Ecological Restoration:

Sustaining Diversity On the

South Puget Sound Prairie Landscape

By

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Abstract

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Anthropogenic climate change is unequivocal and unavoidable; the average global temperature has increased over the past century and will continue to rise an additional 1.1 to 6.4 degrees Celsius by 2100. Climate is one of the most significant factors determining the geographic distribution of species and ecological communities. As the climate changes species will persist through adaptation, migration to new regions, or go extinct. Unlike animals, plants that cannot readily migrate to a new location will be particularly challenged by climate change.

Climate change is causing a sorting of vegetation into bands along migration fronts, led by the fastest (most invasive) dispersers and trailed by the slowest (least invasive), which are perhaps at the greatest risk of local extinction (Neilson et al., 2005). Plant communities will increasingly become composed of species that exhibit high phenotypic placidity, fecundity and the ability to disperse over long distances (Malcom and Pitelka, 2000). It is widely believed that climate change will necessitate the adaptation of restoration and conservation practices, yet there is a lack of research and data for practitioners to act upon. In order to better understand the affect climate change will have on restoration practice, I utilized the south Puget Sound prairies in western Washington as a case study. Conclusions are based upon the scientific literature including journal articles reporting climate change projections based on computer models. The author also generated original data through structured interviews of south Puget Sound prairie restoration practitioners to determine what if any changes they were making to their approach. I also explored the adaptations practitioners anticipate over the coming century.

The Idaho-fescue bunchgrass prairies of the south Puget Sound are one of the most imperiled ecosystems on the planet. Prairie plant species were and still are culturally valued by the Salish tribes who maintained prairies through fire and harvesting practices as the climate changed during the late Holocene. European settlers valued the clear flat prairie landscape for agriculture and development, which led to its degradation through fragmentation, fire suppression and the introduction of invasive species. Currently, a myriad of Federal, State, local and non-profit groups which value diversity have committed to restoring and preserving the prairie ecosystem. Climate change is expected to exacerbate the current challenges to prairie restoration and conservation and is prompting practitioners to redefine historical targets. The actions of restoration practitioners in the south Puget Sound might be indicative of how the entire field of restoration is responding to climate change.

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Puget Trough Prairies: the case for a case study

Scientific evidence confirms that the composition of the Earth's atmosphere and climate has changed over the last 250 years. Amounts of greenhouse gases (GHG) are increasing as a result of industrialized human activities—since 1750, carbon dioxide has increased 32%, and methane has increased 150% (Climate Impacts Group, 2010). The changing of the climate system is unequivocal, as is now evident from observed increases in global average temperatures, widespread melting of glaciers, and rising global average sea level (IPCC, 2007). In the absence of significant changes in human activities, atmospheric concentrations of GHG's have continued to increase. Even if major global action reduced emissions significantly, the thermal inertia of the oceans will continue to drive climatic change for decades and will require adaptive responses to maintain biodiversity (Heller and Zavaleta, 2008). While people and animals may be able to adapt to climatic changes rather quickly, plant communities have been slower to respond to past climate changes.

As the climate changes plants will persist, adapt or migrate according to their life history characteristics. Climate is one of three main abiotic factors that determine the floristic composition of a region (Radosevich et al., 2003). The climate change predicted to occur over the next century will influence plant populations through several factors: changes in range and means of temperature, increased disturbances, as well as, water, carbon dioxide and nitrogen availability (Drake et al., 2003). Anthropogenic climate change may occur at a rate greater than any experienced in the past 10,000 years (Houghton et al., 2001). Ecosystem simulations of future climate scenarios suggest that the preferred range of many species could shift tens to hundreds of kilometers over only 50-100 years (Neilson et al., 2005). Climate change is expected to become the first or second greatest driver of global biodiversity loss (Heller and Zavaleta, 2008) and it is very likely that 20-30% of the planet's flora that cannot readily adapt to climate change will expire (IPCC, 2007). Restoration and conservation practitioners have struggled with how to adapt practices with on-going climate change in order to protect the biodiversity and ecosystem functioning which our society values (Heller and Zavaleta, 2008). Over the last 22 years, widespread calls to action and recommendations throughout the scientific literature have been reiterated frequently but without the elaboration or specificity necessary to act on the site level (Heller and Zavaleta, 2008). There is little guidance for how specific communities and ecosystems should be created, restored and managed in a manner that anticipates the development of future species assemblages (Seastedt et al., 2008). Despite uncertainties it would be fallacious to adhere blindly to a rigid creed of historic conditions, and fail to recognize that a new world of altered climates is hard upon us (Seastedt et al., 2008). Indeed, practicing restoration in a warming world involves a paradigm shift as restoration and conservation practitioners re-examine historical targets in light of a deepening ecological understanding of the relationship between the climate and ecosystem composition.

In order to further understand how the field of restoration will be affected by climate change, I examined on-going restoration efforts of bunchgrass prairie and oak woodland on the south Puget Sound landscape. South Puget Sound prairies once extended over 150,000 acres on shallow, sandy, and gravelly loam soils from south of Tacoma to Oakville (Crawford and Hall, 1997). Prairie and oak woodland habitat has been reduced by 90%, with only 3%, or less than 5,000 acres preserved (Crawford and Hall, 1997). Original vegetation cover varies from 80% in the least impacted areas to less than 10% in heavily grazed, plowed and replanted areas

(Purcell, 1987). The prairies are a seral grassland community which if not maintained would become invaded by non-indigenous species and overshadowed by coniferous forest. There are numerous State and Federally endangered, rare or threatened plants, insects, birds, reptiles, and mammals, several known extinctions, and most likely numerous unknown extinctions, indicating that it is not just certain species which are endangered but the entire bunchgrass prairie and oak woodland ecosystem. There are several on-going challenges to preservation including fire suppression, invasive species, habitat fragmentation and continued development, which may be exacerbated under future climatic scenarios.

In order to understand current restoration practices, I explore the ecological and cultural forces that created today's prairie landscape. I examine general circulation models which project possible future climate scenarios. Finally I interviewed 14 south Puget Sound prairie practitioners about how they will adapt their practices to a changing climate. My analysis will demonstrate that climate change is already affecting restoration practices on the south Puget Sound prairie landscape. Due to the lack of connectivity, practitioners are beginning to source restoration material regionally and adopt practices to facilitate the reintroduction of species. As restoration targets which focus on recreating a pre-settlement landscape become less and less realistic, the field of restoration is utilizing an ecological perspective to guide restoration practice. While the challenges of climate change are great the current network of professionals, agencies and organizations are collaborating in order to increase diversity, which is perhaps the best way to prevent disastrous ecosystem failures in an increasingly disturbed warming world.

I. <u>Natural History of Puget Trough Prairies; Ice, Fire and Management</u>

The south Puget Sound Prairie and oak woodland landscape evolved at a time when the climate was much different than it is today. During the Pleistocene epoch, 110,000 years ago the planet began a cycle of cooling and warming as large ice sheets advanced from polar regions and mountain tops to cover immense expanses of the northern hemisphere. Around 70,000 yrs. B.P. the Cordilleran ice sheet covered the majority of western North America, and stretched from northern Oregon all the way to the Alaskan panhandle. The Fraser Glaciations refer to three periods or stades of advance and retreat between 20,000 and 10,000 yrs. B.P. (Kruckeberg, 1991). During the last period, or Vashon Stade, ice covered the Puget Trough as far south as Tenino, Washington (Kruckeberg, 1991). These immense continental ice sheets transported massive amounts of rock, transformed waterways and had a significant impact on the ecosystems of western Washington.

Climate is one of the main abiotic factors which influences plant distribution patterns. By studying vegetational communities that occurred in the past, scientists are able to understand how plant species might react to current anthropogenic climate change. By utilizing pollen grains trapped in wetland sediments and plant remains from packrat (*Neotoma*) middens, scientists are able to reconstruct changes in the climate since the end of the Frasier glaciations. In general, plant population responses to climatic changes include persistence, range shifts, adaptation, or extinction (Davis et al., 2005). Indeed, the best evidence that plant ranges shift with climate comes from paleontological studies from the Holocene epoch 11,000 yrs. B.P. (Iverson and Passard, 2001). However, paleoclimate reconstruction from the pollen record depends upon the assumption that species tolerance limits have remained stable throughout time (Davis et al., 2005). Certainly species tolerance limits (degree growing days, mean temperature of the coldest month) have evolved over the past 11,000 years. Empirical modeling has shown that detectable adaptive divergence evolves on a time scale comparable to past climatic changes, within decades for herbaceous species and within centuries or millennia for longer lived trees (Davis et al., 2005). What the pollen record demonstrates in western Washington is that individual plant species were present at specific locations, during a certain time frame, and within a probable climatic envelope.

Paleo-ecological History

Between 18,000 and 15,000 yrs. B.P. the lowlands of western Washington were covered by glacier ice. Tundra like plant communities existed in mountain refugia and other areas that were not covered, such as parts of the Olympic Peninsula. Vegetation may have resembled modern high altitude communities east of the Cascades with abundant grasses (*Graminoids*), snakeweed (*Polygonum bistortoides*), corn salad (V*alerianella*), and Sitka berry (*Sanguisorba*) along with tree species; lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmanii*), Sitka spruce (*Picea sitchensis*), Pacific silver fir (*Abies amabilis*), and Grand fir (*Abies grandis*) (Leopold and Boyd, 1999, Barnosky, 1985). Around 15,000 yrs. B.P. glacier ice in the lowlands of western Washington began to melt.

The ice sheet of the Vashon Stade melted in 3,000 to 4,000 years, which is fairly quick compared to other ice sheets of the Pleistocene epoch. As the ice sheets wasted, temperatures warmed, precipitation increased and species adjusted their ranges and abundance according to environmental tolerances (Whitlock and Knox, 2002). Between 15,000 yrs. B.P. and 11,200 yrs. B.P. much of the Puget Trough was open, flat, gravelly terraces of glacial outwash. Lodgepole pine (*P. contorta*) appears to have initially colonized the outwash throughout the de-glaciated zone, and was soon followed by Mountain hemlock (*Tsuga mertensiana*) and Sitka alder (*Alnus sinuata*) indicating a cooler wetter climate compared to the present (Barnosky, 1985).

The climate of western Washington continued to change and eventually temperatures exceeded present day values. In western Washington the observation of western hemlock (*Tsuga heterophylla*) pollen grains at Nisqually Lake as early as 12,700 yrs. B.P. provides the first floristic evidence of post glacial warming (Barnosky, 1985). By 11,000 yrs. B.P. temperate taxa are registered at other sites as well indicating a transition from tundra parkland to open forest parkland with patches of prairie intermixed (Barnosky, 1985, Leopold and Boyd, 1999). The pollen data suggest an expansion of Willamette Valley vegetation northward into southwestern Washington (Barnosky, 1985). Between 11,000 and 10,000 yrs B.P Douglas-fir (*Pseudotsuga menziesii*) invaded, most likely from the Willamette Valley, and quickly established itself replacing lodgepole pine (*P. contorta*) as the dominate species of the lowlands (Barnosky, 1985). The expansion of western hemlock (*T. heterophylla*) occurred at a much slower rate than Douglas-fir (*P. menziesii*) and was not a climax species until after 4,500 yrs. B.P. when the climate changed again becoming colder and wetter (Hansen, 1947).

