Conservation of Prairie-Oak Butterflies in Oregon, Washington, and British Columbia

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Abstract

Prairie-oak butterfly species in the Willamette Valley-Puget Trough-Georgia Basin (WPG) ecosystem have declined dramatically due to widespread habitat degradation and loss of prairie-oak ecosystems in the region. Conservation of prairie-oak butterflies offers unique opportunities and special challenges. Here we provide an overview of butterfly conservation in WPG prairies. We begin with a review of the status of at-risk butterfly species in the region, an introduction to five species that are the focus of current conservation efforts: Fender's blue (*Icaricia icarioides fenderi*), Taylor's checkerspot (*Euphydryas editha taylori*), mardon skipper (*Polites mardon*), island marble (*Euchloe ausonides insulanus*), and Oregon silverspot (*Speyeria zerene hippolyta*), and a brief review of 10 additional at-risk butterfly species in the ecoregion. We follow with a discussion of three key threats (habitat loss and fragmentation, invasive species, and lack of appropriate disturbance) and four dominant management approaches (fire, herbicides, mowing, and habitat restoration). We discuss current challenges and emerging issues for these species, and focus on invasive species management, understanding basic biology, conserving multiple species, and adapting to climate change. We highlight several success stories from around the region. We conclude that butterfly biologists and land managers in the WPG are in a unique position to conserve the region's threatened prairie butterflies. Facilitating greater communication across the region through organizations such the Cascadia Prairie-Oak Partnership will assist in recovery of the WPG's threatened, endangered and at-risk butterfly species.

Introduction

Prairie-oak obligate species in the Willamette Valley-Puget Trough-Georgia Basin (WPG) ecosystem have declined dramatically due to widespread habitat degradation and loss of prairie-oak ecosystems in the region (Dennehey et al. 2011, Fazzino et al. 2011, Hamman et al. 2011, Wold et al. 2011). Among these are several butterfly species protected under the U.S. Endangered Species Act (ESA), the Canadian Species at Risk Act (SARA) and by state and provincial wildlife agencies (Table 1). Conservation of prairie-oak butterflies offers

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TABLE 1. At-risk butterfly species in the Willamette Valley-Puget Trough-Georgia Basin Ecoregion. *Note, information gaps and research needs common to many species are indicated numerically, with full text below.

Species and Status	Current WPG prairie distribution	Estimated # of prairie populations (size range)	Prairie flight season	Host Plants	Species-Specific Information Gaps and Research Needs*	References
island marble (*Euchloe ausonides*) US Species of concern, WA state candidate CAN extirpated	WA: San Juan and Lopez Island prairies	WA: 4 (few-100)	early April-late June	Mustards: field mustard (*Brassica rapa* = *B. campestris*), tall tumble mustard (*Sisymbrium altissimum*) (non-natives) and tall pepper grass (*Lepidium virginicum* var. *menziesii*) (native)	1, 4, methods to create, enhance, and maintain habitat, success of use of native mustard (*Arabis*), success of deer exclosures, taxonomic status	Hanson et al. 2010, Fleckenstein and Potter 1999, Potter unpublished data and pers comm., Peterson 2008 & 2010, Davis pers comm., Potter et al. 2011, Pyle 2004, Guppy & Shepard 2001
tailed copper (*Lycaena arota*) No at-risk status	OR: oak associated riparian areas in Benton and Polk counties	OR: 3 (<100)	July-August	spreading gooseberry (*Ribes divaricatum*)	4, taxonomic identity, reproductive habitat, dispersal	Ross and Warren pers comm.
great copper (*Lycaena xanthoides*) no at-risk status	OR: remnant wetland prairie in west Eugene	OR: 4 sites (52-200, one large metapopulation)	early July-mid August	willow dock (*Rumex salicifolius*)	4, taxonomic status	Severns and Villegas 2005, Severns et al. 2006, Severns and Karacetin 2009, Ramsey and Severns 2010
hoary elfin (*Callophrys polios obscurus*) WA species of conservation concern	WA: south Puget Sound glacial outwash prairies	WA: 10-15 (few-50)	WA: mid April – early May	Kinnikinnick (*Arctostaphylos uva-ursi*)	1, 4, taxonomic status – uncertain if south Puget Sound segregate is a distinct sub-species, methods to augment and connect kinnikinnick patches	Hinchliff 1996, Potter unpublished data, McAllister unpublished data, Pelham 2008
Fender's blue (*Icaricia icarioides fenderi* = *Plebejus icarioides fenderi*) US Endangered	OR: Willamette Valley upland prairies	OR: 17 (few – 1000)	late April-mid June	Kincaid's lupine (*Lupinus sulphureus ssp. kincaidii* = *Lupinus oreganus*) spur lupine (*Lupinus arbustus* = *L. laxiflorus*), sickle-keeled lupine (*Lupinus albicaulis*)	1, 2, 3, methods to accurately and efficiently monitor population trends, role of nectar quality and quantity, role of habitat heterogeneity in supporting persistent populations	Schultz et al. 2003, Fitzpatrick 2009, USFWS 2010

TABLE 1. Continued.

Species and Status	Current WPG prairie distribution	Estimated # of prairie populations (size range)	Prairie flight season	Host Plants	Species-Specific Information Gaps and Research Needs*	References
Puget blue Blackmore's blue (*Icaricia icarioides blackmorei*) = (*Plebejus icarioides blackmorei*) WA state candidate, BC blue-listed	WA: south Puget Sound glacial outwash prairies BC: extirpated from prairies, occurs at mid- and high elevations	WA: 7-10 (few-100s)	in prairies, late May-late June	WA: sickle-keeled lupine (*Lupinus albicaulis*)	4, ant species and degree/extent of myrmecophily, lupine propagation and transplant methods	Hays et al. 2000, Hays unpublished data, Potter unpublished data
island blue (*Plebejus saepiolus insulanus*) CAN endangered (extirpated?)	BC: Vancouver Island endemic, distribution unknown	unknown	unknown	thought to be native clover species	very little known – last recorded in the 1960's, not relocated despite 5 years of active search, introduced clovers thought to outcompete native host	Shepard 2000, BC Conservation Data Centre 2010
field crescent (*Phyciodes pulchella* nr. *pulchella*)	OR: remnant wetland prairies Near Eugene	OR: 10 (several-500)	late May-early June	Hall's aster (*Aster hallii* = *Sympiotrichum hallii*) possibly Willamette daisy (*Erigeron decumbens* var. *decumbens*)	4, taxonomic status, dispersal, reproductive habitat, life history	Severns pers comm.
great spangled fritillary (*Speyeria cybele pugetensis*) WA state species of concern	WA: south Puget Sound glacial outwash prairies	WA: 7-10 (few-50)	July-August	*Viola* sp. including early blue violet (*Viola adunca*), prairie violet (*V. praemorsa*), stream violet (*V. glabella*)	1, 4, adult and oviposition habitat requirements, Viola outplanting methods, site specific host plant use, within site location of occupied patches	Hinchliff 1996, Potter unpublished data, Warren 2005, Pyle 2002, Hays unpublished data, Anderson et al. unpublished data
Oregon Silverspot (*Speyeria zerene hippolyta*) US Threatened WA Endangered (extirpated)	Oregon and northern California coastal grasslands	OR: 4 (120-1500) CA: 1 (700)		early blue violet (*Viola adunca*)	1, 3, dispersal; see text for additional details	Pickering et al. 1992, Hays 1999, USFWS 2001, Hammond 2009, Patterson 2009

TABLE 1. Continued.

Species and Status	Current WPG prairie distribution	Estimated # of prairie populations (size range)	Prairie flight season	Host Plants	Species-Specific Information Gaps and Research Needs*	References
Taylor's checkerspot (*Euphydryas editha taylori*) US Candidate, WA state endangered, imperiled in OR, CAN endangered, BC Red-listed	BC: Gulf Island meadow and clearcut WA: glacial outwash prairies and balds in south Puget Sound, balds and coastal dune/estuarine habitat in northeast Olympic Penninsula. OR:Willamette Valley upland prairies	BC: 1 (10,000-13,000), WA: 5-10 (few-1000), OR: 2 (few - hundreds)	late March-early June	Varies among populations Pre-diapause: English plantain (*Plantago lanceolata*), common plantain (*P. major*), harsh paintbrush (*Castilleja hispida*), *Veronica* sp. Post-diapause: *C. hispida*, *P. lanceolata*, *Veronica* sp., small-flowered blue-eyed Mary (*Collinsia parviflora*), large-flowered blue-eyed Mary (*C. grandiflora*), sea blush (*Plectritis congesta*), dwarf owl-clover (*Triphysaria pusilla*)	1, 2, 3, adult, larval, and diapause habitat requirements, taxonomic status, dispersal, adult life span, monitoring, population size, metapopulation structure, connectivity of habitats, occurrence of separate host plant sub-populations	Page et al. 2009, Heron unpublished data, Stinson 2005, Potter unpublished data, Hays unpublished data, Fimbel et al. unpublished data, Severns and Warren 2008
valley silverspot = Bremner's fritillary (*Speyeria zerene bremnerii*) US Species of Concern, WA state candidate, BC Red-listed, OR extirpated	BC: Eastern Vancouver Island prairie WA: south Puget Sound glacial outwash prairie possibly extant in San Juan Islands prairies	BC: 1 (<200) WA: 4-6 (few-100)	July-early September	WA: early blue violet (*Viola adunca*); BC: montane violet = prairie violet (*Viola praemorsa*)	1, 4, adult, oviposition and larval habitat requirements, *Viola* outplanting methods, native nectar sources	BC Conservation Data Centre 2010, Hinchliff 1996, Potter unpublished data, Hays et al. 2000, Anderson et al. unpublished data, Hammond pers comm.
island ochre ringlet (*Coenonympha tullia insulanus*) BC Red-listed	BC: Vancouver Island Garry oak and associated ecosystems, wet meadows and open areas WA: Whidbey and San Juan Islands island prairies	BC: 10 (??) WA: 6-10 (??)	two: one in May/June and second in August	unknown grass species	1, 4, 5, hostplant(s), life history requirements, taxonomic status, adult and oviposition habitat requirements, site specific host plant use, within site location of occupied patches	BC Conservation Data Centre 2010, Pyle 2002, Warren 2005, Hinchliff 1996, Potter unpublished data

TABLE 1. Continued.

