and the Coastal Sand Ecosystems Recovery Team. Overall risk-tolerance scores were discovered to vary considerably between conservation subjects, with low risk-tolerance typical during the species assessment process and high risk-tolerance accepted in goal-setting and habitat protection.

Determining The Most Efficient And Effective Large-Scale Native Seeding Techniques To Restore Native Species To Degraded Prairies

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Native prairie habitats have been nearly extirpated from the Pacific Northwest due to altered fire regimes, habitat fragmentation and invasive species. Past efforts to restore these landscapes have focused primarily on outplanting containerized seedlings of native plant species, an extremely labor-

intensive approach. Large-scale seeding may be a viable option to increase efficiency, although it is unknown which seeding techniques are most effective for germination and establishment of rare prairie species. Because seed availability is often a limiting factor in large-scale restoration, it is also important to evaluate seed application rate to determine the lowest rate that provides the desired density of adult plants. We assessed three seeding techniques (drill, broadcast, hydroseed) and five seed application rates (0, 2, 4, 6, 8 lbs/acre) on germination and establishment of three native prairie species (***Festuca roemeri, Eriophyllum lanatum, Erigeron speciosus***) in a large-scale, spatially- and temporally-replicated experiment in western Washington. We found that the site in which treatments were applied was more significant than the method used, suggesting spatially-dependent environmental limitations on germination. There was a general increase in seedlings with increased application rates, but saturation occurred at 4 to 6 lbs/acre at most sites. Native species richness at the restoration site was the variable most strongly positively correlated with germination, suggesting that facilitation may play a large role in native plant establishment. These results will help managers select for habitat variables that support native plant establishment and utilize the most effective and efficient seeding techniques for large-scale restoration of Pacific Northwest prairies.

Ecological Drivers Of Seedling Establishment And Survival Of Endangered Prairie Plants

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Identifying the mechanisms that determine who lives and who dies is the first step in developing successful restoration techniques for rare species and endangered habitats. We studied interactions that affect establishment of native plant species at the seedling stage to support the theoretical basis for restoration activities in Pacific Northwest prairies. Specifically, we tested the hypothesis that seedling establishment is controlled by 1) competition with or 2) facilitation by existing vegetation. We seeded ***Lupinus oreganus***, a threatened perennial, into 20 plots with a wide range of grass in high-stress upland prairies at each of three sites. We counted seedlings and estimated cover of plant functional groups as well as litter, bare soil and disturbance. We used linear regression to test for effects of these factors on seedling establishment. We found evidence of indirect facilitation of seedling establishment in the first year by grass: higher accumulations of leaf litter increased ***L. oreganus*** seedling numbers at two sites. In the second year, there was evidence of facilitation by live vegetation and litter at one site, but no net effect of either competition or facilitation at the other two sites. Overall, we found more evidence for positive interactions than we did for competition. In particular, litter appeared to have a positive effect on seedling establishment for this species. This is contrary to the common perception that litter inhibits plant establishment but supports the theory that facilitation is more

Recovering Species On The Edge: Garry Oak And Associated Ecosystems In Canada

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The Garry Oak Ecosystems Recovery Team (GOERT) has been implementing species recovery under an ecosystem-based recovery strategy for more than 10 years. With more than 100 species at risk and only fragments of the historical landscape remaining, our approach has been to manage for individual species at risk as well as the broader landscape. This multi-scale recovery program, involving many organizations, governments, institutions and individuals, has encountered difficulties and celebrated successes over the last decade. We will outline some of our results to date, present examples of successful projects, and discuss challenges that we have faced. Some of our greatest challenges have been protecting species and habitats on private land, deciphering species needs and learning how to propagate rare species, and the need to do more recovery with fewer resources. Our greatest successes have been the result of dedicated collaboration by partner agencies working in Recovery Implementation Groups. These groups focus on approaches to recovery laid out in the ecosystem strategy and they have completed much of the required recovery planning, developed tools and resources for recovery action, and have developed a substantial body of knowledge about rare species, as well as Garry Oak and associated ecosystems. It may be argued that an ecosystem-based approach to rare species recovery is complicated and unwieldy, but our results demonstrate that it is both effective and sustainable.

Welcome Back: Reintroduction Of Golden Paintbrush (*Castilleja levisecta*) To Oregon

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Golden paintbrush is listed as Threatened under the Endangered Species Act (ESA). The objective of this talk is to outline the process used for reintroducing golden paintbrush into prairie habitat in the Willamette Valley, Oregon. Historically the species was found in the Willamette Valley of Oregon, the Puget Sound region of Washington, and British Columbia. Its global distribution has been reduced to twelve populations, and it has been extirpated from the wild in Oregon since 1938. The Recovery Plan calls for reintroducing the species to 5 protected locations in Oregon, with the goal of sustaining populations with more than 1,000 plants. Habitat in the Willamette Valley is poorly understood compared with existing populations in Washington and B.C. Multiple pathways of inquiry within the historic Oregon distribution, including the Golden Paintbrush Challenge, media ads, and outreach materials confirmed the regional extirpation of the species. Field surveys were conducted at historic locations and 10 sites characterizing the historic conditions were selected to test the species performance. Using an adaptive management approach, sites showing the highest survival were selected and planted with 500-1000 seedlings in 2011. Seeding methods were also tested and opportunistic seeding will be implemented at sites where seeding proved successful. This translocation addresses climate change through production and planting of genetically diverse seed (3 pounds produced in 2011 from 4 sources), planting into a diversity of sites along moisture gradients, and emphasizing sites with high native cover. Significant progress is underway toward recovery of golden paintbrush in the Willamette Valley.

The Status Of Recovery Planning For Federally Listed Plant Species In Canada

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Since the enactment of Canada's Species at Risk Act (SARA) in 2003, 138 vascular plant species have been listed as Endangered, Threatened or Extirpated. Under SARA, species in these three risk categories require the development of a recovery strategy and a recovery action plan to set out goals and actions to aid in species recovery. To date, fewer than half (58 of 138) of these recovery strategies have been finalized, and only 2 plants have finalized action plans. We conducted an analysis that aimed to identify the features of species for which finalized recovery strategies have been produced. We considered features of the species' distribution and status outside Canada among the potential explanatory variables. We then examined finalized recovery strategies and their objectives. Our analysis considered the scope of population and distribution objectives, the nature of the documented threats, and the basis for critical habitat designation to evaluate the likelihood that significant recovery is possible under the plan. The formalization of recovery strategies and action plans are by no means the only tools for achieving progress towards recovery. But as a cornerstone of Canada's strategy for preserving biodiversity, the SARA legislation is expected to produce significant progress in protecting and recovering species-at-risk. Our analysis points to deficiencies in achieving the aims of the legislation.

Hanford Reach National Monument by Wendy Gibble

SESSION F
REINTRODUCTION IN A CHANGING WORLD: HOW WELL IS IT WORKING, HOW CAN IT BE DONE BETTER, AND UNDER WHAT CIRCUMSTANCES IS IT APPROPRIATE OR NOT?