Fire regimes were also altered during the Holocene epoch, and it was likely that increased fire due to the warmer drier climate (11,000-7,800 yrs. B.P) was the proximal disturbance which affected vegetation shifts (Whitlock and Knox, 2002). The composition of vegetation in the lowlands of western Washington was savanna like; prairies were not early successional stages but persistent features of a landscape shaped by frequent fire disturbance (Barnosky, 1985). The pollen evidence clearly indicates that the peak abundance of prairie elements like grasses (*Graminoids*), hazel (*Corylus*), and oak (*Quercus*) occurred in the early Holocene, before 6,800 yrs. B.P. (Leopold and Boyd, 1999). Drought and disturbance adapted species; Red alder (*Alnus rubra*) and bracken fern (*Pteridium aquilinum*) were much more abundant occurring as successional species (Leopold and Boyd, 1999). Douglas-fir (*P. menziesii*) and Garry Oak (*Quercus garryana*) were the main trees associated with grasses (*Graminoids*) and forbs from the *Apiaceae*, *Agavaceae*, *Saxifragaceae*, and *Polygonaceae* families, which flourished periodically after local fires (Leopold and Boyd, 1999). Before 6,800 yrs. B.P. the growth of western hemlock (*T. heterophylla*) and western red cedar (*Thuja plicata*) populations was delayed probably as a result of drought conditions and a regular fire regime (Barnosky, 1985). After 4,500 yrs. B.P., the pollen record indicates the formation of closed forests of Douglas-fir (*P. menziesii*), western hemlock (*T. heterophylla*) and western red cedar (*Thuja plicata*) throughout the Puget trough marking the temperate humid climate of today. The story of the south Puget Sound prairie ecosystem would have ended with this shift in climate if it was not for the actions of another species.

Cultural Landscape

Just as plants and animals followed the retreat of the glaciers, so too did humans. Some of the earliest archeological evidence from Washington dates back to 13,000 yrs. B.P. Evidence suggests that these people were hunters who crossed a land bridge from Siberia. In a few generations their population dramatically increased at the expense of mega fauna like mastodons, whose extinction they may have caused (Martin, 1967). Across most of North

America, by 7,000 yrs. B.P, hunting cultures adapted to vanishing game by foraging on the nutritious parts of plants (Kruckeberg, 1991). Eventually a complex culture developed in the lowlands of western Washington. The Salish people, as they would later be called, occupied the lands west of the Cascade Range throughout British Columbia, Washington, and Oregon (Underhill, 1945). The economy of the Salish was based upon a wide range of wild foods, including fin and shellfish, game (deer, elk, small mammals, and fowl), roots, seeds, and berries (Underhill, 1945)

While salmon was a prominent food staple and significant cultural icon of the Salish, food crops from lowland prairies such as camas (*Camassia quamash*) , salmonberry (*Rubus spectabilis*), and bracken fern (*Pteridium aquilinum*) were also of great importance (Underhill 1945, White 1980, Leopold and Boyd, 1999). Historical and scientific evidence clearly demonstrate that the Salish maintained prairies throughout the Puget Trough as a result of climatic changes in the late Holocene. The warm and dry period of the middle Holocene (9,500 -4,500 yrs. B.P) created a climate suitable for a cohort of prairie and savanna species to develop under a frequent fire and drought regime (Barnosky, 1985, Leopold and Boyd, 1999, and Hansen, 1947). From 4,500 years B.P to the present a climatic cooling enabled conifers forest to expand at the expense of prairie and savannah grasslands (Leopold and Boyd, 1999). Within a few generations the lack of frequent disturbance should have led to the establishment of the Douglas-fir/western hemlock ecotone. Yet the Salish culture adapted to climate change by restoring ecological process through the use of fire and frequent disturbance.

Isolated prairie fragments remained throughout the Puget Trough from Oregon to British Columbia because they had a cultural, economic and ecological value for the people of the Pacific Northwest. On the glacial outwash and bottom lands of the Puget Trough, the Salish maintained an oak savannah/ grassland mosaic comprised of many food and medicine producing plants. Of the 157 inventoried prairie plant species, 35% are edible and over 85% have some documented ethnobotanical use (Storm, 2004, Norton et al., 1999). The Salish were dependent upon the diversity and density of prairie species for food, medicine and tools (Norton et al., 1999). The table (Fig. 1) lists some of the plants associated with prairies that had cultural, nutritional and medicinal values.

> Rather than being major Indian food sources because they dominated the prairies, bracken, nettles and camas more likely dominated the prairies because they were major Indian food sources. (White, 1980)

Salish tribes developed sophisticated methods for maintaining the functional value of the landscape, which enable the persistence, adaptation and dispersal of prairie species through fire and harvesting practices (Agee, 1993, Storm, 2004, Anderson, 2005).

Fire

Fire was commonly used across North America as a multi-purpose management tool in many Native cultures (Vale, 2002). On the south Puget Sound prairie landscape fire was primarily used to create open spaces for prairie species and maintain oak stands. Anthropogenic fires occurred later in the season and at shorter intervals than natural fires. In July and August burning was sporadic, most likely occurring after the harvesting of seasonally and locally available wild foods in limited areas (Boyd, 1999). In late August and early September large fires were set on prairies when most species were dormant and climatic conditions were appropriate (Boyd, 1999). Salish tribes likely managed the prairies on a landscape scale coordinating cross-tribal burning practices and rotating burns every couple of years (South Sound Prairies, 2009, Storm, 2004).

Without routine burning the prairie species would not have clear spaces and disturbed habitat to grow. Fire is a strong mortality factor for small woody species including Douglas-fir (*P. menziesii*) under 5 feet tall and has the positive effect of releasing nutrients and creating bare soil for prairie species (Dunn, 1998). With the absence of fire from the landscape Douglas-fir (*P. menziesii*) and eventually western hemlock (*T. heterophylla)* replaced the prairie and oak woodland ecotones. As was evident to James Cooper in 1859, after several decades of fire suppression by settlers;

> I conclude that these are the remains of a much more extensive prairie, which, within a comparatively recent period, occupied all the lower and dryer parts of the valleys, and which the forest have been gradually spreading over in their downward progress from the mountains. (Storm, 2004)

Anthropogenic fire not only removed competition but over millenniums increased the productivity associated with the prairies. Camas (*C. quamash*) and other geophytes directly benefited from annual burning in the fall. A seven year study comparing fall burning to summer burning on Mima Mounds Natural Area Preserve found that the ecological effect of burning in the fall increased camas (*C. quamash*) populations and decreased cover by Idaho Fescue (*Festuca idahoensis*) (Schuller, 1997). I

The oak woodlands associated with the prairies benefited from regular low intensity burning which created standardized well groomed oak groves that resembled European fruit and nut orchards (Boyd, 1999). Early descriptions of oak woodlands reinforced the idea that these were even aged and well spaced stands ideal for harvesting.

> Our route has been through what might be called a hilly prairie country, the grass mostly burned off by recent fires, and the whole country sprinkled with oaks, so regularly dispersed as to have the appearance of a continued orchard of oak trees

(Henry Eld Wilkes Expedition 1841). (U.S.F.S., 2007)

Fire increased productivity by reducing competition from conifers, smaller oaks, and shrubs. Prescribed burning also had the effect of removing bio-litter, which aided in the harvest of acorns (Anderson, 2005).

Fire was utilized by the Salish to create open spaces for prairie species and maintain oak stands. Fire has a positive ecological effect on prairie species through the mortality of competing trees and shrubs along with promoting nutrient cycling. While fire was an important management practice of the Salish, harvesting practices also had a profound impact on the landscape, and is worthy of more research.

Harvesting Practices

The Salish significantly modified the composition, structure and genetic diversity of the prairie landscape through harvesting. Over time the Salish selected geophytes that were adapted to herbivore and developed harvesting practices that enhanced the population of certain prairie species. Over millennia of animal and human selection, protection and replanting of offshoots, these species most likely underwent genetic changes. Research in northern California and British Columbia has demonstrated that the recurring excavation of plants selected for specific genotypes that thrived under frequent disturbance regimes (Anderson, 2005, Beckwith, 2004). In fact the growth of bulblets and cormlets in some geophytic species is slow or suppressed until they are detached from the parent (Anderson, 2005). Geophytic plants of the prairies were reliant upon people and animals to spread their seed, while people and animals were reliant upon the harvest of these plants for their survival.

In particular, the density and variety of camas (*C. quamash*) that once existed on the prairie landscape was not fortuitous but correlated to general harvesting practices, individual stewardship of prairie plots and probable trade amongst the Salish.

Traditional cultures conveyed knowledge through an oral tradition, that kept management practices relatively consistent from generation to generation (Nabhan, 1989). Amongst the Salish, sustainable camas harvesting practices were developed as part of a tradition which valued production, to ensure that cormlets and bulblets would have a greater chance at germination and growth (Beckwith, 2004). The practice of harvesting with a digging stick divided the bulbs and created bare aerated soil, conditions ideal for germination, not just for geophytes, but also for annual prairie species (Anderson, 2005). While little research has been conducted, harvesting camas on a scale to support the estimated 40,000 Salish of the interior Puget Trough valleys would undoubtedly have created a significant disturbance from which certain annual species most likely benefited. Extensive ethnobotanical research in northern California revealed that some Native harvesting practices were to;

spare some individual plants
harvest after seed-set
replant cormlets and bulblets
leave a lower section of the tubers
weed around favored plants
burn areas in which the plants grow to decrease plant competition and recycle nutrients (Anderson, 2005)

By utilizing these tactics harvesters increased the densities of populations ensuring that these important food crops would return year after year.

Secondly, individual stewardship of the land would have increased genetic diversity through the practice of seed selection. The Salish managed food crops on the prairies through cultivation or tending of plants similar to a garden or orchard (Storm, 2004). Amongst the Salish in Victoria B.C. access and use of inherited resource sites were controlled by their respective owners or "skilled specialists" within the family (Beckwith, 2004). Extensive and more productive harvesting grounds were likely associated with families of higher status (Beckwith, 2004). As Mary George of the Straits Salish of Victoria, B.C. explained to anthropologist W. Suttles in 2003;

> [T' Sou-ke people] had lots (plots). They didn't just dig anywhere. Stakes marked them. Women owned them, and they would fight for their claims. If someone came on to a woman's plot, she would quarrel. If the owner died, a near relative got the plot. (Beckwith, 2004)

Most land-based cultures have practices that guide plant selection and seed saving (Nabhan, 1998). Each individual might develop their own variations based on site conditions but the general scheme is passed on from generation to generation (Nabhan, 1998). Amongst the Salish, camas gathering sites in particular were the responsibility of a family unit and gatherers were careful about the management of their sites (Storm, 2004). Once natural selection sets a course in Native fields, cultural selection and replanting of the biggest or best tasting varieties is reinforcing (Nabhan, 1989). With a food crop as significant as camas (*C. quamash*), it is possible that, specific designations and local distinctions for camas variants have disappeared over time as the management of these populations declined (Beckwith, 2004).

Finally, the Salish most likely distributed seeds and bulbs through harvesting and trade. While there is a lack of direct historical evidence demonstrating the extent to which the Salish distributed plants, tending and trading of food crops was a common practice among many Native cultures. For example, when the potato was introduced all Salish tribes moved easily and rapidly to the cultivation of that crop without any direct instruction from whites (White, 1980). Bulblets and cormlets were moved into fresh areas, at first unwittingly, but later with zeal and care (White, 1980). A common practice of many tribes was to disperse plants along trading and seasonal migration routes. In 1853 James Cooper catalogued the plants along the Kilikitat trail, which connects the Columbian Basin with northern California. Of the sixty-five plants observed, fifty eight had nutritional or medicinal uses (Norton et al, 1999). In Victoria B.C., Salish maintained populations of camas and berries near their camps, although there is little evidence to determine whether they planted or just enhanced these populations (Beckwith, 2004). It is well established that the Salish used fire and harvesting practices to increase population densities of important food crops. It is a fair assumption that they most probably dispersed seeds, cormlets and bulblets into new areas that were easily accessible to them during travel and at seasonal camps.

Pestilence on the Prairie

When the first settlers arrived in the Puget Trough, most viewed the prairie landscape as natural or wild, waiting to be tamed and cultivated. This perspective overlooked the millennia of labor that the Salish people expended to create the breadth, beauty and bounty of the prairie landscape. Adding to cultural misperceptions of an untamed wilderness, was that the Salish population, which maintained the prairie landscape was decimated by disease, before many of the settlers arrived. Vancouver was one of the first Europeans to explore the Puget Sound in 1770 and noted in his journals the lack of inhabitants and presence of human remains;

> It was a fact not less singular than worthy of observation, that on the whole extensive coast of New Albion, and more particularly in the vicinity of those fertile and delightful shores we had lately passed we had not seen any inhabitants, or met with any circumstances that, in indicated a probability of the country being inhabited … In our different excursions, the skull, limb, ribs, and back-bones, or some vestiges of the human body, were found in many places promiscuously scattered about the beaches in great numbers. (Vancouver as in Gibbs, 1877)

Some scholars estimate that up to 95% of the interior valley population was expired by 1850 when the homestead and donation land claim acts began to fuel settlement in the Puget Trough (Boyd, 1999).