Species and Status	Current WPG prairie distribution	Estimated # of prairie populations (size range)	Prairie flight season	Host Plants	Species-Specific Information Gaps and Research Needs*	References
Propertius duskywing (*Erynnis propertius*) WA state species of concern, BC Red-listed	BC: Southeastern Vancouver Island garry-oak ecosystems WA: south and north Puget Sound prairie oak OR: prairies associated with oak-woodlands	BC: many occurrences but range restricted WA: 5 (few-100s) OR: widespread	late March-early July	Garry oak = Oregon white oak (*Quercus garryana*)	4, basic biology habitat needs, especially for pupae and larvae, effects of prairie oak woodland restoration including fire, development of methods for oak understory restoration, and removal of over-topping trees	Guppy and Shepard 2001, Hinchliff 1996, Potter unpublished data, Miskelly and Potter 2005, Pyle pers comm.
Oregon branded skipper (*Hesperia colorado* nr: *oregonia*) BC species of special concern, WA state species of concern	BC: gulf island prairie WA: south Puget Sound glacial outwash prairies and San Juan Island prairies	BC: 3-4 (??) WA: 6 (few-50)	late July-August	unknown grass species	1, 4, taxonomic status, basic life history, habitat requirements, within site location of occupied patches	Hinchliff 1996, Potter unpublished data, Guppy and Shepard 2001 Pelham pers comm.
mardon skipper (*Polites mardon*) US Candidate, WA state Endangered	WA: south Puget Sound glacial outwash prairies (see text for additional details)	WA: 3 (100-<1000)	mid May-mid June	Roemer's fescue (*Festuca roemeri* = *Festuca idahoensis ssp. roemeri*)	1, 2, 3, 4, 5, taxonomic status, dispersal, life span, reintroduction methods including potential of adult translocation	Potter and Olson unpublished data, Chramiec 2004, Wolford et al. 2007, Fimbel et al. unpublished data, Hays unpublished data, Henry 2010
Sonora skipper (*Polites sonora siris*) WA state species of concern, CAN species of special concern, BC Blue-listed	WA: south Puget Sound glacial outwash prairies BC: unknown OR: unknown	BC: 6 (??) WA: 3-4 (??) OR: 12 (<100)	mid June-August	Unknown grass species	4, 5, hostplant, understanding of specific threats, basic life history, adult and larval habitat requirements, effects of livestock grazing and forest succession	COSEWIC status report, BC Conservation Data Centre 2010, Severns 2008, Potter unpublished data, Hinchliff 1996

*Information Gaps and Research Needs: 1) Impacts from and demographic and behavioral responses to habitat restoration activities, 2) Influence of habitat quality on population size and growth rates, 3) Population genetics to describe inbreeding within populations and relatedness of current population network(s), 4) Trends in population size, growth rates and distribution; number and size of current populations, 5) Effects of grass specific herbicide-based management on survival, demography and behavior unique opportunities and special challenges. These species exhibit a wide array of life-history strategies and specific habitat requirements. Where rare butterfly species co-occur, a balance must be struck in managing and restoring habitat to meet the needs of each species. In addition, remaining butterfly populations are highly fragmented and occur on a diverse landscape of federal, state, municipal, and private lands. Here we provide an overview of butterfly conservation in prairie-oak ecosystems from western Oregon to southwestern British Columbia. We begin with a review of the listed (federal, provincial, or state) butterfly species in the region, followed by a discussion of current threats facing these species. Next, we review current approaches in prairie-oak butterfly habitat management and restoration, as well as discuss current challenges and emerging issues. Finally, we highlight several success stories from around the region.

Status of At-risk Butterfly Species in the Prairie-oak Ecosystem

The following butterfly species are the focus of current conservation, restoration and research efforts in the region (Figure 1, Table 1).

Island Marble (*Euchloe ausonides insulanus*)

The island marble was historically known to occur only on Gabriola Island and the southern end of Vancouver Island (Guppy and Shepard 2001). It was last recorded there in 1908 and thought to have gone extinct until it was rediscovered on San Juan Island, WA, in 1998 (Fleckenstein and Potter 1999). Today, island marbles occur in scattered grasslands in southern San Juan and Lopez Islands, WA. There appear to be four distinct populations ranging in size from a few to 100 individuals (Peterson 2008, Hanson et al. 2009; Christopher Davis, San Juan Island National Historic Park, personal communication). The primary hosts for the island marble are the non-natives field mustard (*Brassica rapa* = *B. campestris*), tall tumble mustard, (*Sisymbrium altissimum*) and the native Menzies' pepperweed (*Lepidium virginicum* var. *menziesii*). All are annual plants found in disturbed areas. In addition to suffering from an overall lack of habitat, island marbles and their host plants occur in a predominantly human-dominated landscape. Within this landscape, there are many large and small population sink habitats where adults lay eggs that are later destroyed (as eggs, larvae, or pupae) by agricultural activities, livestock grazing, mowing and development (Hanson et al. 2009). Another threat to the island marble is browsing of host plants by deer (Amy Lambert, University of Washington, unpublished data). The high density of black-tailed deer in the San Juan Islands is likely a significant limiting factor for the butterflies. Habitat enhancement and creation are vital for the maintenance and expansion of butterfly populations.

Fender's Blue (*Icaricia icarioides fenderi*)

Fender's blue, a subspecies of the Boisduval's blue butterfly, is endemic to the Willamette Valley in western Oregon. Following its initial description in 1931 by Macy, no further observations were made until scientists discovered about a dozen surviving populations in the 1980s (Schultz et al. 2003). Today, we know of 17 populations on native prairie remnants that total approximately 185 ha in size (Schultz et al. 2003, USFWS 2010). Many of these populations are small and isolated, occurring only in areas containing the larval host plants, primarily the federally threatened Kincaid's lupine (*Lupinus sulphureus ssp. kincaidii* = *Lupinus oreganus* (Heller)) and longspur lupine (*Lupinus arbustus* = *L. laxiflorus*), and occasionally sickle-keeled lupine (*L. albicaulis*). Censuses from 1993-present indicate that the valley-wide totals fluctuate between 2000 and 6000 individuals (USFWS 2010). However, local populations often number in the dozens, and most occur on private land, which has led to significant efforts to protect populations on private land (see Appendix 1). Fender's blue butterflies depend on the availability of host plants and native nectar plants, both of which are negatively impacted by the encroachment of woody plants and tall exotic grasses. To maintain suitable prairie habitat, management efforts focus on removal of non-native species and encroaching woody species, prescribed burning, mowing, and *de novo* habitat restoration. In addition, landscape-level planning focusing on restoring historic metapopulation processes are a central part of recovery planning (USFWS 2010). Continuing these practices will be critical for the protection and recovery of Fender's blue butterfly (see Appendices 1 and 2).

Taylor's Checkerspot (*Euphydryas editha taylori*)

Historically the Taylor's checkerspot ranged widely from Vancouver Island, BC, to the southern Willamette Valley, OR. It was once so numerous that Dornfeld (1980) described Willamette Valley meadows as "fairly swarming" with checkerspots. As recently as 1997, Potter (unpublished data) estimated a one-day count of 7000 Taylor's checkerspots at a site at Joint Base Lewis-McChord, WA. Numbers have declined dramatically in

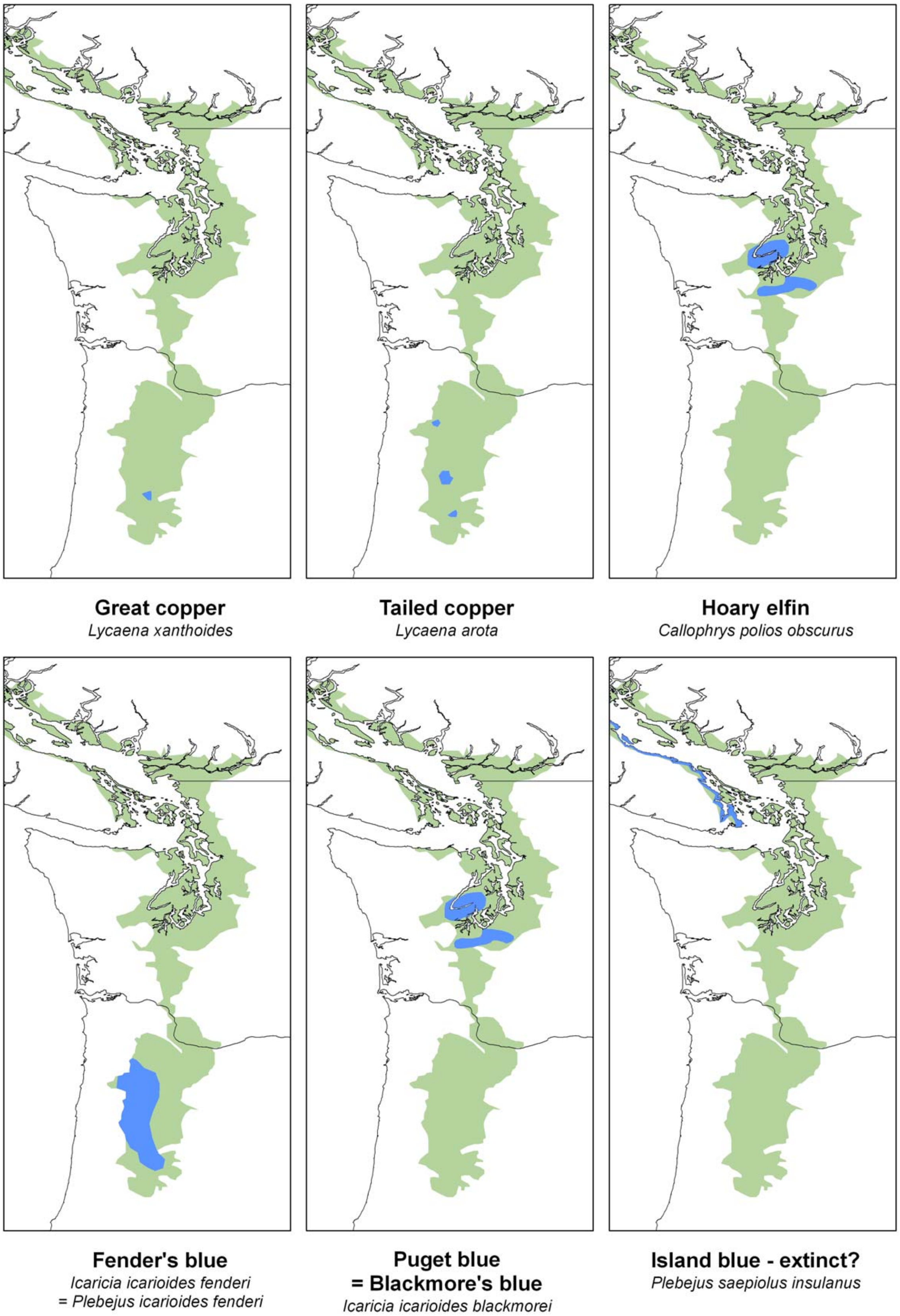

Figure 1. Current distributions of butterfly species (in blue) in Table 1. Shaded green area is the historical distribution of the Willamette Valley-Puget Trough-Georgia Basin (WPG) Ecoregion. (Figure 1 continued on pages 286-287.)