The Role Of Reintroduction In The Recovery Of *Fritillaria gentneri*: Current Successes And Future Directions

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Fritillaria gentneri (Liliaceae) is listed as endangered by Oregon Department of Agriculture (ODA) and U.S. Fish and Wildlife Service (USFWS). A Recovery Plan for this species, including recommendations for population augmentation and reintroduction, was released by USFWS in 2003. To initiate implementation of the Plan, ODA, in cooperation with the Bureau of Land Management, USFWS, and other partners, documented sexual and asexual reproduction in this species, developed protocols for producing transplants, and began creating and augmenting populations as specified. To determine the potential for using wild-collected seed in recovery projects, we evaluated seed production in naturally occurring populations. In the first year, no fruits were produced in response to 189 within-population pollination treatments. Later studies documented that flowers pollinated with pollen from distant populations did produce seed, but at low levels. Low field seed production, combined with the propensity for fritillaries to produce interspecific hybrids, limits the value of collecting field-produced seed for recovery projects. Fortunately, mature fritillaries produce many bulblets that can be collected and cultivated under nursery conditions. Recovery efforts since 2004 have focused on cultivating these bulblets to a robust size, then transplanting them into suitable sites within the Recovery Unit from which they were collected. By 2011, 17,391 bulbs had been transplanted into 17 sites. Over 4000 of these transplants emerged in 2011 and some are beginning to flower. Currently, we are evaluating the potential value of mixing transplants grown from geographically disjunct propagule sources in order to promote seed production in created populations.

Spatial And Temporal Variation In Plant Establishment

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Experiments under carefully controlled conditions, as in a greenhouse, have been criticized as having limited applicability because they do not adequately reflect the heterogeneity of natural environments. This heterogeneity, arising from multiple sources, can affect the success of plant reintroductions. Our objective was to understand how spatial and temporal variability affected plant establishment in a field restoration experiment. We conducted this experiment at four sites (two each in North and South Puget Sound) and in three seeding years (2009-2011), for a total of ten site-year combinations. Sites were abandoned agricultural fields initially dominated by non-native grasses. We killed the extant vegetation with glyphosate, burned the site to remove litter and expose bare ground, re-applied glyphosate to kill seedlings that germinated after the fire, broadcast seeded a diverse mixture of 20-26 native species in autumn, and measured establishment (species richness, cover, and density of seeded species) in spring of the next year. Establishment was greater in North than South Puget Sound, and varied more among years than among sites within regions. Inferring when and where to apply experimental results requires understanding how the experimental conditions compare to the range of conditions expected in other sites and years. Reintroductions to new regions should be experimentally tested there rather than assuming that results from elsewhere are directly applicable. It is more difficult to incorporate temporal variability into reintroduction planning, but our results suggest that without temporal

Staged-Scale Restoration: A Systematic Approach For Improving Restoration Effectiveness

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In many ecosystems, restoration is increasingly focused on developing communities ***de novo,*** such as creating prairies in abandoned agricultural fields. These efforts often face formidable challenges in controlling invasive weeds, selecting appropriate native species to match local site conditions, developing effective methods to establish species assemblages, securing adequate quantities of seed for desired species, and directing successional processes with appropriate management tools. Often, practitioners decide upon a restoration strategy based on anecdotal observations, inferences from past experience at other sites, extrapolations from ecological theory, and educated guesses. This can result in failures that are both costly and time-consuming. We have developed a "staged-scale" restoration strategy that rigorously explores multiple solutions to these problems in an adaptive management context, and promotes the development of more effective restoration protocols that are tailored to particular site conditions. This strategy begins by identifying several promising restoration approaches, selecting those that can be feasibly applied at large scales, and testing them first in small, replicated

experimental plots. Based on the results of these small-scale tests, the most successful treatments are applied in scaled-up plots (e.g., 10x area) while incorporating refinements suggested during the small-scale experiments. Restoration proceeds in steps by continuing to scale up the most successful approaches, building on accumulating experience. By delaying treatment of large areas until later in the process, effectiveness is enhanced, and the likelihood of large, costly failures is reduced. The additional time before treating large areas also allows practitioners to increase essential resources, such as seed quantity and diversity.

Experimental Reintroduction Of Pink Sand-Verbena To Vancouver Island

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Pink Sand-verbena (***Abronia umbellata***) has been collected from British Columbia three times over the past century, including one occurrence of a transient population along Clo-oose Bay in 2000. Widespread surveys since 2003 have failed to locate any extant populations so a re-introduction program was initiated using plants grown from seeds collected in 2000. A greenhouse-based program was used to create a large reserve of seeds and to propagate seedlings for outplanting to three locations. Some outplanted individuals grew well and produced abundant seed. No plants managed to successfully overwinter. Microhabitat conditions appeared to play a role in outplanting success. There was limited recruitment from the seed bank created by outplanted individuals, and those plants which did germinate tended to produce little or no seed. It appears that in many years, Pink Sand-verbena is unable to thrive on the beaches and dunes of Vancouver Island without assistance. Anecdotal evidence, however, suggests that it may be able to persist by replenishing its seed bank in exceptional years, perhaps when favourable weather conditions prevail.

Is Managed Relocation Of Rare Plants Another Pathway For Biological Invasions?

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Most rare plant reintroductions are conducted within the historic geographic range of the species into previously or currently occupied sites. With climate change reintroductions may need to be potentially far outside that range. There is concern that these introductions will become biological invasions, causing environmental problems. We examine the theories of invasion biology including biotic resistance/resilience, propagule pressure, and the traits of invasive and rare species to evaluate managed relocation of rare species outside their ranges with regard to these theories. Using established Weed Risk Assessment (WRA) methods, we compared rare species introduced to Florida for conservation with

species introduced for horticultural use. We used Florida as a test because 1) an internationally accepted WRA has been validated for Florida and 2) local botanic gardens provided unique data on previous introductions. We found that WRA provides a useful method for evaluating the invasive potential of rare species that can be extended to other geographic areas. Each species and each reintroduction site must be considered individually, but managed relocations may be a safe way to preserve some species under global climate change.

Salix tweedyi **by Bob Jackson**

SESSION G
STRATEGIES FOR IMPLEMENTING CONSERVATION: PARTNERSHIPS, OUTREACH, AND PUBLIC ENGAGEMENT

Kincaid's Lupine (*Lupinus oreganus*) On Boistfort Prairie: A Conservation Success Story

Joseph L. Arnett[1]

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In 1986, during a floristic inventory of the Willapa Hills, Cathy Maxwell discovered a small population of Kincaid's lupine by an old cemetery in the Boistfort Valley in Lewis County, Washington. This species had previously been considered to be a Willamette Valley endemic; six years later, she noticed another small patch in a pasture nearby owned by John and Mary Mallonee. Her discoveries took on greater significance in 2000, when Kincaid's lupine was listed as threatened under the Endangered Species Act, and the Mallonee's land was proposed as critical habitat. Because their organic dairy practices appeared to provide ideal habitat conditions for the lupine, the Mallonees were able to prepare a management plan as an alternative to having their land designated as critical habitat. The plan, developed with support from federal and state agencies, was the beginning of a rewarding relationship between the Mallonees and the broader conservation community. The Mallonees have been enthusiastic about the rare plants on their property and that its habitat needs are compatible with their use of the land. With support from Organic Valley Family of Farms, for the past five years the Mallonees have sponsored a "Lupine Field Day" in Boistfort. A slide show is presented in the grange hall, free lunch is provided by Organic Valley, and the Mallonees lead field trips through the prairie habitat on their farm. An added benefit has also appeared: four additional species with state rare plant status have been found on their land in the subsequent years.

Tanoak Refuge: Intervention For A Threatened Traditional Food Plant

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A century ago a non-native disease inadvertently introduced on an infected garden plant began to spread in North America's eastern deciduous forests. Within decades the once widespread American chestnuts succumbed to chestnut blight and no longer produced nutritious nuts for people, livestock, and wildlife. Today, a similar fate may await a West Coast native nut tree: tanoak (***Notholithocarpus densiflorus***). Since the horticultural trade accidentally introduced sudden oak death (SOD) to North

America, over a million tanoaks have died and an unknown number are infected. First detected in California in 1995, this exotic disease is spreading despite government efforts. Currently no cure exists and thus far tanoak exhibits little genetic resistance. Fortunately large areas remain uninfected. The southern most tanoak populations near Santa Barbara and inland populations away from the coast are probably too dry to support SOD. However, computer models rank uninfected areas on the north coast of California as high risk for infection. Plant pathologists recommend timely establishment of tanoak refuges prior to the projected exponential growth of North American SOD populations estimated to occur roughly in 2016. Based on spatial analysis, potential refuges are identified. Traditional ecological practices that foster tanoak wellness are also explored. Lessons learned from the chestnut blight response are discussed in relation to the current threat to biodiversity posed by SOD. Tanoak deserves more conservation attention due to its cultural and ecological importance. This magnificent tree, along with its relative American chestnut, remind us that even common plants can rapidly become threatened.