The high mortality of the Salish population to disease can be attributed to the lack of immunity and social responses to illness. These epidemics are termed virgin soil diseases, referring to the fact that they were introduced into a population that had never previously experienced them (Boyd, 1999). There were several such epidemics in the early recorded history of the Pacific Northwest: 1770's smallpox, 1830's malaria, 1838 influenza, 1844 dysentery, and 1848 measles. In the Puget Trough the defining disease was malaria. All Pacific Northwest tribes also experienced early small pox, and most suffered from dysentery and measles as well (Boyd, 1999). The data shows that small pox traveled through the population at widely spread intervals, about once per generation (Boyd, 1999). Malaria however, once established, had a chronic debilitating effect on the Salish, taking a yearly toll of newborns and infants (Boyd, 1999).

Population estimates of the Salish have increased as technology and mindsets have changed over time. Powell in 1877 estimated a population of 8,000 for the tribes within the Straits of Juan de Fuca and 26,800 for the entire population in western Washington. Early approximations like Powell's were often biased and erroneous, asserting that the epidemics that ravaged the Salish were natural, ignoring historical accounts;

> too great stress is not to be laid upon the assertion of the Indians themselves that they were once a great many, for their ideas of numbers are vague at best, and the recollection of any former mortality would probably be greatly exaggerated. (Gibbs, 1877)

Most recently in 1996, Boyd using computational analysis based upon the earliest reliable censuses, estimates a population of 183,661 for the coastal area of Washington and northern

Oregon, and approximately 40,000 for the interior valleys of the Puget Trough (Fig. B). Boyd's estimates are five times greater than Powell's estimate. By 1850, when the Donation Land Claim Act spurred settlement in the territory, the release of invasive diseases had diminished the population of Interior Valley tribes to roughly 2,000, a shadow of pre-epidemic densities. As the population of the Salish declined so too did the traditional maintenance practices of prescribed burning and harvesting.

Salish culture possessed ecological knowledge and exhibited management practices which increased the fecundity and diversity of certain prairie species on the south Puget Sound landscape. The utilization of fire and harvesting practices preserved a seral grassland ecosystem that contained value in both form and function. The traditional knowledge of the Salish culture was diluted by debilitating epidemics. By the time settlers began to arrive in western Washington, Douglas-fir (*P. menziesii*) was already encroaching on to the prairie landscape.

II. Development and Fragmentation

An American explorer said of the Cowlitz and Chehalis prairies, “here the ground is ready for the plough and nature seems as it were to invite the husbandman to his labor” (Leopold and Boyd, 1999). However, the husbandman’s land management practices were vastly different from the Salish and overtime have proved to be unsustainable. Even though settlers and the Salish shared a similar diet of salmon, game, and root crops, the ecological effect of their labor was stark (White, 1980). After the 1850’s the landscape was “so cataclysmically altered and with such unanimity of purpose that no single voice of conscience could have effectively stemmed the onslaught on the land” (Kruckeberg, 1991). Western style agriculture required the destruction of native flora, suppression of fire and the introduction of non-indigenous species, which changed the composition, structure and connectivity of the prairie landscape. Today the prairies which survive are islands amongst a sea of development, and the composition of the vegetational community will forever remain a mixture of original and introduced species (Purcell, 1987).

Settlement

The United States government enacted policies to encourage settlement which led to the development and fragmentation of the South Puget Sound prairie landscape. In 1841, the Preemption Act gave the opportunity to purchase property rights to squatters on government land not to exceed 160 acres (Hibbard, 1939). Nine years later, the Donation Land Claim Act was passed into law by Congress to promote the settlement of the Oregon Territory, which included Oregon, Washington and Idaho (Hibbard, 1939). The act granted 160 acres to every white male 18 or older and 320 acres to every married couple who arrived in the territory before December 1, 1850. Settlers arriving between 1851 and 1854 were eligible for half the amount of land. In order to claim land under the Donation Land Claim Act settlers had to live on and cultivate the land for at least four years. Similarly, the 1862 Homestead Act required that applicants live on the land, build a 12 x 14 dwelling and grow food crops. Both the 1850 Donation Land Claim and the 1862 Homestead Acts required settlers to cultivate the land they intended to claim, presumably with western style agriculture techniques including plowing and row cropping.

The people who moved to Washington during the 1850's and 60's settled prairie and wetlands first because they were relatively free of trees and appeared to be very productive (White, 1980). Even though past attempts of row cropping at Fort Nisqually had proved unsuccessful, farmers continued to settle on the prairies. Perhaps they were motivated by exaggerated claims of fertility;

> The fine fertile, plains and prairies offer far greater inducements (than the forested lands). Fruit of various kinds, particularly apples, can be cultivated very readily, and in the greatest perfection…wheat, barley, oats, and potatoes yield the most abundant crops, of the finest quality. (James Swan, 1859 as in White, 1980)

In reality the Puget Sound prairie soils were too droughty and nutrient deficient for European row cropping. The best land for growing European crops was actually the woodlands surrounding the prairies where loamy soils existed (U.S.F.S., 2007),

> The best land occurs where prairies are intersected or broken by belts of woods, that have dense undergrowth, consisting of hazel, *Spiraea, Cornus*, and *Prunus.* (Charles Wilkes, 1841 as in U.S.F.S., 2007)

Regardless of the fertility, settlers had to make improvements and cultivate their potential property within a short time frame in order to qualify for the Donation Land and Homestead

Acts and prairies were much easier to clear than forested lands. While the soil types of the South Sound prairies proved to be unsuitable for farming they were adequate for grazing (White, 1980). 7,437 households alone were registered under the Donation Land Claim Act between 1850 and 1855. Many of these households claimed prairie land for agricultural and grazing purposes.

The ecological destruction of the prairies was inherent in the policies of the U.S. government between 1841 and 1862. Policies that encouraged migration to western territories essentially ecologically and culturally transformed the prairie landscape. Farmers replaced the rich and diverse prairie ecosystem with monoculture fields and permanent pastures (White, 1980). This European style of agriculture required the suppression of fire and released invasive species which were detrimental to the prairie ecosystem functioning (Kruckeberg, 1991).

Farming, Fire Suppression, and Population Growth

As farming and animal husbandry practices were established fires were discouraged, and the use of the prairies by the Salish was largely ended (South Sound Prairies, 2009). Domestic livestock, road and rail construction, grassland conversion to agriculture, urbanization and rural development all contributed to the direct or indirect exclusion of fires (Hesberg et al., 2005). As stated fire was an important ecological process of the Puget Trough prairies and to the extent that settlers were successful in excluding fire from the prairies, so too were they at degrading the prairie soils (Purcell, 1987). Settlers were quick to realize the destructive power of fire, but were slow to understand its power to restore and renew the landscape (Purcell, 1987). In 1913, it was apparent that the forest was encroaching upon the prairies;

> In retracing surveyor's lines run 50 years ago, the limits of forest growth were found to have advanced on the prairies…Many Gnarled skeletons of the broad spreading prairie oaks are found moldering in a dense growth of young fir which has killed them in the last half of the century. (Kruckeberg 1991)

Due to the lack of fire, prairies on the south Puget Sound landscape may have been lost at a rate of approximately 100 acres per year since the 1850's due to the conversion to Douglas-fir (*P. menziesii*) forest (Kruckeberg, 1991).

Settlers and Salish shared a functional value for the landscape: sustenance, but the methods that they utilized had radically different ecological effects. While the prairies seemed rich and fertile, given the density and diversity of species, these soils were typically low in nitrogen, highly acidic, prone to drought and were generally unsuitable for western style agriculture (Crawford and Hall, 1997). The first several centimeters of these soils have a thin layer of organic material, followed by approximately a foot of strongly acidic gravelly sandy loam with high organic content, until eventually a layer of coarse sand and gravel (Crawford and Hall, 1997). Plowing was necessary for introduced European row crops such as wheat, oats, barley, peas, corn, cabbage, carrots, turnips, beets, tomatoes, melons and squash but it destroyed the native cover of the prairie increasing evaporation rates, especially during the dry summer months (White, 1980). The raising of animals also had a drastic ecological impact. Cattle and sheep grazed upon prairie grasses and pigs were set free to forage upon bulbs, in particular pigs ate an inordinate amount of camas (*C. quamash*) (White, 1980, Beckwith, 2004). Despite poor soils, farming continued on the prairies for centuries. In practice these small subsistence farms were synonymous with poverty and produced neither adequate food nor shelter for their owners (White, 1980).

Strawberry production is a great example of how European row cropping agriculture was not sustainable on the South Puget Sound prairie landscape. After World War I up to 3,000 acres of Grand Mound prairie were converted to commercial strawberry production (Purcell, 1987). Interestingly enough berries were a predominate Salish food source and as Upper Chehalis elder Mary Heck testified, were abundant on the prairie landscape;

> We had kinikinik berries, black berries, wild raspberries, and crab apples, salmon berries, sala berries, and another berry called Kamotlk…They had june berries, wild currents, black cap raspberries and lots of blueberries, and thimble berries grow along the edge of the prairies. (Storm, 2004)

When asked if they has strawberries she says "there was so much strawberries you can smell it from a distance" (Storm 2004). While the native strawberry (*Fragaria virginiana)* was well adapted to the prairie landscape, commercial strawberries were not. Given high production cost, low soil fertility, and erratic strawberry prices, production on Grand Mound prairie proved to be unsustainable and the endeavor was abandoned by the 1940's (Purcell, 1987). While berries were a main food crop produced under the Salish system, their production was not sustainable utilizing western agriculture methods.

Development and fragmentation of the prairie landscape did not stop in the 19th century in fact it continues to this day. In the south Puget Sound region, prairie soils primarily exist in five counties Grays Harbor, Thurston, Lewis, Mason and Pierce (Crawford and Hall, 1997). Figure (C.) illustrates the population growth of these five counties since 1900. Between 1900 and 1920 population in Pierce, Thurston, Lewis and Grays Harbor more than doubled from roughly 100,000 to 250,000. During this time much of the prairie landscape was transformed by the plow and tractor for small subsistence farms (Purcell, 1987). Another population boom was experienced between 1960 and 1980 as the populations of these counties increased by another 300,000. Housing development intensified as developers were once again seeking relatively cheap, flat and clear land to develop (Purcell, 1987). While development and fragmentation have contributed to the loss of habitat and connectivity between prairie landscapes, they are not the only threat to biodiversity and may not even be the greatest.

Invasive Species

Today, hundreds to thousands of non-indigenous species including invertebrates, vertebrates, plants, bacteria and fungi have become established in all but the most remote areas of the planet (Ricciardi et al., 2000). The south Puget Sound prairie landscape is no exception. As a result of European settlement, thousands of non-indigenous species were introduced on the prairie landscape. The purposeful and inadvertent introduction of non-indigenous species has been detrimental to the bunch grass prairie ecosystem (South Sound Prairies, 2010). Purposefully, settlers planted non-indigenous plants mainly for ornamental and agricultural purposes. Inadvertently, non-indigenous species were transported along road and railways, through farm fields and even the ballast of ships (White, 1980).

Agriculture was perhaps the greatest source of non-indigenous species. Beside the plants that farmers were intending to grow they often grew weedy species as well. For example;

> In 1865, Granville Haller, who owned a farm near Oak Harbor, examined 391 lbs of seed wheat. He estimated it to be one-third waste, "barley, oats, buckwheat, and peas besides an abundance of cheet and smut" (White, 1980).

Weeds are an inevitable result of trying to restrict the landscape to a single species. While some of these non-indigenous species failed to colonize or have maintained relatively small and benign populations, other species possess traits that cause us to label them as weedy, noxious or invasive. In general, only about 1% of all introduced species become invasive (Mooney et al., 2001). Yet this 1% causes severe economic and environmental harm.