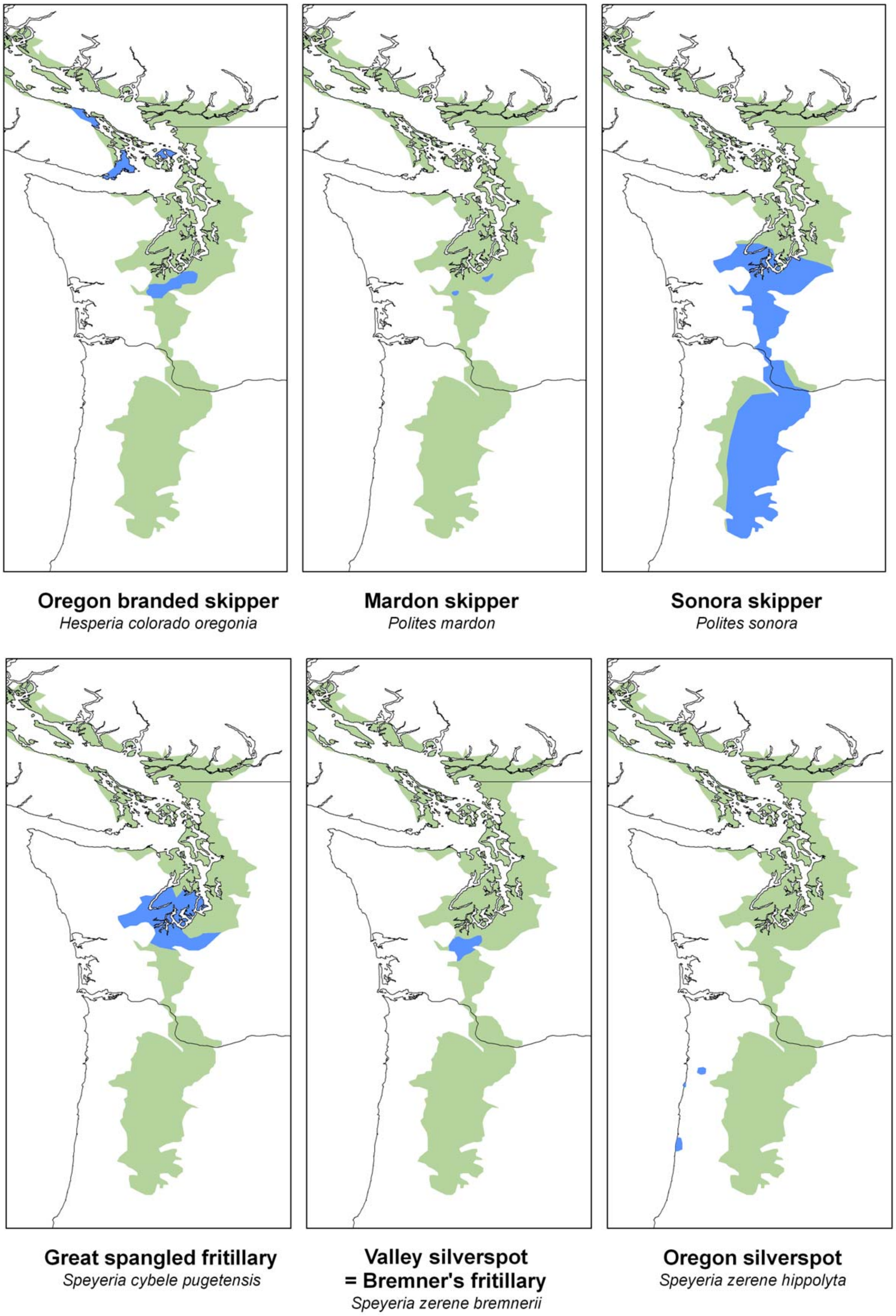

Figure 1 (cont'd). Current distributions of butterfly species (in blue) in Table 1. Shaded green area is the historical distribution of the Willamette Valley-Puget Trough-Georgia Basin (WPG) Ecoregion.

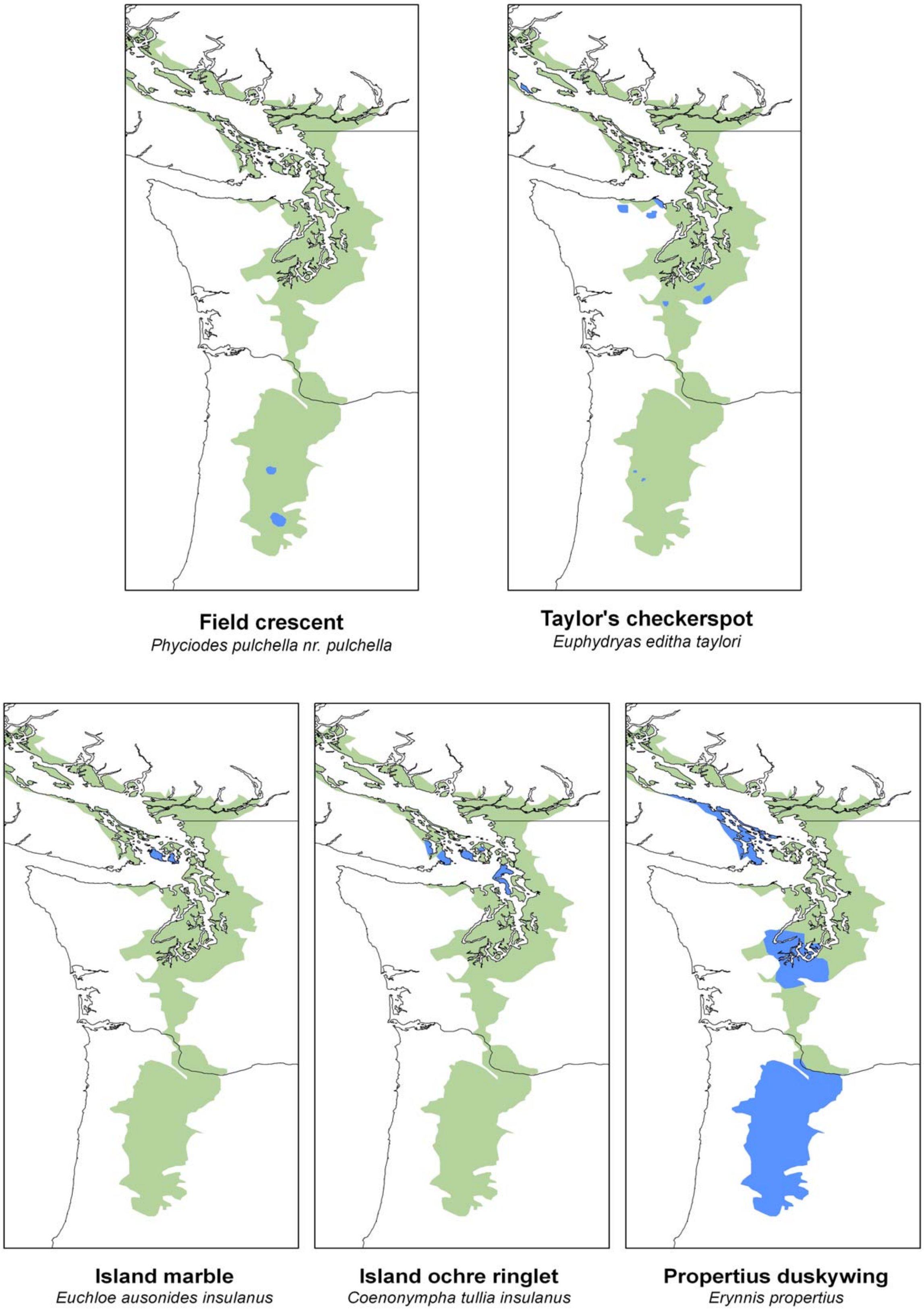

Figure 1 (cont'd). Current distributions of butterfly species (in blue) in Table 1. Shaded green area is the historical distribution of the Willamette Valley-Puget Trough-Georgia Basin (WPG) Ecoregion.

recent years and the butterflies have disappeared from historically occupied sites. Today, extant populations persist in British Columbia (one currently occupied site; Appendix 4), Washington (6-10 populations, two from recent reintroductions, and two with no recent detections), and Oregon (two extant populations) ranging in size from a few to 1000+ individuals. Taylor's checkerspots use a variety of hosts across the range and the hosts for pre and post diapause larvae sometimes differ. Pre-diapause hosts include the native species harsh paintbrush (*Castilleja hispida*), and marsh speedwell (*Veronica scutellata*) as well as the non-natives English plantain (*Plantago lanceolata*), common plantain (*P. major*), thyme-leaved speedwell (*V. serpyllifolia ssp. serpyllifolia*), and European speedwell (*V. beccabunga*). All of these species are post diapuse hosts as well, as are small-flowered blue-eyed Mary (*Collinsia parviflora*), large-flowered blue-eyed Mary (*C. grandiflora*), sea blush (*Plectritis congesta*), and dwarf owl-clover (*Triphysaria pusilla*). The recent (2005) discovery of Taylor's ovipositing on *Veronica* sp. suggests that other closely related taxa may also be suitable hosts for the butterfly. As with other prairie-dependent species, forest encroachment and non-native grass and forb species have degraded Taylor's habitat (Stinson 2005). Extensive management, including herbicide, mowing, prescribed burning, and nectar and host-plant enhancement, is therefore vital to the species' survival (see Appendix 3). Specific populations of Taylor's are also threatened by road maintenance, military training, recreation, and pressure to develop existing habitat. In the Puget Sound prairies of Washington, large-scale captive rearing and reintroduction programs combined with intensive habitat management have met with preliminary success (see Appendix 5).