The New Native Seed Network

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Prior versions of the Native Seed Network have presented an online directory to seed suppliers and profiles of commercially available native plant materials. The new Native Seed Network complements this with a social platform for collaboration, bridging the gap between academic journals and your personal inbox. This online community is an accessible and informal way to advance the goals of plant conservation. The site offers public and private workspaces for sharing information and experiences among an audience of conservation professionals. Discussions, wikis, and document repositories are all available within a group context to facilitate organization of content and build partnerships. Groups are regional or topical and can originate organically to address emerging interests. As participation in the community increases, we are building an invaluable repository of our collective experiences with the multiple facets of plant conservation, from collecting seed and growing seedlings through restoring and maintaining ecosystems. This talk will provide (1) an overview of this new tool, (2) a tutorial on how to get engaged, and (3) discussion about the needs of the audience and how online collaborative tools can – and can't – meet them. Ultimately, the new Native Seed Network is offered as the place to continue the conversations taking place at this conference, build relationships among attendees, and advance the science and practice of conservation.

Don't Believe That Database! Potential Problems With The Use Of Digital Herbarium Records In Plant Conservation

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The availability of digitized herbarium records facilitates documentation of past and current plant distributions and abundances. However, information from databases can potentially mis-inform conservation and restoration. While some problems are common to collections whether they are digitized or not, others are unique or more likely to go undetected if specimens are not examined. Data entry mistakes, and challenges with specifying geolocations can introduce errors or uncertainty to inferred distribution ranges. Furthermore, when data are shared among institutions, data integrity can be eroded, as updates to specimens at the source may not reach these peripheral resources. These sources of uncertainty will have a greater impact on species with few known locations, which includes many of the targets of conservation. We will use examples from BC rare plant data to illustrate some these features of databases, and discuss their possible impacts on conservation efforts. Our key recommendation is that while such digital resources provide a gateway to the wealth contained in collections, validation through direct accessing of the collections and verifying and vouchering observational reports remain vital components of our efforts to document the flora.

"From Salmonberry To Sagebrush" - Engaging The Public In Native Plant Curricula

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Resource Professionals and teachers are challenged to find environmental curricula that are placed-based and relevant to engaging the public and students outdoors. *"From Salmonberry to Sagebrush: An Exploration of Native Plants"* is an innovative framework model that can be applied nationwide. Designed to be ecoregionally-based, the curriculum gives professionals the tools to customize lessons for the place they work. The workshop session will lead professionals through history and guidelines for developing native plant curriculum. Participants will be given hands on exploration of sample lessons followed by guidelines for adapting the curriculum to their region. All participants will be given a free copy of the curriculum. The book includes seven chapters: Plant Identification; Ecoregions; Ecology of Native Plants and pollinators, Natives/non native plants, Ethnobotany, Climate Change/Native Plants; and The Future of Native Plants. The chapters explore interactions between plants, soil, animals, people, and climate change. The curriculum works to connect professionals to resources in their ecoregion leading to meaningful community service, and engaging the public in citizen science that is relevant to both the learner and the community. Lessons introduce the public to the skills needed to work on local conservation projects and encourage building agency partnerships.

Sisyrinchium sarmentosum (Pale Blue-Eyed Grass) Conservation Strategy And Agreement

Andrea Ruchty[1]

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Sisyrinchium sarmentosum is a small member of the Iridaceae family found in south-central Washington and north-central Oregon, where it grows in seasonally wet meadows. There are twenty-two documented occurrences of *S. sarmentosum*, worldwide. *S. sarmentosum* is a Forest Service Region 6 Sensitive Species in both Oregon and Washington. In 2009, the U.S. Fish and Wildlife Service announced a 90-day finding on a petition to list *S. sarmentosum* as threatened or endangered under the Endangered Species Act; this finding determined that listing of this species may be warranted. Region 6 Forest Service Sensitive Species policy requires the agency to maintain viable populations of all native species in habitats throughout their geographic range. In addition, management actions must preclude a trend towards federal listing. A Conservation Strategy and Conservation Agreement were prepared to address these objectives for *S. sarmentosum*. The Conservation Strategy describes the management actions necessary to maintain a high likelihood of well-distributed populations across the species' range, and avoid a trend toward federal listing. The Conservation Agreement formally documents the responsibility and timeline for achievement of these actions. The *S. sarmentosum* Conservation Strategy and Agreement were prepared through collaboration between the Forest Service, other federal and state agencies, academia, and private entities. This presentation describes the collaborative process used to develop these documents, a powerful approach to conservation of a rare species on federal land.

***Synthyris pinnatifido* var. *lanuginosa* by Richard Ramsden**

SESSION H
TAXONOMY, ECOLOGY, AND POPULATION DYNAMICS OF RARE AND ENDANGERED PLANTS

Decline And Persistence Of Persistentsepal Yellowcress (*Rorippa columbiae*) In Remnant Free-Flowing Segments Of The Columbia River In Washington

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Rorippa columbiae, endangered in Washington, is a prostrate rhizomatous perennial that grows between high and low water levels on riverbanks and lakes; the two known occurrences in Washington occur in cobbles along the Columbia River. Along the Hanford Reach, the Bureau of Land Management has monitored island sites on five permanent transects. Populations have plummeted, from counts of approximately 3,200 stems in 1994 to 30 stems in 2009. Pacific Northwest National Laboratory has monitored numerous other sites since 1991. Populations have declined since 1993 at downstream locations, persisting at higher riverbank elevations than previously. Conversely, botanists have also observed extremely large numbers of stems in some areas and have reported the appearance of plants in new areas. Although sexual reproduction may be limited by inundation, plants appear to thrive when water levels decrease long enough for plants to emerge and grow. Downstream from Bonneville Dam, The Nature Conservancy monitored an occurrence in 1991 and 1992 on six permanent transects and more recently has recording the presence or absence of the species in each of 425 40-meter GIS generated hexagons. Presence has varied from 13 percent in 2000 to 33 percent in 2001, with intermediate counts in 2007. We speculate that most riparian habitat for this species was lost as dams were constructed along the Columbia River. More recent changes are likely due to higher water levels remaining into summer and fall. Siltation and invasion by noxious weeds, notably false indigo (***Amorpha fruticosa***) in the downstream population, may also exacerbate decline.

Lessons Learned About Practicable Rare Plant Monitoring

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Many monitoring efforts prove to be too labor intensive to be continued regularly or consistently and fail to adequately document population trend or size. Recovery planning requires population records extending for years and according to defined criteria. We recommend that monitoring be prioritized to achieve, by the simplest, least labor intensive, and most repeatable method, the following three

objectives: **An estimation of population size, using the criteria in the species recovery plan**: A simple count of flowering individuals may be the quickest and most precise method of tracking population size; a few rhizomatous species are tracked by estimates of foliar cover. Labor intensive measurements of plant dimensions are more often collected than analyzed, likely to vary more widely than population size, and may draw resources away from frequent population monitoring. If required, numbers of vegetative plants may be extrapolated from a sample. **An efficient method for detecting trend over time**: In populations several times larger than the recovery criterion for size, transects in marginal areas may be effective for monitoring expansion or contraction of the population; frequent census may not be necessary. **A spatial record of distribution:** Maintaining data according to explicitly defined subareas provides opportunities to evaluate spatial changes; it also allows observations of portions of large populations to be tracked, even when monitoring the entire population cannot be accomplished. The design of a spatial arrangement depends on the characteristics of each site. Finally, we stress the importance of an accessible and secure central repository for data.