The difference between a non-indigenous or introduced species and an invasive species is the value to humans. The earth supports a massive array of ecosystems, which are critical for sustaining life and provide direct value to humans through the goods and services they provide (Malcom and Pitelka, 2000). Invasive species degrade this value. The National Invasive Species Information Center (NISIC) defines an invasive species as;

> a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112, 1999). (NISIC, 2010)

Invasive species threaten national economies, human health, and global biodiversity (Simberloff et al., 2005). In 2000, the economic impact of invasive species was estimated to exceed $138 billion a year (Rossman, 2001). In the agriculture sector alone 25% of the gross product is lost to a growing variety of invasive species (Ricciardi, 2000). Across the globe invasive species are recognized as a considerable threat to biodiversity and can profoundly alter ecosystem structure and function (Longsdale, 1999). On the south Puget Sound prairie landscape invasive species are the greatest threat to biodiversity and have drastically altered the composition and functioning of the ecosystem (South Sound Prairies, 2010).

By definition, an invasive species has competitive traits that enable the invader to displace native species (Radosevich et al., 2003). Invasive species flourished on the prairies due to the massive disturbances of grazing, plowing and the repression of fire (Purcell, 1987). Invasive species were able to colonize and persist on the prairies because they possess characteristics that enable them to out-compete native flora. Invasive species often display phenotypic plasticity, or the ability of an organism to change its phenotype in response to the environment (Sakai et al., 2001). Another important feature of many invasive species on the prairies is that they are effective dispersers and have high reproductive rates (Malcolm and Pitelka, 2000). In particular, Scotch broom (*Cytisus scoparius*), has displayed an enormous ability to dominate the prairie landscape and reduce the diversity and density of native species.

Scotch broom (*C. scoparius*) is one of the prominent invasive species that threatens biodiversity on the south Puget Sound prairie landscape. Scotch broom (*C. scoparius*) is naturalized in lowland areas throughout western Washington (Washington State Noxious Weed Control Board, 2010). It is a long-lived, bushy shrub with stiff, slender branches that can grow to be up to 12 feet tall (USDA Forest Service, 2009). In its European range, it is considered a minor weed (Sheppard et al., 2002), however, in North America it is one of the most common and widespread invasive species impacting several plant communities throughout the Puget Trough (USDA Forest Service, 2009) . The first recorded specimen of scotch broom (*C. scoparius*) was collected from a Seattle garden in 1888, and has been regarded as a noxious pest in rangelands and natural areas since (Parker, 1997). On the south Puget Sound prairie landscape, it displaces and impacts threatened species such as golden paintbrush (Castilleja levisecta) and Taylor's Checkerspot (*Euphydryas editha taylori*) (USDA Forest Service 2009). Its effects are compounded by its nitrogen (N) fixing abilities, which often facilitate a new cohort of vegetation. A study focusing on three Puget Trough prairies found that invasion by Scotch broom (*C. scoparius*) is associated with an increase in total N and N availability, an increase in cover of other invasive species and a decline in native species richness (Parker, 2000). While eradication of scotch broom (*C. scoparius*) may never be possible, if it is not controlled it will continue to degrade the prairie landscape.

The U.S. policies to promote settlement of western Washington facilitated the destruction of bunchgrass prairies. The land management techniques of settlers were incongruent with that of the Salish, fire suppression, agriculture, and the introduction of invasive species decimated the prairie ecosystem. Ultimately agriculture proved unsuccessful, but as the population of western Washington continues to grow, development, fire suppression and the introduction of invasive species persists. There is another threat to prairies, a silent threat which exacerbates the current challenge bunchgrass prairies face. The industrialized processes that fueled western expansionism also released an extraordinary amount of carbon dioxide (CO_2) into the atmosphere, the effects of which we are still trying to understand today.

III. <u>Climate Change</u>

Gases in the atmosphere absorb and emit infrared radiation, essentially trapping heat within the troposphere of the earth creating a greenhouse effect. Amounts of greenhouse gases (GHG) are increasing as a result of industrialized human activities—since 1750, carbon dioxide (CO2) has increased 32%, and methane has increased 150% (Climate Impacts Group, 2010). The influx of these gases is primarily responsible for a temperature increase of .74 + or - .18 degrees Celsius over the course of the 20^{th} century. Most governments have signed the Kyoto Protocol in hopes to curtail GHG emissions before levels in the atmosphere reach catastrophic levels. Over the past 20 years the atmospheric CO2 growth rate has more than doubled. As global economic activity increases and becomes more carbon intensive, significant global reductions seem a distant goal at best (Heller and Zavaleta, 2008). Anthropogenic climate change is unequivocal and unavoidable; the question to be asked then is how much change can be expected over the next century.

General Circulation Modeling

There is uncertainty in the forecasting of future climate scenarios. Currently, scientists utilize General Circulation Models (GCM's), which are based on mathematical equations of a rotating sphere with thermodynamic inputs for various energy sources (radiation, latent heat). Accurate models must take into account a complexity of interconnected biological, chemical, and fluid dynamic variables (Crumpacker et al., 2001). All GCM's contain assumptions not just about the behavior of the Earth's atmosphere and oceans but also in their forecast of future anthropogenic growth and land development (Salmun et al., 2006). GCM's are evolving, becoming more precise and accurate—it is the predicting of human actions in which the onus of uncertainty rests.

The Intergovernmental Panel on Climate Change (IPCC) has developed a number of scenarios to estimate future anthropogenic Green House Gas (GHG) emissions. The possibility that any one scenario will occur is unlikely, but together they encompass the current range of future GHG emissions arising from sources such as demographic, social, economic and technological developments (IPCC, 2007). For the wide range of GHG emissions scenarios, the Earth's mean surface temperature is projected to warm by 1.4 to 5.8 degrees Celsius as compared to 1990 average mean global temperatures by the end of the 21st century (PEW, 2003). The 2004 IPCC worst case scenarios projections were actually surpassed in 2007, indicating that under a "business as usual" scenario a 1.4 degrees Celsius rise is all but certain and a temperature increase of 5.8 degrees Celsius is more than probable by the year 2100 (IPCC, 2007).

Climate change is not uniform though and will occur at different rates for different regions. The most notable areas of warming are in the land masses of northern regions (North America and North/Central Asia), which exceed global mean warming in each climate model by more than 40% (Climate Impacts Group, 2010). In contrast, warming is less than the global mean change in South and Southeast Asia in summer and in southern South America in winter (Climate Impacts Group, 2010). So what does climate change mean for the Pacific Northwest and more specifically what affect, if any, will climate change have on the south Puget Sound prairie landscape?

Pacific Northwest

In the Pacific Northwest, the effects of climate change over the last century have been fairly uniformed and widespread (Climate Impacts Group, 2010). The Pacific Northwest has been getting warmer and wetter, and these trends will continue and accelerate over the next century (Climate Impact Groups, 2010). Overall, historical trends from the 20th century of temperature, precipitation and snow pack demonstrate that the Pacific Northwest is having longer, drier summers and shorter, wetter winters. The past 80 years of observation clearly indicate a general increase in temperature and precipitation across the Pacific Northwest.

With greater technical abilities than even just a few years ago projecting multiple GCM simulations or ensembles and presuming that the distribution of future changes is well represented within is now common practice (Mote et al., 2009). In 2008 Climate Impacts Group, an interdisciplinary research group studying the impacts of global climate change in the Pacific Northwest projected temperature and precipitation changes based upon 20 global models utilizing the B1 and A1B1 IPCC emission scenarios. The averaging of these models projects an increase in overall temperature on the order of 0.2°-1.0°F (0.1°-0.6°C) per decade throughout the 21st century (Climate Impacts Group, 2010). Small mean increases in temperature reflect higher variability in temperature ranges. Temperature increases will occur across all seasons with the largest increases in summer (Climate Impacts Group, 2010). Temperature increases are expected to accelerate in the latter half of the century, yet there is higher variability during this time frame based upon which GHG scenario was modeled (Climate Impacts Group, 2010). Projected changes in annual precipitation are less certain. Some GCM's show a decrease of up to 10% while others show an increase of 20% by 2080 compared to

1970-1990 (Climate Impacts Group, 2010). The majority of emission scenarios yield decreases in summer precipitation and increases in winter precipitation, with a small net average increase of 1-2% in overall precipitation compared to 1970-1990 (Climate Impacts Group, 2010). While ensemble models project a wide distribution of possible outcomes, in order to better understand how fine scale weather and land surface processes will respond to climate changes, a more precise regional model with higher meso-scale resolution is necessary (Elsner et al., 2009).

The ECHAM5/MPI-OM (European Centre for Medium-Range Weather Forecast 5th generation and Max Planck Institute Ocean Model) is one of the finest scale (15 km grid spacing) and most accurate models completed for Washington state in 2008. The model assumed the A2 IPCC emission scenario, which is a relatively aggressive outlook of GHG emissions, and completed projections for four decades 1990-1999, 2020-2029, 2045-2054, and 2090-2099. The ECHAM5/MPI-OM model has relatively high horizontal and vertical resolution and produces realistic synoptic scale patterns in comparison to other coarser models (Salathe et al., 2008).

The predictions for temperature and precipitation change of the ECHAM5/MPI-OM model contain a finer level of detail than the ensemble of models. In particular, the combined effects of decreased albedo and increased down welling long wave radiation amplified temperature increases under an A2 scenario. In addition to the domain wide warming 0.2°-1.0°F (0.1°-0.6°C) per decade, the ECHAM5/MPI-OM produces amplified warming along the flanks of the Cascade Mountain Range, this pattern is well established by 2020 and yields to considerable localized warming by the 2090s (Salathe et al., 2008). As snow pack diminishes less radiation is reflected into the atmosphere and is absorbed by the landscape. During the spring season, enhanced warming will move upslope following the snowline and maximum warming will be found along the crest of the Cascade Range (Salathe et al., 20008). Along the coastal areas of the Puget Sound the regional model showed considerably less warming of maximum daytime temperatures but increased night time temperatures (Salathe et al., 2008). The greater warming of the continental interior, relative to the oceans will increase low level cloudiness amplifying the downwelling of infrared radiation at night, producing a warming effect after the sun goes down (Salathe et al., 2008). The ECHAM/MPI-OM illustrates that the rate of warming will vary throughout the seasons, across the landscape and even over the course of a single day.

The global models indicate a small increase in precipitation over the Pacific Northwest during the months of November through January. While amounts and seasonality are similar, the ECHAM5/MPI-OM provides greater detail about where we can expect increased precipitation (Salathe et al., 2008). The ECHAM5/MPI-OM model captures effects such as large-scale moisture flux, frequency and intensity of large-scale storms, changes in large-scale circulation and interactions with the surface orography (Salathe et al., 2008). The model illustrates that regional topography will have a significant impact on where increased precipitation will fall. The shift to more onshore flow increases the orographic precipitation along the north-south ridges of the Cascade Range (Salathe et al., 2008). Increased precipitation analogous to increased temperature will occur mainly at higher altitudes along the Cascade and Olympic Mountain Ranges.

In the Pacific Northwest, the climate is changing. Average annual temperature and precipitation has increased along with extreme heat and storm events. Climatologists are confident that the climate will continue to get warmer and wetter. Climate change will be accelerated at higher elevations but this does not diminish the effects on the lowlands of western Washington. Understanding the effect that climate change will have on vegetational communities is critical for conservation and restoration efforts on the south Puget Sound prairie landscape.

Range Movement

Globally, the IPCC evaluated the effect of climate change on biological systems by assessing 2,500 published studies. Forty-four studies met the following criteria: twenty or more years of data, measured temperature as one of the variables, and had a statistically significant correlation (IPCC, 2007). Approximately 80% showed differences in the biological parameter measured (e.g., start and end of breeding season, shifts in migration patterns, shifts in animal and plant distributions and changes in body size) in the manner expected with climate change (IPCC, 2007). Climate change is currently and has been for some time impacting the distribution of flora and fauna across the globe.