Oregon Silverspot (*Speyeria zerene hippolyta*)

The Oregon silverspot is a subspecies of the widespread zerene fritillary that is confined to coastal meadows in Oregon and northern California (Pelham 2008). Although the Oregon silverspot distribution is outside of the range of the WPG ecoregion, it shares common habitat characteristics and threats with rare butterfly species in the WPG and is a butterfly of significant conservation concern in the region. Historically, the Oregon silverspot inhabited coastal grasslands from Del Norte, CA to Westport, WA (although the California extent may be *S. z. behrensii* rather than *S. z. hippolyta*, Warren 2005). Coastal development and scrub/forest encroachment have contributed to a dramatic loss of the butterfly's habitat (USFWS 2001). The silverspot is now found only in four sites in Oregon: Mt. Hebo, Cascade Head, Rock Creek-Big Creek and Bray Point, and one site in Del Norte, CA (Lake Earl). In 2009, populations at these sites ranged from 124 individuals at Bray Point to 1400 butterflies at Mt. Hebo, the largest and most stable site. Non-native grasses and shrubs, as well as native brush and trees degrade these remaining pockets of habitat. Habitat restoration efforts focus on increasing host (early blue violet, *Viola adunca*) abundance in short stature (2-15 cm) upland prairies, and nectar resources (yarrow, *Achillea millifolium*, western pearly everlasting, *Anaphalis margaritacea,* Pacific aster, *Symphyotrichum chilense*, and Canada goldenrod, *Solidago canadensis*) in adjacent wet meadow habitat (Hammond 2009). In addition, habitat management to reduce shrub, tree, and non-native grass is critical. Larvae raised in captive-rearing programs at the Oregon Zoo and the Woodland Park Zoo have been used to augment Oregon silverspot populations at three of the Oregon sites (Pickering 2010). Without these augmentations, these populations would be at far greater risk of extirpation (Crone et al. 2007).

Mardon Skipper (*Polites mardon*)

Mardon skippers exist in four disjunct areas including coastal grasslands in Del Norte, CA, montane meadows in southwest Oregon and the southwest Washington Cascades, and prairies in the South Puget Sound. Historically widespread in the Puget Sound region, mardon could be found at eight sites into the late 1980s (Potter et al. 1999). In the last three decades, invasion of structure altering invasive species, primarily Scotch broom (*Cytisus scoparius*) and tall oatgrass (*Arrhenatherum elatius)*, as well as possibly prescribed fire, have reduced the occupied sites to three (Dave Hays, unpublished observations). The north and south units of Scatter Creek Wildlife Area support populations of 100-300 and 400-1300 individuals, respectively (Ann Potter and Gail Olson, Washington Department of Fish and Wildlife, unpublished data). Populations are patchily distributed in the Artillery Impact Area (AIA) at Joint Base Lewis-McChord and are roughly estimated to be 200-400 butterflies (Chramiec 2004, Wolford et al. 2007; Lisa Randolph, Joint Base Lewis-McChord, unpublished data). In the prairies, mardon larvae feed on Roemer's fescue (*Festuca roemeri=Festuca idahoensis ssp. roemeri)*; Henry 2010) and adults nectar primarily from common vetch, *Vicia sativa,* and early blue violet, *Viola adunca* (Hays et al. 2000). Habitat management at Scatter Creek focuses on invasive species eradication in occupied areas through spot spraying and hand pulling as well as enhancement of nectar sources (see Appendix 3). In addition to habitat loss and invasive species, mardon skippers are threatened by military training on the AIA and recreational activities at Scatter Creek. Efforts to develop mardon skipper rearing methods that could be used to produce large numbers of skippers in captivity have not been successful to date (Linders 2007a). Therefore, translocation experiments have been proposed as a method to expand the species' regional range.

Other Species of Concern

There are several other species of concern in the region (Table 1). Some are limited to a few locations but are locally abundant (e.g., Puget blue = Blackmore's blue). Others are common in one part of the region yet have limited distributions elsewhere (e.g., Propertius duskywing). There are also some species that may be naturally rare, or rarely observed (e.g., Dun skipper). For many of these species we lack detailed information on population distributions and formal population size estimates, but local experts have observed declines in recent years. For all of these species of conservation concern, the main overarching threats are similar: habitat loss and fragmentation, invasive species, and succession of prairies to shrubland and forest. Restoration activities are not explicitly targeted for most of these species. However, some current restoration efforts will benefit multiple rare butterfly species (e.g., planting *Viola adunca* for mardon skipper will also enhance habitat for valley silverspots), and efforts should also be made to prevent unintentional negative effects of restoration efforts on these butterflies.

Current Threats

Habitat Loss and Fragmentation

Habitat loss is the overriding driver of species extinctions and declines world-wide (Groom et al. 2006). Lands are continuously converted to development, agriculture, resource extraction, and uses incompatible with many species' existence. Historically, the prairie-oak ecosystem was widespread from the Willamette Valley of Oregon to the Georgia Basin in southern British Columbia. Based on soil type, scientists estimate that 60,000 ha of prairie existed in the Puget Sound (Crawford and Hall 1997), about 400,000 ha in the Willamette Valley (Alverson 2006), and 15,000 ha in southern British Columbia (Lea 2006). Since the arrival of Europeans in the 19th century, these numbers have shrunk dramatically and it is now estimated only 0.5% of Willamette Valley prairies (Noss et al. 1995), 2.5% of the Puget Trough (Crawford and Hall 1997, Chappell et al 2001) and 5% of Georgia Basin prairies remain (Lea 2006). This contraction of prairie habitat continues to be mirrored by declines of prairie-dependent species (Dunwiddie et al. 2006). For these species, it is not only a loss of habitat, but also fragmentation of existing habitat that impacts their populations. For example, Crawford and Hall (1997) estimate that the Puget Sound region historically contained 233 prairie sites with an average size of 250 ha and numerous very large prairies. Today, there are only 29 sites with an average size of 175 ha and most sites are quite small. This is a dramatic reduction in total prairie area, patch size and potential connectivity between habitat patches. Because of this, sites where species have been locally extirpated are unlikely to be re-colonized given their isolation from any source population. Historic metapopulation structure is not well understood for most butterflies in the WPG, with possible exception of Fender's blue (McIntire et al 2007). Recovery strategies for at-risk butterfly species in these habitats need to incorporate understanding of a species' dispersal biology and population dynamics to manage populations in fragmented landscapes (Schultz et al. 2008).

Invasive Species

After habitat loss, invasive plants represent one of the greatest threats to prairie butterflies in the prairie-oak ecoregion. In addition to outcompeting native species, the presence of these plants may fundamentally alter the structure and microclimate of the prairie-oak ecosystem, thus further reducing already limited habitat. Woody invasive shrubs such as Scotch broom and Himalayan blackberry (*Rubus discolor* = *R. armeniacus*) threaten butterfly habitat throughout the region. The most problematic grasses are tall perennial species, including slender false brome (*Brachypodium sylvaticum*), velvetgrass (*Holcus lanatus*), tall fescue (*Festuca arundinacea* = *Schedonorus phoenix*), and tall oatgrass. The presence of highly invasive tall grasses reduces fitness and deters oviposition by Fender's blue, Taylor's checkerspot and mardon skipper (Severns 2008, Severns and Warren 2008, Henry 2010). However, invasive non-native species sometimes provide rare butterflies with key resources. English plantain (*Plantago lanceolata*) is now a key larval host for some populations of Taylor's checkerspot, and Fender's blues and mardon skippers commonly nectar on non-native vetches (*Vicia* spp.) (Hays et al. 2000, Black and Vaughn 2005, Severns and Warren 2008, Rhiannon Thomas, Washington State

University, unpublished data). Habitat management, therefore, must be selective in addressing threats from non-native species. Removing the invasive grasses and shrubs known to negatively impact rare butterfly populations is necessary. However, eradicating all invasive non-native species, including English plantain, would be harmful to some butterfly species in prairies, such as those occupied by Taylor's checkerspots in Oregon where it is the only host used by the butterflies (Severns and Warren 2008). What is less straightforward is how to promote the establishment of native plant communities while maintaining adequate nectar resources for butterflies. The comparative nutritional value of different native and non-native nectar species is largely unknown; therefore it is difficult to measure the impact of management strategies that favor native nectar species over non-native.

Lack of Appropriate Disturbance

In addition to habitat loss and degradation, lack of sufficient disturbance impacts remnant prairie quality. Before Amerindian settlement of the region, a warmer and drier regional climate as well as soil conditions favored maintenance of the prairie-oak system (Dunn and Ewing 1997). Late-summer fires regularly set by Native Americans to sustain food production and manage hunting grounds (Boyd 1986) maintained prairie and oak savanna. After European arrival in the 1800s, these deliberate ignitions ceased. Combined with a cooler, wetter climate, this led to encroachment by woody species (Johannessen et al. 1971, Towle 1982). It is widely recognized that encroachment by trees and shrubs represents a conservation concern to WPG prairies (Clark and Wilson 2001, Maret and Wilson 2005); therefore, land managers seek to restore appropriate disturbance regimes to prevent succession of prairie to conifer forest and restore former prairies (Clark and Wilson 2001). However, balancing disturbance, in the form of fire, with endangered species management, exotic weed invasion, and adherence to governmental rules for ensuring safety makes restoring fire to the prairie landscape difficult (Clark and Wilson 2001, Schultz and Crone 1998, Hamman et al. 2011).