Vascular Plant Endemism In Northwestern North America: Mapping Regional Endemics And Detecting Hotspots With A Biogeographical And Conservation Context

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Vascular plant conservation efforts often favor regions identified as hotspots of endemism, necessitating that all hotspots be identified non-subjectively within a greater geographical context. The present study is the first in northwest North America applying non-subjective methods to detect hotspots of endemic vascular plants. From the native flora northwest North America, 1723 taxa were retained after filtering taxa more widespread than an upper threshold of geographical extent. Border endemics (straddling the boundary of the study area) were retained. Using an even grid, herbarium and selected literature records were entered as presence/absence data for each grid cell. Values were calculated both for endemics richness and endemicity scores. The Siskiyou region of southwest Oregon and adjacent California is richest in regionally endemic plants of the highest endemicity scores. Other major hotspots occur elsewhere in Oregon, Idaho and Washington. Some regions identified as hotspots in previous studies were found to have only low to moderate richness of regionally endemic plants and endemicity scores. Nearly the entire region that was under continental ice sheets during the Pleistocene is very poor in regional endemics. Southern unglaciated regions are generally much richer in endemics and of higher endemicity than northern unglaciated regions. Factors of climate, geology, glacial history and vegetation are cited as likely causes of some regions' richness of endemics and high endemicity, and current threats to hotspots are highlighted. These results underscore the importance of non-subjective identification of regional endemics, and the need to avoid considering only jurisdictional endemics in conservation efforts.

Rare Plants In Uncommon Ecosystems: Informal Fen Studies On Five PNW National Forests

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Funding from the USFS/BLM Interagency Special Status and Sensitive Species Program, from the USFS R6 Minerals and Geology program, and from forest-level projects has allowed the author to conduct informal studies of fens on four "eastside" national forests in Oregon and one national forest in Washington. These studies usually include a plant inventory, soil probes with a 5' fiberglass rod, notes concerning surface wetness and a brief assessment of wetland condition. On one forest, this information is being supplemented by installation of a series of subjectively placed 4x4 meter vegetation plots with paired wells for monitoring water table behavior. Initially, these studies were undertaken due to a developing awareness of the remarkable assemblage of rare and uncommon plants - especially bryophytes - that are found only, or largely, in these peatland-meadow complexes. It was subsequently realized that these peatland-meadow complexes are themselves variously rare or uncommon groundwater-associated ecosystems with important historic functions such as being "hotspots" of biodiversity and carbon sequestration. Fieldwork and literature review has resulted in a base of experience from which the following topics will be briefly discussed: recognition of fens from the office; recognition of fens in the field; how to build a fen; forests are not equally endowed; rare and uncommon fen plants; fen reference taxa; patterns of fen vegetation; fen condition assessment; threats; field unit and regional office roles.

Population Viability, Trends, And Demography In *Cypripedium fasciculatum* In Southern Oregon

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Cypripedium fasciculatum (clustered lady's slipper, Orchidaceae) is a rare woodland orchid that can be found in scattered populations throughout northwestern North America. Although several studies have explored its relationship with mycorrhizal fungi and habitat associates, there has been little information on the species' demography and population trajectories. In a ten-year demographic study of 28 medium- to large populations, we found that the number of emergent stems and proportion of flowering plants varied significantly between sites and years. The majority of plants returned in the same stage as in previous years. 13% - 45% of emergent plants will become dormant the following year; the majority re-merging after one year. We found no clear correlations between habitat nor environment to explain population fluctuations. We also surveyed over 180 populations from Oregon and California that were initially visited 1 to 29 years prior. We found that 59% of these populations declined in size and 33% fell to zero. The chance of extinction was highest in small populations (<10 plants); which went extinct in 50% of the cases. Similarly, annual growth rates in our demographic study were less than one. Our data suggest an ongoing trend of population decline and local extinction and that estimates of the total number of populations of *C. fasciculatum* based on historical records may highly overestimate the number of extant populations. Future research with this species should focus on methods to encourage recruitment within populations and reintroduction methods.

An Interagency Work Group Approach To Conserving The Rare Fungal Species *Bridgeoporus nobilissimus*

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The fungal species ***Bridgeoporus nobilissimus*** is a US Forest Service (FS) and US Bureau of Land Management (BLM) Sensitive species (G3, S3 in Oregon, not ranked in Washington). It is known mainly from the northwestern Cascade Mountains of Oregon with several scattered sites in western Washington, the Oregon Coast Range and northwestern California. Perennial polypores are produced near the base of large-diameter snags, stumps, and occasionally live trees of noble fir (***Abies procera***) and infrequently on Pacific silver fir (***Abies amabilis***). This species was identified to the Interagency Special Status/Sensitive Species Program (ISSSSP) by multiple FS/BLM field botanists as a high priority species with many information gaps and conservation needs. A FS/BLM ***Bridgeoporus nobilissimus*** work group was convened in January 2007 to identify, prioritize, and develop a strategy addressing key information and conservation gaps to assist in managing the species in accordance with BLM and FS Special Status and Sensitive Species policies. Initial tasks such as compiling all different efforts for this species, adding to the species fact sheet, and updating the polypore survey protocol were relatively easy to complete. Other questions such as "what conditions/habitat should be maintained or created to allow a site to persist" have been more difficult to address. However, significant progress has been made to develop a genetic method to sample for the fungal organism rather than surveying for conks. This presentation will review the work group strategy and preliminary results from the genetic field work.

A Molecular Analysis Of *Hackelia venusta* (Boraginaceae) And Related Taxa

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Hackelia venusta (showy stickseed) is a charismatic wildflower endemic to the Wenatchee Mountains of Washington State. Traditional taxonomic treatments recognize the taxon as including both blue-flowered and white-flowered forms which occur in discrete populations in close proximity but at different elevations. Some authors have questioned this interpretation and have suggested that the high elevation blue-flowered form and the lower-elevation white-flowered form represent two distinct species. Although both forms exhibit a narrow geographic distribution, small population size, and vulnerability to loss, only the white-flowered form is currently listed as endangered by state and federal agencies, due in part to its more limited occurrence but also the belief that it represents a separate taxonomic entity. Molecular analysis of the ***trn***L intron, ***trn***L-F spacer, ***atp***B, and ITS regions, in the context of other closely related taxa, does not support independent species level designations for the blue-flowered and white-flowered forms of the species. Further, gene tree structures suggest potential conflicts with the current taxonomic treatment of other northwestern North American ***Hackelia*** examined. To better illuminate these findings we recommend additional analyses, including approaches targeting potential population level genetic diversity.