In Washington, historical and scientific studies have shown that climate change is leading to vegetaional shifts. Plant migrations due to climate have been recorded through photographic evidence and tree coring data at high altitudes in Olympic National Park and Mount Rainer National Park. Tree establishment in subalpine meadows, particularly subalpine fir (*Abies lasiocarpa*) on drier slopes, has been documented in several studies which; purposely selected relatively non-flammable north facing sites showing no signs of recent fire, avalanches or rock slides (Woodward et al., 1995, Rochefort and Peterson, 1996). Warmer, drier summers from 1956-1985—which are now attributed to climate change—have created conditions favorable for subalpine fir (*A. lasiocarpa*) to establish on the southwest slopes of the Olympics, and west slopes of Mt. Rainer (Woodward et al., 1995; Rochefort and Peterson, 1996). While the re-distribution of plants at high altitudes due to climate change is evident, shifts that may be occurring on the south Puget Sound prairie landscape are less conclusive.

Paleontological evidence suggests it is unlikely that species will move at the same rates and that the composition of most ecosystems will very likely be significantly altered (IPCC, 2007). Climate change scenarios based on GCM's can be linked to biological models to predict these plant migrations (Crumpacker et al., 2001). These biological GCM's are important guides to understanding the migration of plant species in response to climate change, such as those related to decreased fertility and seedling viability of ecologically important plant species near their range limits (Crumpacker et al., 2001). Fine scale predictions of how ecosystems will change are difficult to gather because of topographic complexity, but most GCM's show that changes in ecosystems will occur as complex small-scale movements rather than broad northward shifts (Malcolm and Pitelka, 2000).

Unfortunately, the south Puget Sound prairie landscape is not well represented in even the finest scale biological models for two reasons. First the prairie landscape is a seral grassland community maintained through an anthropogenic fire regime that is not represented in the models. Secondly, the extent of the existing prairie and oak woodland preserves is small relative to the scale of even the most precise models to date. Vegetation models do provide broad projections about how the Western Forest Zone surrounding the prairie landscape will react under specific GHG emission scenarios and GCM's. Understand how the forest responds to climate change will facilitate an appreciation for how the prairies might react in relation to the forest.

The vegetation type modeled throughout the Puget Trough region is Maritime Conifer Forest, which is comprised mainly of Douglas-fir (*P. menziesii*) and western hemlock (*T. heterophylla*), yet that might change under future climate scenarios (Rogers, 2009, Elsner et al., 2009). Depending upon which GHG and GCM is utilized the maritime conifer forest of the Puget Trough is projected to undergo large scale conversions similar to what the region experienced between 12,000 and 3,500 yrs. B.P. with the expansion of xerophytic or grassland taxa (Rogers, 2009). Key species within the lowland forest will have a decreased competitive ability due to loss of growth, vigor and large-scale disturbances (Little, 2006). By 2060, under a moderate GHG scenario it is likely that Douglas-fir (*P. menziesii*) will have decreased juvenile survival rates due to increased evapotranspiration during the summer months throughout the Puget Trough (Elsner et al., 2009). The rate and composition of forest conversion in response to climate change will be driven more by disturbance than by gradual changes in tree population and will likely be more rapid than projected models of future species range shifts indicate (Elsner et al., 2009).

Changes in the frequency, intensity, extent and locations of disturbances will affect the rate at which existing ecosystems will be replaced by new plant assemblages (IPCC, 2007). The natural disturbances, which have the most significant impact on forests, include fire, drought, introduced species, insect/pathogen outbreaks, hurricanes, windstorms, ice storms and landslides (Dale et al., 2001). In the Pacific Northwest, windstorms and fire are of particular concern—in many cases, large-scale disturbances such as fire or windstorms will remove much of the over story and facilitate a new cohort of vegetation (Little, 2007). The regeneration phase after a disturbance will be the key stage at which species will compete and establish in a warmer climate, thus determining the composition of future ecosystems (Little, 2007). We must therefore interpret vegetation shifts in the context of local factors, such as seed sources, migration pathways, successional status, real-world disturbance history and potential future disturbances (Rogers, 2009). There is little evidence to suggest that climate change will increase species richness, and abundant evidence suggesting that species richness will decrease (IPCC, 2007).

Climate change is occurring, has been occurring and will continue to occur into the future. General circulation models downscaled to the Pacific Northwest project variations in temperature and precipitations. Changes in climate will significantly affect vegetation communities as species persist, adapt or migrate to a more suitable climate. The Idaho-fescue bunchgrass ecosystem persisted when the climate changed during the late Holocene, but that was only because people placed a certain value upon prairie species and maintained the bunchgrass community through fire and harvesting practices. The fate of bunchgrass prairies will continue to be dependent on people, and the cultural value we have for uniqueness and diversity.

IV. Ecological Restoration in a Warming World

The first prairies were a result of climatic conditions following the last ice age. As the climate changed the south Puget Sound prairie landscape was maintained by a framework of tribes and clans. These different groups were united by a common cultural value for the land and shared similar management techniques. The practices of the Salish influenced the composition, structure and connectivity of the prairie landscape which enabled the seral grassland community to persist even as climate changes had altered the natural fire regime. As European settlers moved to the Puget Trough the prairie landscape was developed because it was relatively flat and clear of trees. Settlement had a profound ecological impact; agriculture, fire suppression and the introduction of invasive species, degraded the functioning and services that the prairie landscape once provided. However, there is another chapter to human management of the prairie landscape, the establishment of public and private prairie preserves and the growing community of prairie practitioners dedicated to conserving the prairies.

Beginning in the 1970's prairie conservation in the south Puget Sound started to emerge as a priority for a conglomerate of different non-profit, state and federal agencies. Alarm at the rate of species and habitat loss influenced a myriad of agencies to begin conserving the prairies. Currently there are 17 different Federal, State, County and non-profit agencies collaborating as part of the South Puget Sound Prairie Landscape Working Group (South Sound Prairies, 2009).

US Fish and Wildlife
Natural Resources Conservation Service
US Forest Service
US Environmental Protection Agency
Ft. Lewis
McChord Air Force Base
WA Department of Fish and Wildlife
WA Department of Natural Resources
WA Department of Transportation
Washington State University Vancouver
Pierce County
Thurston County Parks and Recreation
Port of Olympia
The Nature Conservancy of Washington
Audubon Society
Capitol Land Trust

Friends of Puget Prairies Wolf Haven International

While each agency has its own management or conservation goals this group works together to share expertise, develop resources and implement future conservation activities on the prairie and oak woodlands of the south Puget Sound (South Sound Prairies, 2010). Prairie conservation on the south Puget Sound landscape is an adaptive management scenario as this group actively collects and disseminates information to maximizes resources and reduce uncertainty overtime.

These agencies have been successful at preserving and restoring over 5,000 acres of prairie and oak woodland habitat. Major protected areas include:

	Acres
Mima Mounds NAP WA State - Dept. of Natural Resources	445
Rocky Prairie NAP WA State - Dept. of Natural Resources	47
Glacial Heritage Thurston County - Dept. of Parks and Recreation	1,020
Scatter Creek Wildlife Area WA State – Dept. of Fish and Wildlife	1,200
13th Division Prairie RNA US Army - Fort Lewis	234
Weir Prairie RNA US Army - Fort Lewis	1,096
Bower Woods Ponderosa Pine Forest RNA US Army - Fort Lewis	1,739

(Dunn, 1998)

Preservation status means that these areas are protected from future development, not necessarily fully restored prairie or oak woodland. In fact the idea of what constitutes a restored prairie or oak woodland differs amongst organizations and over time. The management of these areas varies not only from agency to agency but from site to site as well.

I interviewed 14 practitioners with a combined 187 years of experience restoring and conserving grassland habitats. Years of experience range from 2 to 30 with the average being 13.5. All participants are part of the South Puget Sound Prairie Landscape Working Group list serve and were referred through the South Puget Sound Nature Conservancy. Participants were land managers, restoration ecologist, wildlife conservationist and researchers. Collectively, participants represented 10 different nonprofit, state, federal and academic organizations. Interviews were conducted either in an office, meeting room or over the phone. Meetings ranged from thirty minutes to an hour with the average conversation lasting 45 minutes. All individuals were asked the same 13 questions when applicable (Fig. D) but the sequence of the questions varied depending upon the responses that were given. The identity of participants will be kept anonymous due to the sensitive and sometimes contentious nature of adaption to climate change. Each participant is associated with a corresponding letter value. Statistical analysis of interview results discussed is presented in a table (Fig. E.):

Figure E.) Interview results from questions that are discussed throughout the paper. Answers to questions were coded based upon the response provided by the participants. Percentages are rounded to the nearest whole number.

What are your current restoration goals?	**N=14**
manage invasive species	79%
increase diversity	79%
restore ecological process	29%
research or develop tools	21%
restore pre-settlement landscape	29%
increase # of rare species	36%

Is climate change a challenge or an opportunity for prairie restoration?	**N=14**
challenge	100%
opportunity	79%
both	79%

What effect is climate change having on the prairie eco-system?	**N=14**
significant impact	50%
minimal impacts	30%
not yet occurring	20%

What methods do you utilize to achieve your goals?	**N=12**
prescribed burning	50%
mechanical control	66%
planting, seeding, or reintroduction	84%
chemical control	66%

What considerations, if any, do you give to sourcing restoration materials?	**N=11**
site specific	45%
regional mix	55%

Do you think assisted migration of prairie species will be a necessary measure as the climate changes?	**N=14**
necessary	57%
unnecessary	43%

aggressive	14%
avoidance	14%
constrained	72%

Is the term "native" still appropriate in this time of climate change	**N=14**
still appropriate	100%
definition will expand	85%
Mentioned invasive species	50%

What is your perception of what has been lost?	**N=14**
biodiversity	50%
ecological processes	21%
geographic extent/connectivity	64%
mindset	21%
resilience	7%

What can realistically be restored?	**N=14**
maintain existing populations	57%
expand	43%

The restoration goals of most participants could be classified into two themes controlling invasive species and increasing diversity. While some participants were chiefly involved in researching best practices and developing tools for restoration, the majority of participants identified these two interconnected goals. Invasive species are the single greatest threat to biodiversity on the prairie landscape as many of the invasive species out-compete native species even on undisturbed sites (Source E, 2009). Native prairie species are not particularly well adapted to the cooler wetter climate present in western Washington since 4,500 yrs. B.P. and invasive species by nature are extremely competitive (Source F, 2009). Whether practitioners were restoring sites to a pre-settlement landscape composition or to augment the population of a single rare species, controlling invasive species was viewed as necessary to preserve and restore diversity.

While the motivation for increasing diversity varies amongst agencies and individuals, studies have shown that increasing diversity can increase the resilience of an ecosystem to disturbances that will likely be more common under climate change. Increasing taxonomical diversity or the functional redundancy (the replication of components with similar functions) increases the likelihood that individuals who provided a specific function will survive a disturbance (Dunwiddie et al., 2009). Increasing the number of individuals within a population or component redundancy increases the likelihood that some individuals will be able to adapt to or survive a disturbance (Dunwiddie et al, 2009). Research has also shown that intact and species-rich communities not only have increased production, but also are more resistant to invasions (Tilman, 1999). While mandates and targets differ amongst practitioners, controlling invasive species and increasing diversity, may also enable prairie species to persist or adapt to a changing climate.

While adapting restoration practices to a changing climate was not a specific goal of any of the participants interviewed, all individuals had given consideration to how climate change might affect their work. When asked if climate change was a challenge or an opportunity for restoration on the south Puget Sound prairie landscape the majority of participants (79%) said both. 21% saw climate change as only a challenge to restoration and no one exclusively viewed climate change as an opportunity. The most significant reason why practitioners saw climate change as a challenge was the uncertainty associated with modeling human and plant reactions (62%). For land managers and conservationist, "the challenges are in what we do right now because the questions are so huge and we do not have many answers for them" (Source L, 2009). While models provide some information about how ecosystems will respond under a given scenario, they are sensitive to the complexity of interaction amongst species (Hulme, 2005). The effect of climate change is likely to be a very complex response with some species benefiting and some species declining, the indirect effects in regards to competitive relationships, predation and habitat availability will be really hard to predict (Source N, 2009).