In addition to fire, the localized disturbance caused by camas harvesting and the activity of fossorial rodents also likely influenced the plant community, soil characteristics, and nutrient cycling in WPG prairies (Huntly and Inouye 1988). Fossorial rodent populations have declined and camas harvesting has been eliminated since Euro-American settlement. There is little information on how the lack of these disturbances has affected the prairie landscape, and even less on how they might have influenced butterflies. However, both likely created more bare ground and therefore open space, an important characteristic of mardon skipper and Taylor's checkerspot habitat (Severns 2009b, Henry 2010), than exists in today's prairies.

Management Approaches

Conservation management of butterfly habitat requires addressing threats, including recreating or simulating key disturbance mechanisms that historically maintained the prairies, reducing invasive species, and restoring habitat to offset prairie-oak loss and increase patch connectivity. Managers and biologists have spent the last few decades developing management approaches to address multiple threats, some with great success and others proving more problematic. For all of these approaches, we have the challenge of understanding the impact and effectiveness of the approach, as well as demographic, behavioral, and population-level responses of butterflies to these actions. Also important is understanding both short and long-term impacts of different management strategies. This information would allow us to weigh costs and benefits of different actions, predict the proportion of a focal population potentially impacted by each management event, and thus determine appropriate strategies and return intervals for management actions.

Fire

Fire can be a powerful tool for eradicating some problem species and reintroducing a key disturbance process, but it also kills invertebrates (Miller 1979, Warren et al. 1987, Hastings and DiTomaso 1996, Swengel and Swengel 2001). Many native prairie and oak woodland plants, such as Kincaid's lupine (Fender's blue host plant) and camas (*Camassia quamash,* an important early season nectar source), flourish and bloom more prolifically in response to fire (Schultz and Crone 1998, Clark and Wilson 2001). Butterfly oviposition rates also increase in response to habitat improvements after fire provided that butterflies can disperse in from nearby unburned areas (Schultz and Crone 1998). However, not all fires are the same and individual fires may impact butterflies in different ways based on the fire's intensity, severity, and pattern, all of which are influenced by the season, moisture conditions, and quantity and arrangement of fuels (Hamman et al. 2011). Little is known about the variable effects of fire intensity, severity, and pattern on butterfly populations; therefore, conservative burning strategies are often employed in areas known to be occupied by rare butterfly species (see Appendix 6). Because fire enhances the growth of some invasive perennial grasses and stimulates the seedbank of invasive species such as Scotch broom and hairy cat's ear (*Hypochaeris radicata*), habitat restoration goals may not be met with fire alone (Polster et al. 2006, Stanley et al. 2011a,b). Fire is most effective at reducing invasive species when followed by a second, less intense fire 2-3 years later or combined with an herbicide, mowing, or seeding treatment (Agee 1996, Sinclair et al. 2006, Giles-Johnson et al. 2009, Stanley et al. 2011a,b).

Herbicides

Herbicides are an important tool that land managers use to control invasive plants in prairie-oak ecosystems (Schultz et al. 2008, Dennehy et al. 2011). Two common types of herbicide are used in Pacific Northwest prairies: non-selective post-emergent broad-spectrum and grass-specific herbicides. Glyphosate (Roundup) is the most commonly employed non-selective broad-spectrum herbicide. Glyphosate is broadcast sprayed to reduce vegetation in preparation for reseeding with natives and spot-sprayed to control patchy infestations. In addition, it is wiped on to selectively target taller invasive species, such as tall oatgrass, growing above a native prairie plant community. Sethoxydim and fluazifop-p-butyl (Poast and Fusilade, respectively) are the two most widely used grass-specific herbicides in the region (Clark et al. 2004, Dunwiddie and Delvin 2006). These herbicides target grasses with intercalary meristematic growth (Walker et al. 1988). Many of the invasive grasses in the region's prairies, including tall oatgrass, tall fescue, slender false brome, and common velvetgrass, have intercalary meristems and can be controlled by these herbicides with minimal impact on native forbs and Roemer's fescue. For instance, the application of fluazifop-p-butyl controlled false brome without impacting cover of native plants (Clark et al. 2004). Field studies by Dunwiddie and Delvin (2006) in the Puget Sound prairies demonstrated that sethoxydim reduced tall oatgrass and velvet grass cover by 60% and increased native forb cover.

Greenhouse studies indicate that exposure to the herbicides sethoxydim and fluazifop-p-butyl mixed with the non-ionic surfactant Preference can stress butterflies, resulting in increased rates of development from larvae to adult and decreased wing area in some species of butterflies (Russell and Schultz 2010). Work by Hicks and Schultz (unpublished data) has found that use of alternative surfactants can significantly reduce the impacts of herbicides on captive butterfly morphology and fecundity. Additionally, field trials concluded that female Puget blues had lower residence time in sethoxydim treated plots than in control plots (LaBar and Schultz 2011).

We are only just beginning to understand the impacts of herbicide use on butterflies. Managers should consider the uncertainty of the negative impacts of herbicide use on native and non-target plant and butterfly communities when making decisions to use herbicide as a management tool. However, conversion of a diverse prairie plant community to one dominated by a single invasive weed is clearly more deleterious to prairie butterflies than documented herbicide-induced impacts. One way that managers could balance the costs and benefits of herbicides would be to minimize frequency of herbicide application so as to reduce potential long-term impacts on the native prairie plant and butterfly community. To control weedy species between applications, managers could judiciously apply herbicides using spot-spray techniques or use manual methods of weed control (Crone et al. 2009).

Mowing

Mowing is an alternative in some areas where prescribed fire and herbicides are not feasible. Although its effectiveness at controlling invasive species in prairies is variable (Clark and Wilson 2001, Simmons et al. 2007, Giles-Johnson et al. 2009), mowing can have positive effects on butterfly populations, especially when sites are heavily invaded by woody vegetation (Kaye and Benfield 2005). In the Willamette Valley, Fender's blue populations increased after mowing, as did the number of host plant inflorescences (Wilson et al. 2003). Mowing treatments were also associated with more female Fender's blues, eggs, and larvae, and an increase in larval survivorship (Fitzpatrick 2005). Because many woody species can easily resprout and regain cover in the following year, mowing is most effective when implemented annually over long time scales or combined with another treatment such as fire or herbicide (Wilson and Clark 2001, Giles-Johnson et al. 2009).

Habitat Enhancement and *De Novo* Habitat Restoration

Many endangered Lepidoptera are unlikely to persist without some form of habitat enhancement (Schultz and Chang 1998). Because food plants for butterflies are declining, the enhancement of both host and nectar plants is a critical component of conservation planning

(Smart et al. 2000, Schultz 2001; see Appendix 3). Habitat enhancement may not be sufficient, however, for butterflies surviving in isolated, fragmented populations. These populations will require the expansion of existing habitat ("*de novo*" restoration) and a combination of management techniques, the timing and sequence of which are critical (Appendix 2). Fire is an effective first step in site preparation because it increases the penetration of herbicide by removing litter, reduces the quantities of herbicide that need to be applied by reducing the vegetation structure, and ensures that target plants are growing rapidly when later eradication methods are applied (Sinclair et al. 2006). Once target invasive species are removed, native species must be seeded over the course of multiple years, while invasive species management continues simultaneously (see Stanley et al. 2011a, Wold et al. 2011). *De novo* restoration efforts require long-term management and monitoring that needs to be tied directly to butterfly resource use (Schultz 2001). For detailed restoration techniques to be applicable to multiple sites, management should focus on ecological processes (such as disturbance and competition) rather than site-specific goals (Schultz 2001, Stanley et al. 2011b, Wold et al. 2011).

Reintroductions

For many of the rare butterflies of the WPG ecoregion, natural recolonization of historically occupied sites is unlikely due to the isolated nature of remaining prairie patches. Reintroductions are the only option for a species to establish in restored prairie habitat at sites where they were previously extirpated. Key to the success of reintroduction programs is a solid understanding of the basic ecology and habitat requirements for all life stages of the species, identifying and removing the initial cause of decline, and only reintroducing individuals where high quality habitat exists (IUCN 1998, Schultz et al. 2008). For nearly all of the species of concern in the region, the basic information needed to develop reintroduction strategies is limited (Table 1). Focused research efforts would substantially enhance the likelihood that reintroduction efforts succeed.

Challenges and Emerging Issues

Invasive Species Management

Management of invasive species will be a dominant conservation concern for prairie-oak butterflies for decades to come. With the increasing abundance and number of invasive species in the region, land managers face the challenge of balancing management practices that promote native fauna and flora and limit the opportunity for invasion by another non-native species. Due to resource limitations, land managers are frequently forced to respond to invasive species with a reactive rather than proactive approach. The narrow focus of current invasive-species management provides the opportunity for a revolving door of new invasive species to move into prairies after initial species are eliminated (Bakker and Wilson 2004). Managers could borrow advances in weed management theory that have been employed in management of weeds in an agricultural setting, and apply them in prairie-oak settings. Rather than approaching control of weeds as a set of individual unrelated targets, integrated weed management focuses on addressing underlying causes of weed infestation rather than reacting to establishment of weeds (Buhler 2002) and management of weed communities where containment rather than extermination is the objective (Clement et al. 1994). For example, effective management following the removal of invasive species should focus on immediately filling recently created space with native species and reducing nitrogen levels in the soil to prevent secondary invasion. Native seed mixes may be tailored to constrain selected invaders by representing specific functional groups and life histories (Bakker and Wilson 2004) or multiple spatial and functional groups to increase community stability (Wold et al. 2011). Such a shift away from a single weedy species or taxon management approach to an integrated weed management strategy may prove fruitful to land managers and for butterfly conservation (Buhler 2002).