POSTER PRESENTATION ABSTRACTS

Evaluating The Effects Of Fire On Population Viability Of *Kalmiopsis fragrans*

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Kalmiopsis fragrans (fragrant kalmiopsis; Ericaceae) is a rare perennial shrub endemic to narrow bands of rocky habitat in the Umpqua National Forest in Douglas County, Oregon. Only 15 populations of this species have been located since its discovery in the 1970s, making its conservation a priority for management agencies. This species inhabits openings in forested areas, and wildfires have been suggested as a threat to its persistence. Wildfires in 1996 and 2002 burned two populations, providing an opportunity to evaluate the effects of burning on population viability. Beginning in 2004, we quantified the effects of fire on ***K. fragrans*** by comparing growth rates and flower production at an unburned control and the two burned sites. Percent cover of ***K. fragrans*** per plot was greater at the control than at either of the burned sites in 2004, and remained higher throughout the study period. Plots at the site burned in1996 initially exhibited higher cover values than those at the site experiencing the later burn, but by 2007 differences between the two burned sites were no longer significant. Percent cover at the control site decreased slightly between 2004 and 2007, and increased at both burned sites. In 2005, plants in the burned sites produced significantly more flowers per unit area of ***K. fragrans*** cover than those in the control site. In 2007, both burned sites again produced more flowers than the unburned control, but the difference between values for the control and site burned in 2002 were no longer significant.

Cooperative Recovery Program For Rare Species Affecting Training Ranges At Joint Base Lewis-Mcchord

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Rare species conservation can affect training regimes on military installations. The military has a vested interest in minimizing these effects. At Joint Base Lewis-McChord, the military has partnered with the Center for Natural Lands Management in a program to specifically promote and facilitate rare species conservation actions off the installation. While this program is focused primarily on recovery of animal species, the strategy and techniques used in the program are equally effective for plant conservation. The program uses a strategy that promotes cooperative conservation through: 1) sharing information, 2) linking entities and 3) generating incentives. Specific techniques, such as organizing and supporting regional or species-specific working groups and helping to create priorities for funders, have led to concrete on-the-ground benefits for these rare species and conservation in general. Translation of the strategy and specific techniques can be useful for regional rare plant conservation efforts.

Comprehensive Interactive Plant Keys For Our Region

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Plant conservation and restoration for any given locality is a complex process which depends on reliable and continually updated information regarding what species are found and where. Current climate changes add to the need for the information. This critical data often requires time-consuming initial and ongoing plant surveys. Computerized interactive keys produced over the past 17 years by the author greatly facilitate plant surveys by reducing the time to key unknown species by 90% or more. The proposed presentation would demonstrate the use of the plant identification software, to provide the audience with an understanding of the potential applications of this resource.

The keys for the western U.S. and southwest Canada include all known vascular plants, both native and introduced, which grow outside of cultivation. Plant characteristics may be selected in any order, with no forced choices. Terms are defined and illustrated, extensive references are included, and color photos are provided for over 99% of species. Synonyms and menus of genera and families are provided to reduce problems of changing nomenclature. The software is continuously updated with name changes, new plant finds, and new photos, with free annual updates available for purchasers. It is available by state or larger regions for 18 states and 4 Canadian provinces. In most cases descriptive information is provided for separating subtaxa when present. The keys are a powerful, innovative tool to assist in providing timely plant survey data for plant conservation, restoration, and management.

Genetic Diversity And Population Structure Of Golden Chinquapin (*Chrysolepis chrysophylla*)

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Golden chinquapin (*Chrysolepsis chrysophylla*) is a broadleaved evergreen that grows in coniferous forests from coastal central California to the Olympic Peninsula in Washington. Its range is nearly continuous from the Coast Range of northern California to the Columbia River. A peripheral population in Skamania County just north of the Columbia River and a disjunct population on the Olympic peninsula are the only occurrences of the species in Washington. Because of its rarity, it is on the Region 6 Sensitive Plant List for National Forests in Washington and is listed as a State of Washington Sensitive species (rank G5S2). ***C. chrysophylla*** is also the only known host to the golden hairstreak butterfly (***Habrodais grunus herri***), which is listed as sensitive by the U.S. Forest Service and a Candidate species by Washington State Department of Wildlife (proposed State Endangered). Because the Olympic Peninsula population is at the northernmost part of the species range and is reproductively isolated, it likely has developed significant genetic differences and environmental tolerances than the populations in the core of the species range. A range-wide sampling of golden chinquapin populations will be used to determine levels of genetic diversity and population structure which is currently unknown. This information will be crucial in developing a conservation plan for this species in Washington.

Experimental Reintroduction Of *Artemisia campestris* Var. *Wormskioldii*, A Rare Species Of Dynamic Cobble Bar Environments Along The Columbia River

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Rare plant reintroductions that result in additional or more viable wild populations are important conservation tools for maintaining biodiverse ecosystems. Ideally, such projects are best designed as experiments, to improve biological and ecological knowledge of the selected species. Northern wormwood (***Artemisia campestris*** var. ***wormskioldii***: Asteraceae), a nearly extinct, early seral species restricted to Columbia River riparian habitat, is only known from two native populations in Washington, set 300 river miles apart. Both populations are declining and show minimal recruitment. During initial recovery work (started in 2007), we cultivated and then transplanted northern wormwood plants near Squally Point (Columbia River), Oregon, where 257 reproductive individuals still persisted in late 2010. However, minimal efforts were made during this phase of our work to correlate survival and reproduction with environmental factors. In cooperation with the U.S. Fish and Wildlife Service and Army Corps of Engineers, we set up a second reintroduction project with the objectives of: (1) investigating the effect of environmental factors on survival of northern wormwood, to gain a better understanding of this species' habitat requirements; and (2) creating a second viable population to further recovery objectives. To achieve these goals, we planted 2,100 greenhouse-grown plants on Rufus Island, Oregon, in October, 2011. We transplanted 1,450 of these in experimental plots to examine the impacts of three environmental factors: (1) substrate type; (2) distance from the water line; and (3) presence or absence of the invasive shrub ***Amorpha fruticosa*** (false indigo). Monitoring of survival, reproduction, and recruitment will begin next spring.

Blue Mountains Cooperative Adventures

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Increasingly limited resources combined with environmental challenges have helped forge new partnerships in the Blue Mountains of Northeastern Oregon. Agency botanists and ecologists are learning to enhance the power of small internal federal grants, by forming internal and external partnerships:

- Malheur N. F.: Strawberry Mountains Botanical Foray in cooperation with the University of Washington Herbarium, Forest Service personnel, University of Washington faculty, and volunteers all contributed to the collection efforts. In total, 31 individuals were involved in this project. Over 700 vascular plant specimens were collected, pressed, and labeled.
- Wallowa-Whitman N. F.: Anthony Lakes Fungi Foray with Southern Idaho Mycological Association (SIMA). Forays occurred in 2009 and 2011. In 2011 25 individuals participated, 19 were volunteers from SIMA, and 6 were USFS employees. For all three forays combined, 217 species were identified, about 25 additional specimens were sent to specialists for further identification work.
- Malheur, Umatilla, and Wallowa-Whitman N. F.'s: Greenhorn Mountains Botanical Surveys in cooperation with Carex Working Group, The Nature Conservancy, University of Washington Herbarium, Washington State University, and Whitman College. Collecting centered on sampling serpentine substrates above 6000 feet. In total 4200 acres were investigated by a total of 15 participants. Over 700 vascular and non-vascular specimens were collected. Potential species new-to-science are being evaluated, and other sparsely-collected serpentine substrates in the region are being considered for similar work.
- ***Pyrrocoma scaberula*** Inventory on the Umatilla N.F., Wallowa-Whitman N.F. and Vale District BLM. Participants included botanists and ecologists from the Wallowa Whitman N.F., Umatilla N.F., Vale BLM, and one volunteer. A total of 3750 acres were surveyed, resulting in the discovery of four new ***Pyrrocoma scaberula*** populations and an extension of a known site. Eleven new ***Calochortus macrocarpus var. maculosus*** were documented as well as one ***Silene spaldingii*** population and a separate sub-population.

Collaborative partnering efforts can be very productive and, in conjunction with citizen-science participation, can provide avenues for future direction in a challenging budget environment.