Climate change is a challenge on top of all the other challenges that practitioners have to overcome (Source C, 2009). In particular, roughly 75% of participants cited concern about the relationship between biodiversity and invasive species, “we have no idea whether climate change will make exotic or natives less competitive or more competitive” (Source H, 2009). Research is needed to better understand what effects climate change will have on vegetation communities.

While all participants viewed climate change as a challenge to restoration roughly ¾ also saw an opportunity either from an organizational, personal, ecological or social perspective. For some organizations climate change is an opportunity to re-evaluate objectives such as using historic conditions as a restoration target (Source N, 2009). On a personal level there is an opportunity for research, “for me I think it is a bit of an opportunity because it reinforces my emphasis” (Source C, 2009). The rate of climate change is unprecedented and there will be unique opportunities to research migration and adaptive divergence. Ecologically, longer drier summers should theoretically improve the current prairie habitat, as climate conditions become more suitable for grasslands (Source J, 2009). Yet while climate change might improve conditions for some prairie species it will also improve conditions for invasive species, which are well adapted to surviving in new climates (Source M, 2009). Active management will continue to be necessary to maintain the prairie landscape, because it is a cultural landscape;

> We tend to look at climate change as a bad thing but there are going to be winners and losers. When some species disappear others show up, whether or not they are going to be species we view as beneficial or whether we are going to view them as deleterious those are value judgments (Source K, 2009).

From a social perspective, opportunity lies within enhancing the value of prairies, “as the climate becomes warmer and drier people will surely learn that having grasslands is beneficial”

(Source G, 2009). In general, grasslands are well adapted to disturbances and are effective at storing carbon, the south Puget Sound prairies are no exception (Source G, 2009). Climate change might hold some promise for the south Puget Sound prairie landscape if cultural value expands and invasive species are controlled.

While all participants viewed climate change as a challenge, there was a lack of consensus about the effects climate change is having on the south Puget Sound prairie landscape. Roughly 50% of participants expressed that the effects of climate change on the prairies needs to be addressed or are already been addressed, “we should start laying out the possibilities and exploring options to figure out how to maintain communities. It seems like it is past time” (Source I, 2009). Roughly 30% of participants thought the impacts of climate change were or would be minimal, and 20% thought that climate change was not effecting the prairie landscape yet, “hard to make changes for something that might happen but hasn't happened yet” (Source B, 2009). An overwhelming majority of participants expressed a need for more research and funding to understand exactly what effects climate change is having before adaption can take place. “As we think about anything beyond our basics, (controlling invasive species) and try to manipulate the ecosystem we find we do not know enough” (Source C, 2009). In the absence of more research practitioners are continuing to develop more sophisticated and effective ways to control invasive species and increase diversity, which will enable the ecosystem to be more resilient to increased disturbances projected in the future.

Restoration Techniques

Ecological restoration of land that was originally prairie or enhancing degraded prairies requires reducing the abundance of non-native species and woody vegetation and increasing the abundance of native plants (Fitzpatrick 2004). There are three basic steps to restoration; site preparation, seeding/planting and post seeding management. There are many different techniques used for prairie restoration what has worked best on the south Puget Sound prairie landscape is a combination of mechanical control, prescribed fire, chemical treatment and replanting.

The first step to prairie restoration in the south Puget Sound has been to reduce the number of non-native species and woody vegetation. Initial treatments of sites often involve the removal of scotch broom (*C. scoparius*) through mechanical control, chemical control or prescribed burning. While there are many other invasive species on the prairie landscape scotch broom (*C. scoparius*) is one of the more deleterious and there is a large body of research on controlling scotch broom populations. Mechanical control includes hand pulling (weed wrenches and loppers), motorized brush cutters and mowing (Dunn, 1998). Timing and selection is critical for the success of mechanical control techniques, as cutting is most effective for older individuals during the late summer when they are stressed (Dunn, 1998). Mechanical controls can also require an extensive amount of labor to achieve sufficient results. Chemical controls for scotch broom (*C. scoparius*) have included several different herbicides applied directly to the plant through spot spraying, broadcast spraying and hand application (Dunn, 2002). Chemical controls can be costly and target non-selected species but are also highly effective at reducing scotch broom (*C. scoparius*) cover (Dunn, 1998). Chemical controls, specifically Fusilade have also been an effective post emergence control for grass weeds such as tall oat grass (Source D, 2009). Finally, prescribed fire in a restoration setting has been utilized on bunchgrass prairies in western Washington since the early 80's (Source J, 2009). Fire has been the prominent tool used to manage scotch broom (*C. scoparius*) at several south Puget Sound prairies (Dunn, 1998). Fire not only causes the mortality of Scotch broom (*C. scoparius*) but it also volatilizes nitrogen and creates bare ground for germination. Typically fire will also flush seeds from the soil by stimulating the remaining Scotch broom to germinate (Dunn, 2002). While fire is a natural part of the prairie environment, there are limitations to using fire in a restoration setting. Prescribed fires can burn too hot, may only be set under certain climate conditions and reduce habitat availability in the short term (Source B, 2009). All participants agreed that the best way to manage invasive species is by utilizing a combination of these techniques based upon a variety of factors including labor, funding, overarching goals, site history and what is permitted by the land manager or agency.

After a restoration site has been prepared by the removal of invasive species and woody vegetation, the site is then planted or seeded with desired species. Passive restoration or allowing natural colonization is not possible as the prairies of the south Puget Sound owe their existence to human management, without which they would disappear (Dunn, 1998). There are several methods for seeding and planting, including drilling, broadcasting and plugging. Drilling requires fewer seeds and protects them from wind, water and predation (Fritzpatrick, 2004). Although it may lead to lower survivorship through competition and can look unnatural due to the "row effect". Broadcast seeding requires more seed and may have a lower emergence rate but a higher survivorship rate compared to drilling (Fritzpatrick, 2004). A third method of seeding that is currently being researched on the south Puget Sound is hydro seeding where seed is sprayed with a mulch mixture (Source L, 2009). Seeding is not effective for all species, for example germination rates in the wild for the endangered Golden Paintbrush (*C. levisecta*) can be less than 1% (Source M, 2009). Raising plugs from seed is a very effective technique that can efficiently use limited or hard to seed species. Plugging can lead to higher establishment rates than seeding but is also more expensive and labor intensive (Fritzpatrick, 2004). Techniques for seeding and planting are continually being adapted to what is working best;

> They are constantly changing depending on people's opinions, site location and annual variability in climate. Our flexibility to respond has improved. We understand more than 10-20 years and I think that understand has brought a broader approach instead of just working on one prairie we are working across a broad region. (Source L, 2009)

The utilization of restoration techniques on the south Puget Sound prairies is very much an adaptive management scenario. As techniques for removing invasive species and planting seed become more efficient and productive, practitioners have been able to restore and maintain a greater amount of prairie. As the scale of restoration increases the practice of sourcing restoration materials has become more significant.

Currently the south Puget Sound prairie landscape is fragmented and disconnected. 97% of prairie habitat has been degraded of the 3% that remains only 1% is actually protected (Crawford and Hall, 1997). The continuous patchwork of prairie which once existed is gone and as each sub population comes under a threat or issue it becomes extirpated (Source B, 2009). Fragmentation can lead to decreased vigor and reproductive output of many of the plants and animals due to inbreeding depression and other genetic problems associated with small isolated populations (Fitzpatrick, 2004). In order to increase the resilience of the prairies to climate change, preservation and restoration of areas between existing populations is essential;

> The trick is going to be to patch what we have together so there is connectivity throughout the region. We need to maintain as much habitat as possible to make sure there is an area for species to move to. That requires a lot of the initial treatments we do on low quality prairies. (Source L, 2009)

Identifying, purchasing, restoring and actively managing more land will require additional resources and funding.

One method that has been applied to wetlands and other habitats is mitigation banking. Mitigation or conservation banking is offsetting adverse ecological impacts of development through the creation, restoration, enhancement or preservation of similar habitat. Some agencies want to begin conservation banking and make developers pay a fee for building on prairie habitat, so that lands elsewhere can be purchased to connect existing prairie preserves (Source M, 2009). Beginning in the early 1990's, mitigation banking has been successfully used to restore over 3,000 acres of wet prairie in Eugene Oregon (City of Eugene, 2010). The West Eugene Wetlands Mitigation bank is operated by the City of Eugene Public Works Department which implements wet prairie restoration projects funded by development impact fees (City of Eugene, 2010). Hopefully this strategy will also be successful on the drier south Puget Sound prairie landscape. However, even if connectivity can be restored the rate of climate change and current state of the prairies will necessitate additional methods to maintain and increase diversity.

Migration; Connecting the Islands in a Sea of Change

Paleontological research clearly demonstrates that during past climate changes the geographic distribution of vegetation shifted (Davis et al., 2001). While vegetation does not literally move, new regions are occupied through seed dispersal and establishment.

Anthropogenic climate change is expected to be so rapid that only a percentage of plants may actually migrate fast enough to keep up (Malcolm and Pitelka, 2000). Such threats are likely to be most keenly felt by species with limited dispersal ability (Hulme, 2005). Climate change is causing a sorting of vegetation into bands along migration fronts, led by the fastest (most invasive) dispersers and trailed by the slowest (least invasive), which are perhaps at the greatest risk of local extinction (Neilson et al., 2005). Thus rapidly migrating species will increasingly "invade" new habitat as more sedentary late succession or endemic species will eventually die out (Neilson et al., 2005). Plant communities could become progressively composed of species that exhibit high phenotypic placidity, fecundity and the ability to disperse over long distances (Malcolm and Pitelka, 2000). Two primary options exist: improve the connectivity of habitats to facilitate natural dispersal, or relocate species to appropriate habitats (Hulme, 2005).

Researchers are still seeking to understand the interconnected relationship between adaptation and migration. Adaptation to climate change can occur through the selection of more fit or vigorous genotypes (Dunwiddie et al., 2009). Adaptation is dependent upon a balance between selection and gene flow. Evolutionary understanding of past range shifts indicate that climate change will select against phenotypes that are poorly adapted to local environments and gene migration from neighboring populations will play a significant role in the recombination of genes influencing physiological traits (Davis et al., 2001). Migration of a plant species can occur as a slow local process whereby a species migrates as a front in short steps or as a rapid process through long-distance jumps (Neilson et al., 2005). As the climate changes the leading edge of the migrating front may be enhanced by gene transfer from the center but populations at the trailing edge receive no gene transfer from better adapted populations because those beyond that edge are either extinct or prevented from flowering and setting seed (Davis et al., 2001). Spread from locally isolated populations can occur fairly rapidly, but will be insufficient to keep up with the predicted rates of climate change (Neilson et al., 2005). Long distance dispersal then is the only way, which plant adaptation and migration will keep pace with accelerated climate change, which has caused some practitioners to advocate for methods which facilitate the movement of species.

As replanting and re-seeding efforts on the south Puget Sound prairie landscape have intensified so has the debate about where to source materials, "a year ago we started a seed increase program trying to bulk up seed. We had quite a bit of discussion about seed source" (Source F, 2009). In general, practitioners want to increase diversity and avoid selection of genotypes that may decrease the mean fitness of the genetic pool, such as seed collection practices, processing, nursery propagation and out-planting (Dunwiddie and Delvin, 2006). For example within the past decade a series of mistakes led to the planting of red fescue (Festuca Rubra) rather than the intended Rohmers Fescue (Festuca roemeri) on the south Puget Sound Prairie Landscape (Dunwiddie and Delvin, 2006). When asked, what considerations do you give to sourcing restoration materials (seeds, individuals, ect.), response were generally focused upon the distance materials traveled to the restoration site. The concern over distance lies in the risk of inbreeding or out-breeding depression, and may reflect recent work to develop a regional seed mix, "We had an inter-agency group talk about the area for collection of seed annuals, perennials and rare plants" (Source D, 2009). Studies have demonstrated that both inbreeding amongst close relatives and out-breeding with members of distant populations can result in decreased fitness (Lynch, 1990). However inbreeding almost always ends in decreased mean fitness and out-breeding often has positive effects (Lynch, 1990).