Understanding Basic Biology

Understanding the basic biology of rare butterfly species is fundamental to their successful conservation (Schultz and Crone 2008, Thomas et al. 2009). Without basic information about a species' habitat requirements in terms of host plants, nectar species, habitat structure, and distribution within a site, efforts to increase butterfly populations can inadvertently contribute to butterfly declines (Thomas et al. 2009). In the prairie-oak ecoregion, there have been recent advances in the understanding of the natural history and habitat requirements for many of the rare species (Severns and Warren 2008, Hanson et al. 2009, Severns 2009b, Henry 2010). However, there are numerous gaps in our knowledge that limit conservation effectiveness (Table 1). For example, for the Sonora skipper and Oregon branded skipper, we have a poor understanding of their distribution and population sizes in the region, as well as timing of the life cycles and basic habitat requirements. Without this information, it is difficult to effectively restore quality habitat and population structure.

Coupled with understanding the basic biology of species, we need to understand the impact of habitat management on these rare butterflies. When evaluating the effectiveness of a management strategy, it is important to quantify the response of essential butterfly habitat attributes. Equally important, and often neglected, is measuring how particular butterfly species, or the broad butterfly community, are impacted by restoration activities. By evaluating both habitat and butterfly response, we can elucidate merits or pitfalls of a management technique, and capture demographic or behavioral responses to critical management activities.

Conserving Multiple Species

In many of the remaining prairie-oak reserves in the region, rare butterfly species co-occur. Therefore, as biological knowledge increases for each of these species, land managers face a new challenge of incorporating multiple species' habitat requirements into landscape-level management regimes. For many butterfly species, there is focus on restoring both the at-risk butterfly species and associated at-risk hostplant(s). This includes species pairs such as Taylor's checkerpot with potential hostplant golden paintbrush (*Castilleja levisecta*), and Fender's blue with hostplant Kincaid's lupine. At Scatter Creek Wildlife Area in the south Puget Sound region, the fine-scale structural habitat needs of mardon skipper need to be maintained or created along with Taylor's checkerspot requirements for plantain host plant and warm, open areas (Henry 2010, Severns 2009b). Management for these specific habitat characteristics needs to be done without harming existing sickle-keeled lupine, host plant for the Puget blue, or early blue violet, host plant for valley silverspot and important nectar resource for mardon skipper. In addition to avoiding impacts to important host and nectar plants for non-target species, land managers need to balance optimal vegetation impacts with minimal butterfly impacts when scheduling the timing of activities such as prescribed fire and mowing. In Washington, valley silverspot populations may be threatened by late-season mowing and prescribed fire as well as control of invasive Canada thistle (*Cirsium arvense*, an important late-season nectar source for the species), all activities conducted to enhance habitat for mardon skippers and Taylor's checkerspots. Care should also be taken to balance management of habitat for rare butterflies with other co-occurring taxa of concern. In the Willamette Valley, prescribed burning conducted to enhance Fender's habitat may harm populations of the endangered plants Nelson's checker-mallow (*Sidalcea nelsoniana*) and Willamette daisy (*Erigeron decumbens* var. *decumbens*) (USFWS 2010). But, Oregon vesper sparrows, a U.S. bird of conservation concern, may respond positively to burning (Herkert 1994). These species highlight the complexity of managing lands in the WPG and the challenges that land managers face when weighing the costs and benefits of different management actions.

Adapting to Climate Change

Over the next century, butterflies will experience profound changes due to human-caused climate change. In Washington, temperatures are predicted to rise 0.1 to 0.6 °C each decade (Mote et al. 2005) with an increase in winter precipitation and a decrease in summer precipitation (Mote et al. 2005, Lawler et al. 2006). Although little research has been done so far to assess how WPG butterflies have responded and will respond to these changes, butterfly responses to climate changes have been documented elsewhere. Butterflies are emerging earlier in the spring (Roy and Sparks 2000, Stefanescu et al. 2003, Forister and Shapiro 2003) and populations are moving poleward and up in elevation (Parmesan et al. 1999, Hill et al. 2002); because species respond differently to temperature increases and changes in precipitation patterns, phenological mismatches are occurring between butterflies and their larval host and nectar plants (Parmesan 2007). In some cases, local extinctions have been linked to climate factors. For example, Edith's checkerspot (*Euphydryas editha*), of which Taylor's checkerspot is a sub-species, has experienced multiple population extinctions at the southern end of its range and a net northward shift of 92 km since the 1800s (Parmesan 2005). Similar changes may be taking place in the prairie-oak ecoregion. Rare butterflies are particularly vulnerable to climate change, as their populations are often fragmented due to habitat loss, making latitudinal shifts impossible without human assistance. Rare butterflies are often monophagous and a mismatch in the timing of emergence of larvae and hosts could be catastrophic. Likewise, mismatch between adults and nectar sources could result in nectar limitation which reduces fecundity (Boggs and Ross 1993).

Fortunately, many of the conservation strategies already used to recover rare butterfly species will help to buffer effects of climate change. Invasive species management will continue to be important as the climate changes and new invasive species establish. *De novo* restoration is fundamental to enhancing connectivity in the prairie landscape to assist latitudinal range shifts. Developing refined reintroduction strategies and protocols will improve the potential success of assisted migration if necessary. In existing habitat, planting a variety of nectar species with varying flowering times will help buffer probable phenological mismatches. In addition to these activities, monitoring timing of events such as emergence of host plants, larvae, and adults, as well as peak flowering of nectar species and peak flight periods, will allow detection of phenological shifts and mismatches.

Conclusions

Butterfly biologists and land managers in the WPG are in a unique position to conserve the region's threatened prairie butterflies. Perhaps nowhere else in North America is so much effort being put forward to protect and recover a diversity of prairie butterflies on a wide array of publicly and privately managed lands. As a result, a number of land managers across the region are experimenting with a diversity of prairie management and restoration techniques. However, the results of these experiments often are unavailable in peer-reviewed or publicly available literature. Thus, land managers are limited in their ability to build on the cumulative knowledge of the region's prairie land managers. Facilitating greater communication across the region through organizations such as the Cascadia Prairie-Oak Partnership could prove fortuitous in assisting in the recovery of the WPG's threatened, endangered and at-risk butterfly species.

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Appendix 1: Conservation of Fender's Blue Butterfly on Private Lands

Michele Collins

Ninety percent of the Willamette Valley, Oregon is privately owned. Therefore, conservation and restoration of prairie habitat on private lands is essential to the recovery of Fender's blue butterfly. Partners for Fish and Wildlife (PFW) is a U. S. Fish and Wildlife Service (USFWS) private lands program. Through PFW, USFWS biologists have engaged about 70 private land owners in prairie conservation for the benefit of Fender's blue. One of the strengths of the program is that it is managed out of the Willamette Valley National Wildlife Refuge Complex, where refuge managers have 15 years of experience managing Fender's blue habitat and can apply that knowledge to efforts on private lands.

The PFW has more cooperators on projects than they have resources, which has led to the development of an expanded partnership for prairie conservation on private lands in the Valley. Partners instrumental in assisting with these conservation actions include local Soil and Water Conservation Districts, watershed councils, local and state governments, university experts, the Natural Resources Conservation Service and USFWS Oregon Fish and Wildlife Office (OFWO). This diverse group of partners works collaboratively to cost-share projects and seek additional grant funding to build upon the efforts initiated under the PFW program.

Several of the participating private landowners were concerned that future land use restrictions might apply if Fender's blue butterfly colonizes their property as a result of restoration efforts. To resolve this concern, refuge biologists worked with OFWO biologists to develop a programmatic Safe Harbor Agreement (SHA) to promote voluntary conservation of Fender's blue butterfly. The SHA allows the USFWS and landowners to identify and agree upon the baseline conditions at the start of prairie restoration efforts, which establishes a property's initial state. If a Fender's blue population increases in response to restoration, a landowner with an SHA is only accountable for maintaining baseline conditions. The OFWO serves as the permit holder and works closely with the Willamette Valley National Wildlife Refuge Complex to administer the program. Twelve landowners who are participating in the PFW Program are currently either enrolled or are enrolling in SHAs, and more are expected to follow.

The collective efforts of the partners working on private land in the Willamette Valley have contributed significantly towards achieving recovery goals for Fender's blue butterfly. Specifically, key habitat areas have been identified, core populations have been protected, and thousands of hectares of habitat have been restored to a more natural condition. One of the most significant achievements is an improved understanding of Fender's blue butterfly distribution that has resulted from surveying private lands that were not previously accessible. In recent years, survey results indicate that several populations are more than double their originally estimated size because surrounding lands have subpopulations that were previously unknown. Additionally, survey efforts have resulted in the discovery of new Fender's blue butterfly populations. "It's an exciting story," says Steve Smith, private lands biologist for the Willamette Valley National Wildlife Refuge Complex. "Valley-wide, Fender's blues now number as high as 6000, up by more than 1500 from estimates in 2005, not bad for a creature thought to be extinct until 1989."

Appendix 2: Conservation of Fender's Blue Butterfly in West Eugene, Oregon

Cheryl Schultz and **Emily Steel**

West Eugene, Oregon, has been a focus of conservation and restoration efforts for Fender's blue butterfly for almost twenty years. A mosaic of semi-connected lands owned and managed by multiple agencies, non-profit organizations, and private landowners, the West Eugene Wetlands (WEW) are a 1200-ha complex on the outskirts of Eugene, Oregon. The WEW program (WEWP) has become a nationally-recognized landmark program for collaborative conservation. The WEWP is one of several programs under the umbrella of the Rivers to Ridges Partnership (R2R Partnership), whose members share mutual goals of advancing conservation of native species and habitats, and providing education, recreation, and access opportunities for the citizens of Eugene and the surrounding area. The 9-agency R2R Partnership includes the City of Eugene, The Nature Conservancy (TNC), U. S. Bureau of Land Management (BLM), U. S. Army Corps of Engineers (USACE), U. S. Fish and Wildlife Service, McKenzie River Trust, Willamette Resources and Education Network, Oregon Youth Conservation Corps, and Long Tom Watershed Council.

Set within an urbanizing landscape, the prairies on these protected lands harbor some of the Willamette Valley's largest remaining populations of the Fender's blue butterfly and its host plant, Kincaid's lupine. Threats to the Fender's blue in the WEW are similar to those found elsewhere across its range. Challenges unique to the WEW include the landscape setting at the urban fringe, and multiple site uses that bring people into and near Fender's blue habitat.