Managing Rare Plants On Federal Lands In Oregon And Washington: The Interagency Special Status/Sensitive Species Program

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The Interagency Special Status/Sensitive Species Program (ISSSSP) is a USDA Forest Service (FS) and USDI Bureau of Land Management (BLM) regional level program created in October 2004. The main objective of FS and BLM sensitive species policy is to avoid actions that lead to loss of species viability or Threatened and Endangered listing under the US Endangered Species Act. There are approximately 500 vascular plants, 80 non-vascular plants, and 30 "Sensitive" fungal species for which the FS and BLM must assess the potential impact from any agency action on these species and promote species conservation. Additionally, there are more than 600 "Strategic" flora species that could meet agency Sensitive species criteria, but there is some question surrounding the NatureServe rank, taxonomy, or occupancy and habitat status on federal lands, such that management of the species as Sensitive would be difficult or unwarranted. To assist agency botanists and managers in evaluating potential project impacts and managing for the conservation of these species, the ISSSSP employs surveys, research, and monitoring, and develops conservation planning documents and tools. Over the last seven years, ISSSSP has worked with many partners and funded numerous projects to fill knowledge gaps. These have included inventories to determine species distributions, development of habitat models, population monitoring, genetics and taxonomy, seed collection, data management, specimen identification services and voucher curation with regional herbaria, species fact sheets, and conservation assessments, strategies, and agreements. Project results and conservation tools are available from the ISSSSP website - http://www.fs.fed.us/r6/sfpnw/issssp/.

Seedzone Mapper: A Mapping & Planning Tool For Plant Material Development, Gene Conservation And Restoration

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Deploying vigorous, well adapted, and ecologically appropriate plant materials is a core component of a successful restoration project. To better understand the genetics of adaptation and identify appropriate plant materials (e.g. seeds) for restoration, the USDA Forest Service, BLM, ARS and NRCS have generated considerable data from common garden studies and other research activities relating to seed zone development for key native species. In addition, climate-based provisional seed zones have been developed to assist practitioners in matching seed sources and planting site conditions as closely as possible when empirical genetic data are not yet available. The SEEDZONE MAPPER application allows a broad array of end-users to easily view and acquire available data on seed zones for use in plant material development and gene conservation and restoration activities. Data sources include species-specific seed zones from completed common garden studies as well as climate-based provisional seed zones. Client applications range in functionality from a simple geobrowser (requires only a web browser) to ArcGIS ArcMap, a full-feature GIS software platform that allows the user to integrate their own data and create map layouts. The SEEDZONE MAPPER application is available at: http://www.fs.fed.us/wwetac/threat_map/SeedZones_Intro.html.

SEEDZONE MAPPER is part of a family of Wildland Threat Mapping (WTM) applications developed by WWETAC (USFS Western Wildland Environmental Threat Center, Prineville, OR) to portray the spatial interactions of wildland threats and high value resources that occur in wildlands. In WTM, users can evaluate seed zones in relation to other map services and wildland threats published by WWETAC such as climate change projections or wildfire risk. WTM can be accessed at: http://www.fs.fed.us/wwetac/threat_map/index.html.

Recruitment Limitations Of Endangered Prairie Species: A Case Study Of *Erigeron decumbens*

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Preservation of rare plant species often requires introductions to establish new self-sufficient populations. Recruitment surveys are an emerging method of monitoring to determine population autonomy. This can be accomplished by describing recruitment levels and the limitations of reestablishment. ***Erigeron decumbens*** is an endangered forb endemic to the Willamette Valley of western Oregon. Several populations of ***E. decumbens*** have been introduced by governmental and private agencies. While there has been some monitoring on the survival of reintroduced plants, no systematic surveys have measured recruitment in the new populations. I monitored recruitment in seven introduced populations, and compared abiotic and biotic characteristics in these and five stable natural populations. 70% of introduced populations exhibited some recruitment with 30% exhibiting levels of recruitment sufficient for a self-sustaining population. The majority of seeds from both natural and reintroduced populations were without embryo demonstrating that seed viability could be a strong limitation for this species. Soil moisture appeared to be the strongest factor affecting recruitment, with higher recruitment in drier sites. This study demonstrates the utility of recruitment surveys to population introductions, in general, and will provide important guidelines for future reintroductions of ***Erigeron decumbens***, including planting in drier habitats and using a high diversity of source plants to ensure high seed viability.

Effects Of Litter, Propagule Type And Exposure On Recruitment And Survival In Peripheral Populations Of *Frasera Umpquaensis*

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Frasera umpquaensis is a long-lived perennial the majority of which is found along the Rogue-Umpqua Divide in Oregon. Several populations near Oakridge form the northern most extent of this species' range. Concern for lack of seedling recruitment in these "satellite" populations was noted as early as 1993 in the original Conservation Strategy for the species, calling the long-term viability of these populations into question.

We conducted a four year study to determine that factors limiting recruitment in these populations. We found that seed viability (tested using germination and tetrazolium tests) ranged from 5% - 92%. Greenhouse experiments found plants receiving an extended cold treatment were more robust than plants receiving shorter periods of cold. Some seeds required multiple periods of extended cold stratification to germinate.

In an experiment testing the effects of litter, canopy type, propagule type, and exposure on seedling recruitment and survival, we found seedling mortality (both natural and seeded) was high from one year to the next and survivorship of transplants was higher than seeds. Natural seedlings were found at most sites. We found no evidence for significant effects of canopy type, litter depth or soil moisture on the success of seeded or transplanted individuals. Notably, plants on forest edges with northern exposure had highest survival. North facing areas have a cooler microclimate with less intense sun exposure and longer periods of snow cover compared to south facing exposures at the same site.

Poor recruitment and survival of young plants in these populations may be due to shorter, warmer winters associated with either short-term climate cycles or long-term global climate change.

Evaluation Of Population Trends And Potential Threats To A Rare Serpentine Endemic, *Calochortus coxii* (Crinite Mariposa Lily)

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Calochortus coxii (crinite mariposa lily) is listed as a federal Species of Concern, Endangered by the state of Oregon, and G1/S1 (Globally and State Imperiled) by the Oregon Natural Heritage Program. As of 2004, ***C. coxii*** was known to occur in 24 sites along a ten-mile serpentine ridge system between Myrtle Creek and Riddle, OR. Though populations of ***C. coxii*** were surveyed in the early 1990's, the majority of these sites had not been revisited and their status was unknown. We surveyed previously extant ***C. coxii*** populations to detail their spatial extent and estimate their population size, habitat characteristics, and potential threats. We established permanent monitoring plots in areas with high ***C. coxii*** abundance to increase understanding of population trends and community associations over time. Of nine sites visited, ***C. coxii*** was present at six. Of those sites where it was not present, invasive grasses and evidence of human-caused disturbance were prevalent. Spatial extent of current populations generally appeared to be narrower than that indicated by shapefiles from the BLM, but at three sites individuals were found outside the known range. In areas of high ***C. coxii*** abundance, native species comprised 95% of community composition, with exotic species composed mostly of graminoids. Preliminary results suggest that habitat quality and associations with native species may be necessary in the perpetuation of this rare serpentine endemic. Given the lack of protection on private lands and recent invasion of serpentine-tolerant invasive species, more active management for this species may be necessary.