11 participants were involved in sourcing restoration materials through the course of their work. 45% preferred to source materials on-site or as close to the site as possible, with the belief that those materials are well adapted to the restoration site. 55% mentioned sourcing materials regionally with the criteria that annuals and rare plants would be as site specific as possible and the remaining plants would be collected from a 20-30 mile area (Source D, 2009). In a changing climate sourcing seeds regionally will help species adapt and persist by increasing gene flow (Davis et al., 2005). Several agencies are currently utilizing a regional seed mixture for fescue and developing a mix for forbs and annuals (Source F, 2009). Theoretically a regional seed mix may contain more genetic diversity increasing the component redundancy of the planting or seeding, "the general consensus is that the more mixing genetically the better chance the plants will have to survive"(Source K, 2009). On the fragmented south Puget Sound prairie landscape preserves are essentially islands amongst asphalt and the rate of gene transfer and migration has been significantly altered. The creation of regional seed mixes will facilitate gene flow and hopefully increase genetic diversity, but sometimes greater steps are needed to conserve and restore diversity.

In order for conservationists to meet certain targets sometimes the removing of invasive species, habitat protections and enhancements are not effective enough. Two methods currently utilized on the south Puget Sound prairie landscape for maintaining and augmenting rare/endangered species populations are translocation and reintroduction. Translocation refers to the capture, transport and release of an individual or population typically from a disturbed site to a preserved area within the historical range. There have been several translocation projects on the south Puget Sound prairie landscape, including the Mazama pocket gopher *(Thomomys mazama)*. The Mazama pocket gopher (*T. mazama)* with 27 known populations is a State species of concern and a candidate for protection under the Federal Endangered Species Act. Over 180 individuals have been relocated to Wolf Haven, a private prairie preserve, when their populations were threatened by development, succession or agriculture (Wolf Haven, 2009). While the Mazama pocket gophers *(T. mazama*) are reproducing at Wolf Haven initial survival rates were roughly 30% (Wolf Haven, 2009). Low survival rates are indicative of many translocation projects, "methods still need to be developed for translocation and re-introduction the success rates for birds and mammals are not great" (Source D, 2009). Translocation is just one method that has been undertaken to preserve rare and endangered species.

Reintroduction also relocates individuals or populations but typically the focus is on augmenting populations that are endangered or extirpated at a certain locality through the release of species raised in captivity into the wild. There have been several reintroduction programs on the south Puget Sound prairies, including the Taylor's Checkerspot (*E. editha taylori*) butterfly a federally listed endangered species. A multi-agency project funded by the Department of Defense, captive rearing of Taylor's Checkerspots (*E. editha taylori*) began at the Oregon Zoo in 2003 (U.S. Fish and Wildlife, 2009). The first release was made in 2007 at four locations with limited success. Adaptive management decisions were made following the 2007 release to increase the reproductive success of introduced populations (U.S. Fish and Wildlife, 2009). Restorationists are enhancing the habitat for Taylor's Checkerspot (*E. editha taylori*) through the planting of host plants and creating a variety floral arrangements and micro-habitats (Source C, 2009). Releases in 2008 were more successful as practitioners built upon the success of the 2007 releases. While translocation and reintroduction are fairly accepted as conservation methods and create some gene flow amongst endangered populations, climate change may necessitate new measures for preserving diversity.

One of the most contentious issues within the field of conservation is assisted migration or the practice of deliberately populating members of a species from their present habitat to a new region outside of their historical range. Assisted migration is different from re-introduction efforts because the interaction between the introduced species and the current ecosystem is uncertain. In the past humans have introduced species which significantly altered ecosystem composition and functioning. Yet in the future if avoiding climate driven extinctions is a conservation priority, then assisted migration must be considered a management option (McLachlan et al., 2007).

> We want to first do no harm, but there is also a realization that climate change is something that is happening… If we ignore it we might miss opportunities to conserve species and lose something that we can never get back. (Source N, 2009)

When asked if assisted migration of prairie species will be necessary to maintain diversity as the climate changes participants were split. 43% of responses thought assisted migration would not be necessary while 57% thought it would be.

As a simple yes or no question it would appear that participants were relatively evenly split over utilization of assisted migration strategies on the south Puget Sound prairie landscape. Yet an in depth analysis demonstrates that there is more consensus than what appears on the surface. Attitudes about assisted migration can be categorized into three positions aggressive assisted migration, avoidance of assisted migration and constrained assisted migration (McLachlan et al., 2007). Advocates for aggressive assisted migration are motivated by the imminent threat of extinction and the loss of biodiversity due to accelerated anthropogenic climate changes.

> We have too many islands in this world and if we are putting value on rare plants we are going to have to make sure they persist and are able to migrate. Assisted migration is basically where a lot of our plant and animal conservation is going. (Source D, 2009)

Only 14% of participants could be categorized as having an aggressive approach. Most (72%) of participants are more cautious regarding assisted migration and have a constrained approach which attempts to balance the benefits and risks. This perspective ranges broadly between aggressive and avoidance from; "maybe for certain species" (Source I, 2009) to "seems to me like a last ditch effort" (Source B, 2009). Once again uncertainty of the ecologically impacts and climate models, along with a lack of research, monitoring and planning were cited as reasons to balance the utilization of assisted migration. Only 14% of participants could be categorized as completely rejecting assisted migration as a conservation option on the south Puget Sound prairie landscape;

> I do not think assisted migration will be an issue. What we are doing is introducing species into different parts of the habitat that they might not have been present in before, getting enough population established so that they might survive and do well. (Source K, 2009)

Enabling species to persist in their current habitat and assisting the migration of species will both be dependent upon adaptive divergence and genetic flow (Davis et al., 2005). In all likelihood both persistence and assisted migration strategies will be necessary to maintain genetic diversity as the climate changes. The adaptive management approach to restoration techniques, seed sourcing, translocation and reintroduction seems to be indicative of how practitioners might adopt assisted migration strategies. In the past, new methods were applied in a controlled setting, analyzed and adapted to what worked best (Source M, 2009). Currently scientists are researching the potential for Willamette Valley prairie species to migrate to the south Puget Sound prairies under simulated climatic scenarios in a controlled experiment. It appears as if the process of examining assisted migration strategies for the south Sound Prairies has begun. As the composition of our local ecosystems become less and less familiar, it will challenge our understanding of what should be restored.

What does “native” mean anyway?

Typically, we refer to the plants that have existed at a certain location for an extended period of time as native or endemic. Many of the bunchgrass prairies which exist today, including several on the south Puget Sound landscape, are part of the Washington Natural Heritage Program (WNHP). WNHP was established in 1981 to protect outstanding examples of native ecosystems; habitat for endangered, threatened and sensitive plants and animals, along with scenic landscapes. “Originally we had an image of what the composition and structure of native prairies should be like based on the State Natural Heritage Program descriptions” (Source J, 2009). As climatic changes prompt range shifts and alters community composition new species assemblages will emerge, what is native in Washington currently might be more suitable elsewhere and vice versa (Source G, 2009).

It appears as if prairie restoration is shifting from a native or historical approach to a more ecological perspective. Historic composition is becoming less of a focus as a growing drive towards managing for rarer species develops (Source F, 2009). When asked “what does the word native mean to you, and is it still appropriate in this time of climate change?" all participants believe that the word native will still have utility, but to varying degrees. For some, "It is totally appropriate. I do not think things will really be impacted, certainly on the prairies whatever is native now will still be native in the future" (Source K, 2009). Yet others believe that, "In a couple of generations people are not even going to remember what was native or non-native. This is the attitude in Europe and the old world where they see function and service" (Source E, 2009). The reality is that the ranges of populations are constantly in flux, and society defines what is native;

> This was not a big issue five, ten years ago. I think there are no clear cut answers out there. The whole aspect of defining what we were going to restore was a lot simpler before climate change. The fact that communities might change is a new concept to most restorationist. If we do not start thinking proactively about what these natural areas should look like in the future we may fairly quickly start losing species. (Source J, 2009)

An 85% majority of practitioners expressed that the meaning of the word native will broaden to encompass a wider range of species. A broader definition will enable restoration to still be native without the impracticality of recreating a historic pre-settlement landscape in a warmer invaded world, "we are trying to be open minded about that. We need to recognize that the earth is a dynamic system and sometimes we need to recognize that we should not force old restoration targets into this dynamic system" (Source C, 2009). If the primary objective of restoration is no longer to re-create a historic species composition, then how do practitioners define what to restore or conserve?

Roughly 50% of participants maintained that native will still have utility in terms of limiting the negative ecological consequences of the plethora of invasive species. Invasive species are currently one of the significant threats to prairie conservation on the south Puget Sound landscape “In an ecological sense we found that when there is a site dominated by pasture grasses that is really all that you have out there. Invasive species will dominate ecosystems and make them less resilient” (Source M, 2009). Ecologically, invasive species have particular fitness traits that enable rapid colonization and establishment (Radosevich et al., 2003). Evolutionary theory, paleontological data and observed migrations infer that without management the composition of prairie ecosystems will increasingly become composed of species which exhibit phenotypic plasticity, high fecundity and high dispersal rates. Prairie researchers in Minnesota found that one method of increasing resilience to invasion and perturbations was to increase the abundance and richness of native species (Tilman, 1998). "Native" no longer refers just to a species that existed on a landscape during a specific historical period there is also an underlying ecological meaning. The term implies that these species are beneficial to eco-system functioning, provide ecosystem service and will enhance the overall resilience of the ecosystem.

While predicting exactly what species composition will look like over the coming years is difficult, the end result will inevitably be ecosystems with very different species assemblages. In order to preserve diversity, practitioners are attempting to sustain the functioning of the ecosystem as a whole. Selecting species according to function places an emphasis on the traits or services a species provides,

> now there are a lot of native species that have turned to non-native species to fill certain functional roles. Native plants will always be preferred in restoration but when we value a function we will turn to non-native species. (Source D, 2009)

One common example of a non-native species that is providing a functional role as a host plant is English plantain (*Plantago lanceolata*). The federally endangered Taylor's Checkerspot (*E. editha taylori*) utilizes a rare annual, short spur sea blush (*Plectritis congesta*), as a larva host plant, in the absence of which some populations of Taylor's Checkerspot (*E. editha taylori*) will turn to plantain (*P. lanceolata*). It is easy for conservationist to source plantain (*P. lanceolata*) which is a relatively common weed on the south Puget Sound prairies; in contrast it is difficult to grow the limited amount of seablush (*P. congesta*) seed. In lieu of seablush (*P. congesta*), conservationists have turned to utilizing English plantain (*P. lanceolata*) to enhance habitat for the Taylor's Checkerspot (*E. editha taylori*) (Source B, 2009). Plantain (*P. lanceolata*) is just one example of an introduced species which is filling an important functional role as historical species disappear from the south Puget Sound prairie landscape.

Many people assign values to plants, e.g. natives are good and invasive are bad. As the climate changes which plants we value and choose to maintain will also change. Ecologically speaking, "species move, evolve and disappear. If extinction or migration is not a man caused issue, is it ok?" (Source I, 2009). The reality is that it is impossible to separate people from the landscape; we will always have an impact however minute. Invasive species are often deleterious to diversity, but a historical mindset about what is native may also decrease diversity in a warming world. As species become less competitive in their historical range it is imperative that new species are introduced which provide similar functioning and services. If practitioners adhere to a strict historical native mindset then resources or opportunities to enhance species that are ecologically beneficial could be squandered.

The original south Puget Sound prairie landscape was never catalogued or studied in depth before being altered by development, fragmentation and invasive species. How many plant, invertebrate, and vertebrate species were extirpated as the plow turned the prairies into farms? We may never know the extent to which the composition, structure and size of the prairie landscape was altered. Participants reflected upon the loss of diversity, spatial scale and social value. A majority of participants acknowledged that the original species composition and size of the prairies will never be restored. “Even the highest quality prairie left is still invaded and there really is no way to go back” (Source F, 2009). The hope of many participants was that they could maintain the prairies for “no net loss of diversity” (Source J, 2009) and possible expand the size of the existing prairies by “10% or so” (Source M, 2009). While we can never get back what was once lost, we can hold on to most of what is left, and with climate change maybe create something new in the process.