Over the years, a principal focus of habitat restoration efforts in the WEW has been to augment Fender's blue population size. To that end, significant effort on the part of land managers and restoration practitioners has been invested in monitoring Fender's blue populations and evaluating effectiveness of management actions, as well as supporting research aimed at improving understanding of existing butterfly populations and informing management (Fitzpatrick 2009). Studies assessing potential connectivity through the WEW concluded that restoration of upland prairie, "stepping stones" could promote movement by Fender's blue butterflies throughout the region (McIntire et al. 2007) and subsequent Critical Habitat designations were made for Fender's blue (USFWS 2006). In conjunction with these findings, several habitat restoration projects have commenced over the last ten years with the goals of restoring connectivity, increasing available habitat, and improving habitat quality for Fender's blue butterflies in the WEW, with an eye toward connecting three key source anchors: The Nature Conservancy's (TNC) Willow Creek Natural Area, the Bureau of Land Management's (BLM) Fir Butte site and the US Army Corp of Engineer's (USACE) Fern Ridge Area.

Located at the southeast end of the WEW, TNC's Willow Creek Natural Area supports one of the largest remaining Fender's blue populations regionwide. Conservation efforts for Fender's blue at Willow Creek since 1993 have combined management approaches, including fire, mowing, herbicides, manual and mechanical weed removal, habitat enhancement, and *de novo* restoration, in which former fields are converted back to prairie plant communities. This is a multi-year and multi-faceted process, involving at least two years of site preparation to remove unwanted vegetation, native seed collection and growout to provide sufficient plant materials, and follow up treatment in early phases to give native species the edge over weedy colonizers from surrounding areas (for details on this approach, see Wold et al. 2011). Critical to Fender's blue habitat are the collection, growout and outplanting of Kincaid's lupine, and planting schemes focused on nectar sources. TNC's Willow Creek Preserve currently supports 23 hectares of *de novo* upland prairie restoration, more area of upland prairie *de novo* restoration than any other site regionwide. Initial surveys confirm that Fender's blue are ovipositing in restored areas at distances of at least 165 m from intact habitat (Rhiannon Thomas, Cheryl Schultz, and Alexa Carleton, Washington State University, unpublished data) as well as observations of nectaring, oviposition and mud-puddling behavior (Carleton and Schultz unpublished data).

Fir Butte is a BLM property near the center of the system of Fender's blue habitat patches. At Fir Butte, habitat once overgrown and nearly lost to Himalayan blackberry invasion has been enhanced through several years of mowing and fire. Both Kincaid's lupine and Fender's blue populations appear to be improving.

At the opposite end of the WEW is the USACE site, Fern Ridge. In the early 1990s, Fern Ridge had several small parcels with Fender's blue habitat, some of which supported a few dozen Fender's blue butterflies, other Fender's blue sites had been extirpated and were unoccupied. Through dedicated habitat management focusing on mowing and habitat enhancement, the Fender's blue population has experienced an explosive population growth rate, higher than at any other area in the range, and this area currently supports over one thousand butterflies (Severns 2009a).

Together, these efforts represent commitment by nine agencies, dozens of dedicated conservation professionals, and hundreds of volunteers. The WEWP serves as a model for conservation efforts regionally, nationally, and internationally.

Appendix 3: Rare Butterfly Habitat Enhancement on Puget Lowland Prairies in Western Washington

Cheryl Fimbel, Hannah E. Anderson, Grace Diehl, Rod Gilbert, Jeff Foster, Dave Hays, Ann Potter, Mary Linders, David Wilderman, and **Roberta Davenport**

A primary goal of conservation partners in the south Puget Sound is recovery of mardon skipper and Taylor's checkerspot populations. Prior to 2007, state, federal, and private agencies in the region were implementing numerous parallel efforts to restore and enhance native prairie habitat at sites currently and formerly occupied by the butterflies. It became evident that coordination of these efforts would yield greater success. In 2007, Joint Base Lewis-McChord, an Army/Air Force Installation, started an Army Compatible Use Buffer (ACUB) initiative that included support for a cooperative, interdisciplinary and interagency butterfly habitat enhancement team. The team is comprised of 10 members, including regional butterfly experts, restoration ecologists, and land managers from the Department of Defense, two state agencies, two non-governmental organizations, and a county agency.

The team's goal is to use best management practices to develop, implement, and evaluate an approach to enhance butterfly habitat at occupied sites and to restore formerly occupied habitat for potential reintroductions. The project area consists of 15 butterfly management units totaling nearly 165 ha of semi-native short-stature bunchgrass and forb vegetation across 12 mostly upland prairie sites in Thurston and Pierce counties (Figure 2). Team participants meet several times a year to make site visits and develop a suite of standardized activities to be implemented across the butterfly management

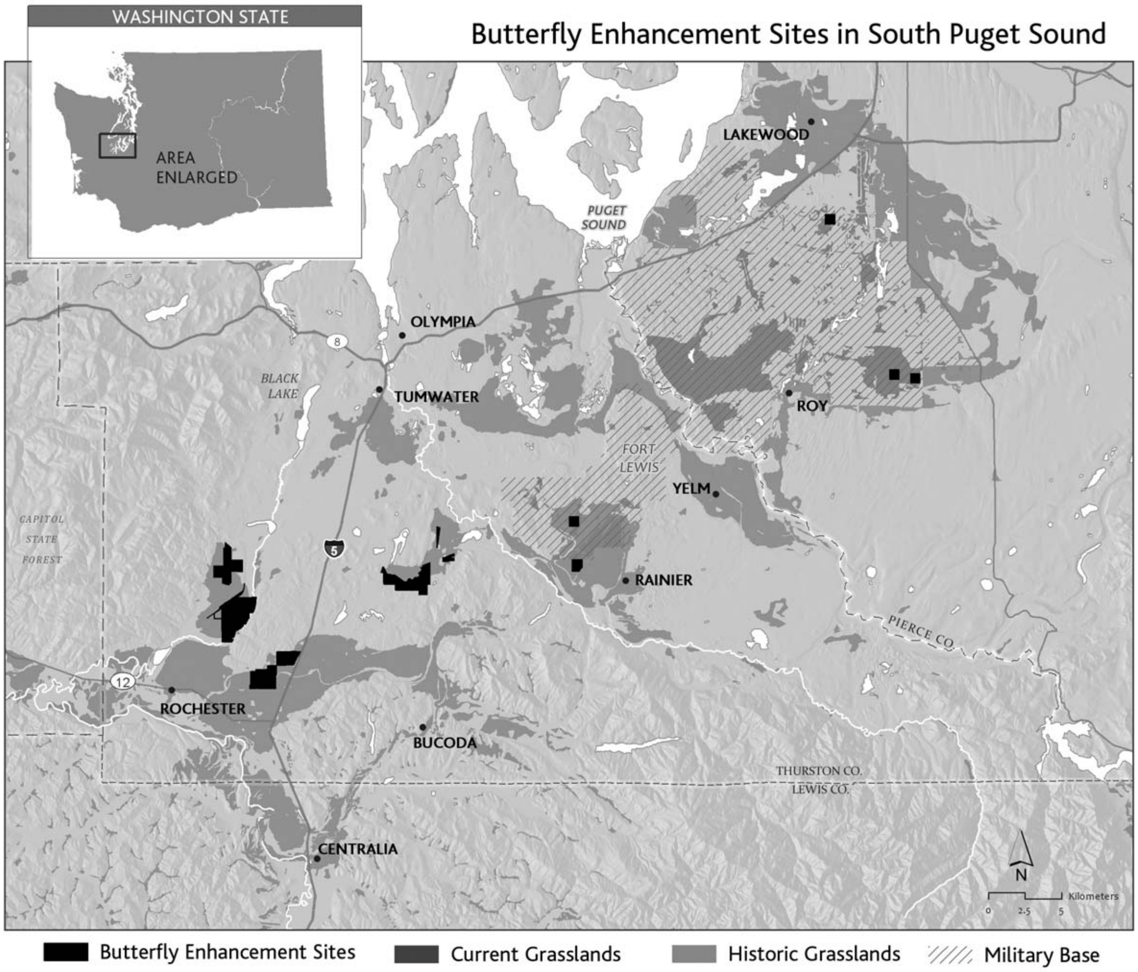

Figure 2. Butterfly enhancement sites in the South Puget Sound.

units. These activities have included 1) evaluating and identifying 15 butterfly management units at 12 prairie sites (Figure 1) using a cooperative and standardized approach based on a suite of critical habitat characteristics for each butterfly, 2) developing quantitative restoration targets based on important habitat characteristics for each species, 3) mapping nectar and host plants to guide location of enhancement efforts, 4) controlling invasive species using combinations of prescribed fire, chemical and mechanical treatments, 5) propagating and planting 129,000 native forb seedlings and 30,000 grass seedlings of nectar and larval host species, and 6) using standardized protocols across multiple prairies to monitor outplantings and evaluate treatment success. The implementation of standardized activities across multiple sites has created a unique opportunity for learning across a large landscape.

Butterfly habitat restoration requires high levels of inputs, including financing, planting stock, and labor resources. Survival of restoration plantings averaged 75% – 90% the first spring after planting, but only 25% – 54% of the original seedlings survived through the second spring. Therefore, enhancement of butterfly resource patches requires repeat plantings to replace seedlings lost to mortality, and multiple applications of a variety of well-timed weed control treatments to reduce competition. Directing intensive enhancement efforts to create high-quality prairie in small-scale butterfly resource patches, and lower levels of input to maintain semi-native habitat in the surrounding matrix, expedites progress toward project goals. This approach relies heavily on native propagules supplied by a local native plant nursery and a large team of dedicated volunteers that participate in all stages of plant production, outplanting, and weed control. Essential elements of the program are the varied expertise and input of numerous partners and agencies. This ACUB initiative serves as a model for integrating research and monitoring into habitat restoration and adaptive management to support butterfly reintroduction efforts across a fragmented system of multiple prairie sites with different owners.