Comparison Of Insect Visitation Rates And Seed Viability At Webster Nursery And The Puget Lowland Prairies

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The rate of visitation by insects to flowers can affect reproductive success in plants. The Center for Natural Lands Management in Olympia, Washington, relies on large-scale production of native seeds in nurseries for replanting into the Puget lowland prairies as part of their restoration strategy. This study investigates the current state of pollination at a local nursery (Webster native seed nursery) and compares it to the Puget lowland prairies to find out if inadequate insect visitation is restricting viable seed production at either site. In 2011, I compared rates of insects visiting ***Viola adunca*** Sm., ***Lomatium utriculatum*** J.M. Coult & Rose, ***Balsamorhiza deltoidea*** Nutt., ***Plectritis congesta*** DC., ***Lupinus***

albicaulis Douglas, and *Potentilla gracilis* Douglas ex Hook at the nursery and prairies. Overall insect visitation rates were significantly higher at the nursery for *L. albicaulis* and *P. gracilis*. Visitation rates were either significantly higher or lower at the nursery for at least one insect group visiting each plant species. Restoration strategies designed to increase visitation, such as planting more floral resources for bumblebees, may be more efficient if geared to specific insect types at each site. In 2012, I will use a more direct method to determine reproductive success of plants at Webster Nursery and Johnson prairie on Joint Base Lewis-McChord. I will measure viable to non-viable seed ratios in conjunction with calculating visitation rates to determine if plants are pollinator limited.

Supporting Recovery Of Cook's Lomatium Through Population Augmentation And Reintroduction

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Endangered species that occur in multiple habitat types pose challenges for reintroduction. In addition, restricted land uses may limit the protections and number of locations at which reintroductions can occur. Cooks' desert-parsley (*Lomatium cookii*) in southwestern Oregon is listed by the US Fish and Wildlife Service as endangered, and may depend on reintroductions and population augmentations for its long-term recovery. The species occurs on both moist serpentine and dry non-serpentine soil types, with the potential for differing selective pressures in these contrasting edaphic environments, and much of the landscape in which it occurs is claimed for mining, restricting which sites can be used to host new populations. Government agencies are partnering with nonprofit groups to 1) develop a plant materials program that creates a large and steady seed supply and reduces pressure on wild sources, 2) identify factors that affect plant establishment; and 3) identify and plant into selected appropriate locations. Since 2009, 15 seed accessions have been collected from 13 sites with special attention to unprotected sites on private lands, and have been placed into isolated productions for two soil types. Experimental plantings have demonstrated that removal of leaf litter and planting in non-wooded patches can improve seedling establishment, and both direct seeding and plug planting result in successful plant growth. Also, planting seeds from one habitat type into another can result in significantly lower success than within-habitat plantings. Site selection for outplantings will emphasize suitable h abitats that are protected, compatible with mining claims, and anticipate climate change.

Relationship Between Soils And Plant Community Composition In A Restored Willamette Valley Upland Prairie

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While high nutrient levels are thought to favor exotics plants over natives, Seabloom et al (2011) recently found that native and non-native grasses had similar responses to soil nutrient levels in prairies of western Oregon and Washington, with abundance of the dominant non-native grass ***Agrostis*** negatively correlated with soil ammonium levels. To test relationships among soil nutrients, exotic grasses, and native grasses and forbs we examined pre- and post- restoration community composition and analyzed soil texture, depth and nutrient levels in an upland prairie in western Oregon. We carried out NMS ordination of community composition data in PC-ORD. The first axis of the ordination separated plots with live or herbicided non-native ***Rubus aremeniacus*** from plots with high forb or grass abundance. The second axis separated plots with high cover of the non-native grass ***Agrostis*** from those occupied by species such as ***Plantago lanceolata***, ***Moenchia erecta***, and bryophytes. These areas had shallow soils, and were the only places in the prairie with remnant cover of native grasses (***Danthonia californica***) and forbs (***Clarkia spp.***, ***Dichelostemma capitata***, ***Linanthus bicolor***). While remnant natives were only found on areas of shallow soil, not all areas of shallow soil had remnant natives. By conference time, we will have data on soil texture and nutrient levels, as well as first-year post-restoration establishment. We will test whether abundance of native and non-native species are correlated with soil variables, and whether these patterns differ before and after restoration.

Changes To The BC Flora 2006-2011

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A committee has been active for the past 6 years in reviewing changes to the British Columbia (BC) flora to allow updates to the provincial standard flora list (BC Ministry of Forests, Lands and Natural Resource Operations) and the BC Species and Ecosystems Explorer tool (BC Ministry of Environment; delivers conservation information on animals, plants and ecological communities in BC). The information is used by resource and land managers, technicians and researchers, as well as proponents compiling information for the Environmental Assessment process in British Columbia. The small team is composed of botanists affiliated with BC herbaria, BC government, and the original publication of the Illustrated Flora of BC (Douglas et al. 1998-2002). Invaluable input from the private sector botanists is also represented on the team. There are no plans to reprint the flora, but we are compiling data on additions and deletions to the flora, as well as taxonomic and nomenclatural changes. A steady stream of changes have been coming in as the flora is updated with Flora of North America treatments (where deemed appropriate) and investigated by a number of keen botanists. Each year the number of exotic

species increases (often 1/3 of additions to the flora each annual update), and several rare/at risk taxa are added. The province has relatively high biodiversity in Canada with an interesting flora to catalogue. It is currently represented by 3189 taxa, 2373 of which are native, 618 of which are rare/at risk, and 8 of which are endemic.

Predictive Geospatial Habitat Modeling Of The Rare Sedge, *Carex idaho*, In The Southern Blue Mountains Of Oregon

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Inventory and management of rare plants and their respective habitats is an increasing priority for State and Federal land management agencies in the Pacific Northwest. Predicting the habitat and distribution of rare plants can be a great aid in discovery and conservation of populations that are susceptible to anthropogenic processes and management activities. Here, geospatial habitat prediction models are utilized to predict habitats and populations of a rare plant on National Forest lands in the Southern Blue Mountains of Oregon.

Idaho sedge (*Carex idahoa*) is considered globally imperiled and is arguably the rarest native sedge in the Pacific Northwest. Prior to 2010, less than 50 populations were known worldwide, with the only documented population in Oregon and Washington being on the Malheur National Forest. Despite its rare status, there is a wealth of information on the specific habitat requirements of Idaho sedge. The type and quality of this information makes this species an ideal candidate for predictive habitat modeling.

A model was developed using geospatial and statistical techniques to predict potential habitat based on environmental factors such as elevation, slope, aspect, rainfall, geology, infrared reflectivity, watershed characteristics, and vegetation composition. Field crews surveyed areas that were identified as potential habitat in order to validate the model and determine if populations were present. Over 4,000 aces of predicted habitat were inventoried and the initial results of the project were an overwhelming success: > 70% of the predicted habitat was correctly categorized and 27 new populations were discovered.

Alternate Hosts Of *Castilleja levisecta* (Orobanchaceae): New Options For Restoration Of A Threatened Species

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Scientists have long been fascinated by the nature of the interaction between parasitic plants and their hosts. Understanding these relationships could greatly improve prairie restoration efforts and preserve native habitat for many threatened and endangered species in the Pacific Northwest (PNW). ***Castilleja levisecta*** (golden paintbrush) is a threatened hemiparasite native to the PNW who's known hosts include ***Eriophyllum lanatum*** (Oregon sunshine) and ***Festuca roemerii*** (Roemer's fescue). However, other species are believed to be potential hosts because ***C. levisecta*** has been found growing robustly without any known hosts nearby. To test this alternate host hypothesis, we propose a multiple-species experiment to determine if alternate preferable hosts exist for ***C. levisecta***. Host species candidates will be selected based on current presence in PNW prairies. A variety of families and functional groups will be tested to provide greater distribution of potential hosts. Fifteen host species will be planted with ***C. levisecta***, including two non-native species: ***Holcus lanatus*** and ***Anthoxanthum odoratum***. Destructive sampling will determine whether haustorial connections have been made. If connections are present, we will determine the relative benefit to ***C. levisecta*** by measuring number of connections per pair, and ***C. levisecta*** biomass and number of flowering stems. We hypothesize that several of the species tested will prove adequate hosts for ***C. levisecta***, and should be considered viable options in future restoration. These findings could increase the chances for survival of this species and others, including several species of rare butterfly, which rely on prairie ecosystems for habitat.