Conclusion

While past research has focused upon what actions practitioners should take to adapt to climate change. This research focused upon the actions practitioners have taken and the attitude they posses for future change. While the sample size was relatively small, participants represented 10 different nonprofit, state, federal and academic organizations. Furthermore the significant ecological challenges posed by fragmentation and invasive species to Puget Prairie restoration commonly confront the field of restoration as a whole. All participants had considered the affects of climate change, in part due to the high availability of climate projections downscaled to western Washington. These factors indicate that these results while descriptive for the population of south Puget Sound prairie practitioners may also be indicative of truths in other regions and ecosystems.

The south Puget Sound prairie landscape is fragmented. Due to the lack of connectivity practitioners are beginning to look abroad for restoration material in order to maintain and increase diversity. The utilization of regional seed mixtures theoretically will increase the genetic diversity of populations making the prairie ecosystem more resilient as there is a greater chance of specific genotypes adapting to climate changes. Translocation and reintroduction are currently being utilized to enhance or maintain populations of endangered species. Finally, assisted migration or facilitating the movement of species to new areas is being explored and researched. A majority of practitioners had a constrained perspective regarding assisted migration strategies which attempts to balance the benefits and risks of introducing species to an eco-system. As the practice of restoration adapts to climate change current historical targets are being challenged and a new mindset which values function and service is being cultivated.

While the main goal of prairie restoration has been and will continue to be increasing diversity in the hopes of preserving a suite of species, the composition of the species that are restored is changing. The field of restoration is undergoing a paradigm shift from a historical to an ecological perspective. Restoration targets that focus on recreating a pre-settlement landscape are becoming less and less realistic. Even the highest quality prairie on the south Puget Sound landscape is comprised of 20% introduced species. Evolutionary theory, paleontological data and observed migrations infer that the composition of prairie ecosystems will increasingly become composed of species which exhibit phenotypic plasticity, high fecundity and high dispersal rates. Practitioners are beginning to redefine restoration according to the functional roles species provide in hopes of preserving the important aspects of the prairie ecosystem. The concept of native still has utility in an ecological sense that some species are beneficial and enhance the resilience of the ecosystem. Most practitioners expressed that the meaning of native will broaden to encompass a wider range of species.

The south Puget Sound prairie landscape will always need maintenance to control invasive species, restore ecological process and increase diversity. In order for prairies to persist the desire to maintain them must also remain. Currently there is a strong commitment from Federal, State, County and non-profit agencies to preserve and enhance the prairie ecosystem. These agencies collaborate with one another, which has lead to a growing understand of how to restore bunchgrass prairies on the south Puget Sound landscape;

> Early on we were trying to see what works more in a demonstration fashion and now we are doing things in a much more valid, scientifically supported way. We are learning as we go and a lot more people are focusing on prairies and grasslands. That collective of science and scientist makes for faster information processing, more collaboration and

better restoration. (Source M, 2009)

While the practice of prairie restoration has become more effective, significant challenges remain. While all participants viewed climate change as a challenge to restoration, there was less consensus regarding what affect climate change is having on the prairie landscape and how the practice of restoration will adapt to the vegetation shifts projected over the next century.

This case study demonstrates that climate change is affecting restoration practices on the south Puget Sound Prairie landscape. There is much consensus amongst practitioners as they begin to research new methods and consider options. All practitioners desire to know more about the effects climate change will have on the prairies so they can make more informed decisions. While the challenge is great the current network of professionals, agencies and organizations are collaborating in order to manage the prairies more efficiently and effectively. As new research, techniques and methods become available these same networks will be able to disseminate best practices regarding climate change. People have maintained the bunchgrass prairie landscape for millennium, and will continue to do so into the future.

Tables and Appendices

Figure 1). The table below lists some of the common prairie species that were utilized by the Salish for food, medicine and tools. The prairie landscape was vitally important to the Salish culture as is evident by the multitude of plant species which were utilized.

Common Name	Scientific Name	Family	Use
Forbs			
Bracken, bracken fern	*Pteridium aquilinum*	*Dennstaedtiaceae*	Food
Chocolate lily	*Fritillaria lanceolata*	*Liliaceae*	Food
Columbine	*Aquilegia*	*Ranunculaceae*	Food
Common camas	*Camassia quamash*	*Liliaceae*	Food
Common vetch	*Vica sativa*	*Fabaceae*	Food
Crown brodiaea	*Brodiaea coronaria*	*Liliaceae*	Food
Death Camas	*Zigadenus venenosus*	*Liliaceae*	Medicine
Fine-leaved lomatium	*Lomatium utriculatum*	*Apiaceae*	Food
Fireweed	*Epilobium angustifolium*	*Onagraceae*	Food, Blankets
Giant camas	*Camassia leichtlinii*	*Liliaceae*	Food
Henderson's Shooting Star	*Dodecatheon hendersonii*	*Primulaceae*	Food
Houndstounge hawkweed	*Hieracium cynoglossoides*	*Asteraceae*	Medicine
Kinnikinnick	*Arctostaphylos uva-ursi*	*Ericaceae*	Smoking/Food
Lupine	*Lupinus albicaulis*	*Fabaceae*	Food
Narrow leafed onion	*Allium amplectens*	*Alliaceae*	Food
Nuttall's peavine	*Lathyrus nevadensis*	*Fabaceae*	Forage Food
Oregon Iris	*Iris tenax*	*Iridaceae*	cordage
Prairie Violet	*Viola adunca*	*Violaceae*	Food
Fine-leaved lomatium	*Lomatium utriculatum*	*Apiaceae*	Food
Puget balsamroot	*Balsamorhiza deltoidea*	*Asteraceae*	Food/Clothing
Small camas	*Camassia quamash*	*Liliaceae*	Food
Stinging nettle	*Urtica dioica*	*Urticaceae*	food, cordage, medicine
Sword fern	*Polystichum munitum*	*Dryopteridaceae*	Food
Wild strawberry	*Fragaria Virginiana*	*Rosaceae*	Food
Yarrow	*Achillea millefolium*	*Asteraceae*	Medicine/Soap
Shrubs			
Blackcap raspberry	*Rubus leucodermis*	*Rosaceae*	Food
Cascara sagrada	*Rhamnus purshianus*	*Rhamnaceae*	Medicine
Chokecherry	*Prunus virginiana*	*Rosaceae*	Food
Gooseberries	*Ribes divaricatum*	*Grossulariaceae*	Food

Oceanspray	*Holodiscus discolor*	*Rosaceae*	Medicine/Tools
Pacific dogwood	*Corylus nuttallii*	*Cornaceae*	Medicine
Red flowering currant	*Ribes sanguineum*	*Grossulariaceae*	Food
Red huckleberry	*Vaccinium parvifolium*	*Ericaceae*	Food
Salal	*Gaultheria shallon*	*Ericaceae*	Food/Fuel
Salmonberry	*Rubus spectabilis*	*Rosaceae*	Food
Service berries	*Amelanchier alnifolia*	*Rosaceae*	Food
Snowberry	*Symphoricarpos albus*	*Caprifoliaceae*	Medicine/Soap
Tall oregon grape	*Mahonia aquifolium*	*Berberidaceae*	Food/medicine
Trailing blackberry	*Rubus ursinus*	*Rosaceae*	Food
Western beaked hazel, Hazelnut	*Corylus cornuta*	*Betulaceae*	Food
Trees			
Garry oak	*Quercus garryana*	*Fagaceae*	Food

Sources: (Norton, 1979), (Storm, 2004), (Leopold and Boyd, 1999)

Figure B). Boyd's 1996 computational analysis demonstrating the population of interior valley Salish tribes is more objective than past population estimates. The anchor number or earliest reliable census data was utilized to determine population in 1770 and 1850.

Interior Valley Population 1770-1850

<u>Group</u>	<u>Anchor No</u>	<u>1770 pre Epidemic #</u>	<u>1850 post Epidemic #</u>
Upper Chehalis	1600	2880	216
Cowlitz	2400	4320	165
Kwalhioqua Clatskine	1350	2430	21
Cathlamet, Wappato, Clackamas, Cascades	6660	11988	300
Kalapuyans	8200	14760	560
Takelma/Interior Athapascans	3000	4500	797
Interior valleys epidemic Totals	23210	40,878	2,059

Figure C). This graph displays population growth in the five counties that contain significant prairie remnants. The population has grown exponentially since the 1900's based upon census data from Washington State.

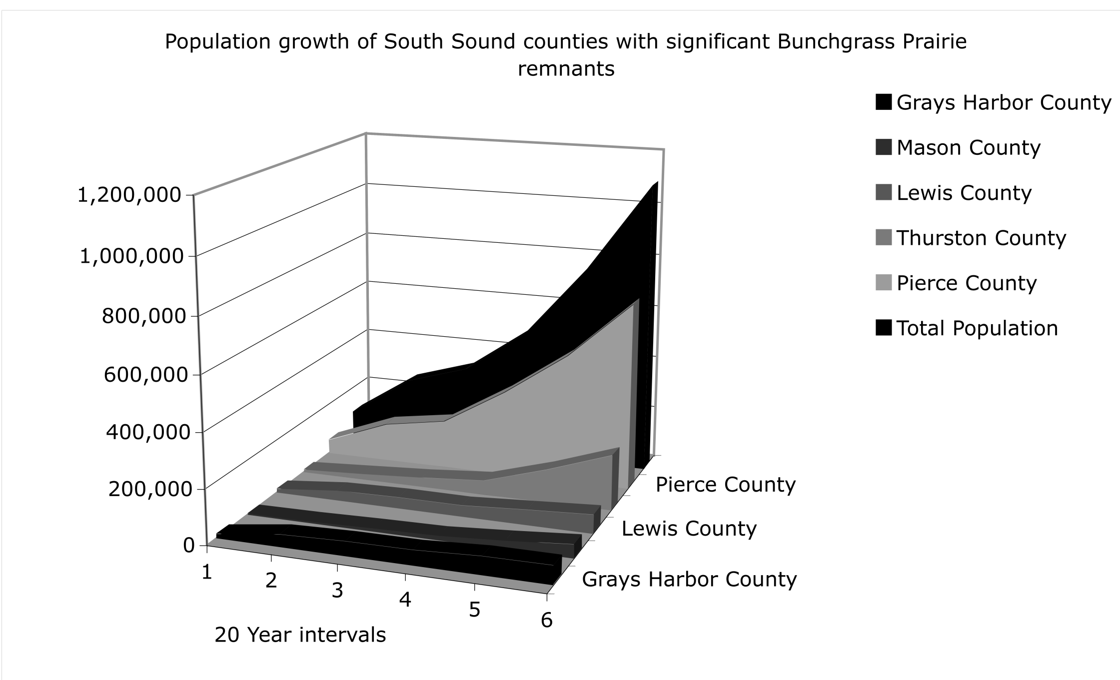

Figure D).
Interview Questions

1.) How long have you been working with prairies and in what capacity?

2.) What are your current restoration and conservation goals and how have they changed over time?

3.) What methods are you using to achieve your restoration goals (introduction, reintroduction, augmentation, fire, herbicide, invasive removal)? How have these methods changed over time?

4.) In your experience what is the best way to manage invasive species?

5.) What considerations do you give to sourcing restoration materials, seeds, individuals?

6.) What considerations if any do you give to affecting ecosystem resilience?

7.) How would you describe the redundancy of the prairie ecosystem, are there many species that provide similar ecologically functions?

> B.) How do you classify species when performing restoration? Do you look at functional groupings, taxonomically groupings, or both? Given your experience is it safe to introduce non-native species which provide similar functional roles as natives?

8). Is climate change a challenge or an opportunity for prairie conservation?

9.) When is the appropriate time to change restoration practices in light of climate change?

10.) It seems as if conservation has shifted from a "native" approach to a more ecological community perspective. What does the word native mean to you, and is it still appropriate in this time of climate change?

11.) Do you think assisted migration of prairie species will be necessary to maintain populations as the climate changes?

12.) What is your perception of what has been lost and what can we realistically hope to restore?

13.) One of the important original functions of the prairies was food and medicine. Given the current state of the prairies, do you think it is feasible to harvest food from them again? If so what effect might harvest have on restoration efforts?

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