Appendix 4: Habitat Characteristics of a Novel Population of Taylor's Checkerspot in Canada

Nick Page, Patrick L. Lilley, Jennifer Heron, Nicole Kroeker, Conan Webb, and **Brian Reader**

Recent studies by British Columbia (B.C.) Ministry of Environment and Parks Canada have assessed the spatial distribution and habitat characteristics of a large Taylor's checkerspot population in recently logged areas on Denman Island, B.C. Taylor's checkerspot was thought to be extirpated from Canada but was rediscovered in 2005. Oviposition occurs on several species of speedwell, species used as hosts by other checkerspot taxa (Bowers 1983, Kuussaari et al. 2004), but not previously recorded as a host plant for Taylor's checkerspot. Here we discuss (1) spatial patterns of adult butterflies; and (2) pre-diapause larval habitat use.

Museum records suggest that most Canadian populations of Taylor's checkerspot were found in coastal meadows on southeastern Vancouver Island and associated with English plantain. Understanding host plant use is complicated by the presumed extirpation of Taylor's checkerspot from B.C. (COSEWIC 2000), and extensive loss of prairie throughout the region (Lea 2006, MacDougall and Turkington 2005).

We assessed the spatial distribution of adult Taylor's checkerspot butterflies in spring 2007 and 2008. Mapping indicates that Taylor's checkerspot is distributed in two spatially discrete subpopulations associated with moist, logged areas. Nectaring was observed on woodland strawberry (*Fragaria vesca*), trailing blackberry (*Rubus ursinus*), cutleaf blackberry (*Rubus laciniatus*), creeping buttercup (*Ranunculus repens*), white clover (*Trifolium repens*), and hairy cat's ear (*Hypochaeris radicata*). However, nectar plant use appears to be opportunistic and appears related to the abundance and phenology of available species. Adult checkerspot butterflies were often observed basking in thermal habitats such as gravel roadbeds, patches of exposed soils, or on wood or dry grass. This population's flight season in 2007 and 2008 was about 2 weeks later than the dates from museum records.

We used paired plots (12 occupied and 12 random) to characterize the vegetation and substrates used by pre-diapause larvae relative to proportion of these habitats in the landscape in 2008. Plots were located in 8–10 yr old clearcut areas on north-central Denman Island. We counted 356 pre-diapause larvae in sampled plots ($\bar{x}$ = 14.2 larvae/ occupied plot). Pre-diapause larvae were observed feeding on marsh speedwell (86% of feeding larvae), thyme-leaved speedwell (10% of larvae), European speedwell (5% of larvae), and common plantain (2% of larvae). English plantain is absent or uncommon throughout the area.

Habitat use by Taylor's checkerspot on Denman Island is different from populations elsewhere. First, it has rapidly expanded into early-successional habitats created by forest harvesting. The success of the Denman Island checkerspot population indicates that anthropogenic habitat disturbance may increase host plant resources that are associated with early-successional habitats. Second, the Denman Island checkerspot population uses a previously unrecorded suite of host plants. Although this is not unexpected given the variability of host plant use in checkerspot taxa (Kuussaari et al. 2004), it substantiates the view that Taylor's checkerspot host plant use is both plastic and opportunistic (Singer et al. 2007). Our research also raises the possibility that native speedwell species were one of the archetypal host plants from which populations switched once English plantain was introduced.

Appendix 5: Restoring Taylor's Checkerspot to Historical Locales in Puget Lowland Prairies: Acting on Unexpected Opportunities for Conservation

Mary Linders

Captive rearing of Taylor's checkerspot was inadvertently initiated by the Washington Department of Fish and Wildlife in 2003 when a voucher specimen from Clallam County, WA began ovipositing on the *Castilleja hispida* on which it was housed. In 2004 captive rearing was moved to the Oregon Zoo where we developed captive propagation methods using a stepwise approach in collaboration with Dr. Gordon Pratt at the University of California-Riverside. The initial objectives were to increase egg to adult survival relative to the 1-5% per year estimated for wild populations in California (Moore 1989) and to release checkerspot larvae into the wild. From 2004-2007 a "head-starting" strategy was employed using eggs collected in the wild. Collection of eggs was limited to 600 eggs per year, 1-2% of the population estimated from annual survey data. Initial efforts focused on identifying suitable host species, rearing containers, and diapause strategies.

In addition to work at the zoo, field trials began in 2006 to identify successful release and monitoring techniques. Because Taylor's checkerspot is a gregarious species and males are prone to disperse at low densities, we targeted immature stages for release. Release trials initially used eggs laid by captive females, pre-diapause, and post-diapause larvae (Linders 2007b). Measures of a successful release included: 1) ease of implementation, 2) behavioral response to release, 3) survival to subsequent life stages, 4) survival to the adult stage, 5) behavioral response of adults to the habitat and to conspecifics, 6) reproduction, and 7) ultimately population persistence. As expected, weather during and after release was a prominent factor affecting success (Oates and Warren 1990). Careful monitoring of egg masses revealed that loss of developing eggs and early instar larvae coincided with periods of heavy rain (Linders 2007b). Release of pre-diapause larvae coincided with a period of excessive heat (>32°C) and dry winds, which caused host plants to wither rapidly, potentially leading to larval starvation (Kuussaari et al 2004). Finding semi-sunny conditions in March for post-diapause larval releases also proved challenging. In spite of early impediments, post-diapause larvae released in 2007 and 2008 successfully produced adult butterflies that were observed nectaring, performing territorial displays, mating, and ovipositing.

By 2008 the Oregon Zoo was successfully rearing checkerspots to the adult stage and was ready to begin attempts at captive mating and egg production. To provide baseline potential egg production data as well as weight and wing measures for comparing wild and captive reared individuals, we collected adult females from the wild in 2008. These activities came none too soon, as Taylor's checkerspot numbers at the source site plunged to an all-time low in 2009 and collection from the wild was deemed too risky. Maintenance of a captive colony then became a conservation requirement.

Captive females responded to favorable weather conditions in 2009, laying 10,000 eggs that produced nearly 8500 larvae. This number far exceeded the zoo's rearing capacity and pre-diapause larvae were released at multiple sites. In spring 2010 we confirmed that these pre-diapause released larvae survived diapause in the field and were on track for the spring flight season and that post-diapause larvae released at the same sites were also faring well. Favorable weather from May 2009 to April 2010 allowed both release sites to produce a prominent display of adults and flight season lengths equal to the source site.

Four successive late-winter releases of post-diapause larvae have resulted in checkerspot flights at our primary reintroduction site each year since 2007. Flight season length has also increased annually; an important measure given that mortality of four-day old butterflies is as high as 52% (Cushman et al. 1994). Although early successes are encouraging, many additional challenges remain. Emerging issues include assembling a sustainable plan for captive and genetic population management; expanding rearing to additional facilities to spread the risk of housing a captive population; tracking population establishment once releases are terminated; and identifying techniques to enhance habitat function and sustainability in the face of climate change and invasive species. Through this multi-pronged approach we anticipate that one day Taylor's checkerspot will again flourish on the Puget prairies.

Appendix 6: Mardon Skipper and Prescribed Fire

Scott Black

Fire is a necessary tool used in the prairie-oak ecoregion, but it is critical to understand the effects of fire on target butterfly species. Burning habitat that supports mardon skippers may kill all butterflies within the fire area, as this species overwinters as a larva at the base of its host plant (Henry 2010). In June 2008 a relatively large population of mardon was discovered at Coon Mountain, a complex of interconnected serpentine meadows dotted with large Jeffrey pines (*Pinus jeffreyi*) in Del Norte County, CA. After the discovery we learned the U.S. Forest Service (USFS) was planning a prescribed fire at the site. These systems are highly fire-adapted with many species dependent on fire to create openings in the habitat. Coon Mountain had considerable encroachment by woody vegetation that could lead to a hot-burning wildfire in the absence of a prescribed burn.

This burn presented the opportunity to examine the effects of prescribed fire on mardon skippers. Working with USFS staff, we designed a study to test the response of the butterfly to a prescribed fire. The site was divided into four monitoring zones ranging in size from 1.3 to 0.2 ha where mardon skippers had previously been detected. Each zone was subdivided into similarly sized burned and unburned areas and a 50 x 10 m transect was set up in each area. In sum, 1.6 ha of habitat occupied by skippers was burned in early winter 2008 (Figure 3). During the following flight seasons (spring 2009 and 2010), adult skippers were counted in the 8 transects using a modified Pollard Walk.

In 2009, transect counts indicated skipper numbers were 3-27 times higher in unburned areas compared to burned areas on the same dates (mean = 12 times greater; Black and Mazzacano 2010). A similar pattern was seen in 2010, with unburned areas continuing to harbor substantially more skippers than burned areas (Black and Mazzacano 2010). However, 2010 surveys indicate some increase in adults within burned areas compared to 2009. We also observed individuals ovipositing, nectaring, and mating in burned areas, indicating that burned sites were being colonized and utilized by individuals from adjacent unburned areas.

Schultz and Crone (1998) recommended burning no more than 1/3 of Fender's blue habitat in a single season, and burning every two years to maximize average annual population growth rate. For skippers, we lack the necessary information to make similar recommendations, and therefore must be conservative when burning occupied skipper habitat. We recommend that USFS limit additional prescribed burns in the Coon Mountain area until skipper numbers in the burned areas have recovered to at least match the numbers in unburned areas. Although this case study is from serpentine grasslands outside of the prairie-oak ecoregion, it highlights lessons that are applicable. The fact that fire kills butterflies is unavoidable; however, with careful planning and communication, short-term negative effects of prescribed burning can be minimized, while still realizing the long-term restoration benefits. Management activities such as prescribed burning lend themselves to experimental manipulation, allowing us to test the impacts of management strategies on target species. In this case, even coarse estimates of butterfly abundance elucidate population-level impacts of fire. More explicit monitoring of individual adult behaviors (i.e. movement, ovipositing, nectaring, mating) and how important habitat elements respond to burning would contribute to our understanding of how quickly burned areas are recolonized.

Figure 3. Prescribed fire at a mardon skipper site in California. *Photo by Brenda Devlin.*

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