Diversity And Phenology Of Plant Nectar Resources For The Fender's Blue Butterfly

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The federally endangered Fender's blue butterfly (is endemic to Willamette Valley upland prairies. Fender's blues feed on their larval host, the federally threatened Kincaid's lupine and, as adults, nectar on numerous flowering plants. We investigated use and availability of nectar by following butterflies and by collecting weekly counts of open flowers in transects at three sites from Eugene to Salem, Oregon in 2009 and 2010. We found high turnover of available nectar species during the Fender's 4 – 6 week flight season. The flowering phases of many nectar plants were shorter than Fender's flight and species available early were replaced by others later on. Male and female Fender's blues nectered on different plant species. Males used more non-native annuals, such as ***Vicia sativa*** and ***Linum perenne,*** and females used more natives, such as ***Calochortus tolmiei*** and ***Allium amplectens.*** Because of both variation in nectar availability and differences in use, we expect that diverse nectar resources (and particularly natives used by females) are important for butterfly fecundity because more species are more likely to provide resources throughout the flight season. Phenology of many species are expected to shift in response to inter annual variation in weather and to long term climate change, so that nectar resources available during peak flight for this study may not be as available to Fender's blue in the future. Redundancy of nectar resources may buffer against effects of extreme weather events and climate change.

Appendix A.

Notes from working groups formed in the final session of the conference

At the end of the conference attendees were asked to participate in three break-out sessions focused on discussing the challenges related to the conservation of native plant communities and rare plants in NW North America. Steering Committee Members facilitated discussions in three focal areas:

- Climate Change
- Ecology/Biology
- Policy and Strategy

Each session was asked to address three questions related to each focal area:

- What are the challenges?
- How can we address these challenges?
- How can we move forward?

These notes are a record of the topics discussed and are meant to serve as a starting point for further discussions as working groups take form and take action! If you are interested in being a part of one or more of these working groups please e-mail us at 2012plantconf@gmail.com and we will add you to the e-mail list.

CLIMATE CHANGE GROUP –Facilitated discussion by Mark R. Mousseaux (Botanist, BLM) and Regina M. Rochefort, Ph.D., (Science Advisor, NPS)

What are the challenges?

- Need cooperation with various agencies and land owners – consensus on goals
- Uncertainty with regard to predicting the outcomes, what will happen?
- Stress on systems and plant communities – not sure what will happen
- How do we prioritize efforts? What choices do we need to make?
- There is limited data at the species and community level
- Disproportionate effects likely – wetlands, edaphic, alpine, coastal strand, and other niche species may be affected differently than more wide ranging species
- How will changing fire regimes affect communities/species
- Differences in climate change policies between agencies (Fed/State/County) and other groups – how do we gain consensus

- Translating the science into public information – Public relations is a challenge – politics and rhetoric creating challenges and misinformation
- The temporal and special scope is large and variable – changes occurring in ppt patterns, snow vs rain, changes in frost free period, wetter winters in some areas, colder others, dryer summers – Climate Change

How can we address these challenges?

- Decide what it is that we (society) wants – define goals; figure out how to measure what we want
- Do you want static or changing situations
- Must use adaptive management
- Use 'bet-hedging', take process a step at a time, be willing to adapt and shift pattern
- Mine historic vegetation data, look at how different models work – validate models using historic data
- We will have to triage – we will not be able to 'save' and address everything, we have to decide what it is we want to work on
- Get normal citizens involved, "Citizen Science" – Plant societies, Horticultural groups, garden clubs, kids, FAA, education and schools
- Need a model using Govt – University – NGO's – Public

How can we move forward?

- Policy and Papers – get the word out – define key issues
- Publish and distribute proceedings from conferences like this, publish quantitative data (monitoring), and even observational data
- Get information on websites and blogs
- Get information out to people who would never hear it – socal media, a 'coffee' table book
- Identify the areas where we agree with the public and opponents – ID the things we have in common and work from there to build consensus
- Communicate the importance of refugia
- Communicate with the public on how things have changed, or are changing right now
- Pull ideas together and get to USFWS Landscape Conservation Cooperative – participate in this process – Publish information
- Ground truth models – link what is happening with what models are predicting – publish this data
- Must look at different climate scenarios – and strategize on how to be ready for different outcomes

- Host additional working group – think tank seminars/conferences regionally – or perhaps nationally, to address the problems, propose solutions, and create a path forward

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ECOLOGY/BIOLOGY GROUP–Facilitated discussion by Joe Arnett (Botanist, Washington Heritage Program, DNR) and Peter Dunwiddie, Ph.D. (Affiliate Researcher, University of Washington)

What are the challenges?

- Need for better long-term monitoring
- Changing phenology impacts on pollinator-plant interactions
- Lack of knowledge of the causes of rarity
- Restoration has been guided by the past, but there are no guidelines for the future. It is hard to sell conservation of something that has not yet existed.
- What is the role of reference areas?
- There are questions of scale
- Biodiversity conservation success is dependent on the social will
- We need to inspire urgency
- We have a lack of understanding of many underlying processes
- We need common methods, terms; cross-walking across borders of all kinds is challenging
- S-ranks are limited (S1 may end as the state border)

How can we address these challenges?

- Coordinate long term monitoring across boundaries
- Internet based data collection, such as EDDMaps, eBird, iMap, iNaturalist
- Encourage citizen science, the benefits of public education and ownership
- Broaden the discussion to include additional skill sets, such as fundraising, social science, economics
- Focused research, better partnerships between schools and land managers, agencies

How can we move forward?

- Group or listserv to develop consistent monitoring methods (NatureServe may fill part of this need); questions differ, and so methods do also)
- Improve communication between managers and researchers
- Seek ways to identify our goals that are beyond historical references (such as processes and functions used in wetland evaluation)

POLICY AND STRATEGY GROUP—Facilitated discussion by Ted Thomas (Senior Ecologist, USFWS)

What are the challenges?

- Funding, what are the best sources of gaining funding, NOW! IS there or could there be clearing house for funding
- What are best opportunities for levering funding? Form partnerships and plan with other agencies, NGOS
- Need for overarching policies to tie climate change to plants
- Develop strategies that provide other services at the time restoration/conservation programs are implemented, for example: provide benefits to reduce fire risks, flood risks, reduction of insect and disease outbreaks
- What are best strategies for managing plants/organisms across jurisdictions? What methods do we have to remove obstacles/barriers to accomplish management cross jurisdictional boundaries?

How can we address these challenges?

- Education and communication
- Establish lobbying efforts to garner political support
- Develop multi-faceted, bet-hedging strategies to keep moving forward while sustaining biodiversity
- Develop methods/tools to manage for uncertainty
- Link Botany, Plant ecology to policies and strategies in the real world with real views
- Establish and Endangered Species Act for Washington
- Update Oregon's ESA list for plants
- Need laws to require commercial growers to provide seed source information by/for provisional seed zones
- Any species on state noxious weed list should be banned from commercial sale
- Update state weed regulations to match current science and need

What can we move forward?

- Develop and implement lobbying campaigns at the local, State and National level!
- Create a market system for provide support for large scale restoration
- Work with the nursery and commercial growing industry to avoid propagating and selling noxious weeds
- Do a better job of translating our science to law makers and emphasizing the gravity of the problems that need to be addressed to inspire action

Inside Back Cover

Conserving Plant Biodiversity in a Changing World:
A View from Northwestern North America