



Taylor's Checkerspot Habitat Enhancement Review and Strategy Development

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Annotated Bibliography: Improving Habitat Enhancement Efforts and Determination of Site Readiness for Taylor's Checkerspot Butterflies in South Puget Sound Lowlands

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Introduction

Taylor's checkerspot butterfly (*Euphydryas editha taylori*) was recently proposed for federal listing as endangered under the U.S. Endangered Species Act (USFWS, U.S. Fish and Wildlife Service 2012a). Range-wide threats to the butterfly are predominantly from degradation and loss of grassland habitat. Prairies are transformed largely due to invasion by non-native grasses and shrubs or by forest succession in areas that were historically managed by fire or grazing, are converted to incompatible uses, or lost entirely to development. Butterfly populations naturally fluctuate. Dynamic metapopulations can move between suitable habitat patches, but changes to the structure and composition of complex prairie landscapes have made essential ecological requirements unavailable, including but not limited to host and nectar plant resources. Additional impacts to their habitat and direct mortality are the result of other human actions.

Taylor's checkerspot persists in Washington, Oregon, and British Columbia in a fraction of its historic range. Near-simultaneous declines and losses of well-established checkerspot populations occurred in the south Puget Sound lowlands over a recent decade, following earlier extirpations from smaller prairie fragments (Dunn and Fleckenstein, 1997; Stinson 2005; USFWS 2012a). The largest remaining semi-natural prairies in the region are on Joint Base Lewis-McChord

(JBLM) (Dunwiddie and Bakker, 2011), where Taylor's checkerspot is extant within the Artillery Impact Area (AIA). Ecological research and restoration on JBLM has been ongoing at multiple sites (e.g., Thomas and Carey, 1996; Dunn, 1998; Foster and Shaff, 2003; U.S. Army, 2008; Dennehy et al, 2011), including butterfly monitoring (Morgenweck, 2003; U.S. Army, 2004) and projects for Taylor's checkerspot on Ranges 50 and 74/76 (Linders et al., 2009). Experimental reintroductions of pre- and post-diapause captive-reared larvae were implemented at Training Area 7 South (2006) and at Pacemaker Airstrip (2006, 2009), with larger releases on Range 50 (2009–2011). Habitat at Pacemaker was enhanced by densely planting native forbs over several years and a 2012 release was planned (Anderson, 2011b; Linders, 2012). JBLM management strategies are, however, subject to revision to support changes to JBLM's mission.

Off the base, habitat restoration and enhancement for Taylor's checkerspot in Washington's Thurston and Pierce Counties is funded by the JBLM Army Compatible-Use Buffer (ACUB) Program and USFWS. Since 2007, the ACUB Unoccupied Butterfly Habitat Enhancement Project (Project) has supported efforts of researchers and agencies to restore and enhance habitat to enable successful translocations of captive-reared Taylor's checkerspot butterflies to habitat occupied historically and to other appropriate locations. Multiple sites are at various stages within a long restoration process, and no two sites have identical environmental conditions (Fimbel et al., 2011; Dunn and Fimbel, 2012). The Project builds on strong prairie conservation efforts (e.g., Dunn and Ewing, 1997; Dunn, 1998; South Puget Sound Prairies Working Group 2002) that have worked steadily towards restoration of a resilient ecosystem that can provide suitable habitat for a dynamic yet stable butterfly population.

The Project's multi-disciplinary Butterfly Habitat Enhancement Team and Technical Review Panel have planned and implemented restoration measures and enhancement strategies (Dunn and Fimbel, 2012) that include identifying specific locations for particular treatments within sites followed by intensive restoration techniques (e.g., Stanley et al., 2011), and enhancement at all sites by planting native grasses, butterfly host plants and nectar sources (Schultz et al., 2011). Captive rearing has been successful, and reintroduction efforts have begun at two sites (Dunn and Fimbel, 2011; Linders, 2012). Range-wide input is provided during Working Group meetings that facilitate an exchange of ideas amongst experts (Anderson 2008, 2011a, 2011b), who stress the importance of collaborative effort, creative management strategies, and basic and applied research to guide decisions (e.g., Dunn, 1998; Dunwiddie and Bakker, 2011).

Methods

This Annotated Bibliography for the ACUB Taylor's Checkerspot Habitat Project is a component of our research team's development of a suite of recommendations to guide the continued success of the Project, gauge its progress, and provide revised site-specific metrics to evaluate habitat enhancement and restoration efforts. We are inventorying butterfly, vegetation, and habitat data and developing a metadata catalogue to submit as a separate element.

Three research team members (Weiss, Niederer and MacDonald) conducted field visits during September 24–28, 2012. We visited habitat for extant, recently extirpated, historic, and potential Taylor's checkerspot populations at ACUB sites (i.e., north and south balds at Bald Hill NAP;

Mima Mounds NAP; West Rocky Prairie; Glacial Heritage Preserve; Scatter Creek North and Scatter Creek South Wildlife Areas; and Tenalquot Prairie Preserve) and on JBLM prairies (i.e., Range 76; Pacemaker; TA 7S; Triangle/South Creek; and the 13th Division prairie). We received comprehensive information about the scope, extent, and challenges of restoration, enhancement, and reintroduction efforts from groups of scientists affiliated with USFWS, JBLM, the Center for Natural Lands Management (CNLM), the Washington Department of Natural Resources (WDNR), the Washington Department of Fish and Wildlife (WDFW), the University of Washington, and Washington State University, who accompanied us on our site visits and provided follow-up data and reports. We appreciate their expertise, candor, and camaraderie.

Near the time of our site visits, we interviewed 20 ACUB Project Cooperators, collaborators and colleagues, and asked them to prioritize research to advance scientific knowledge and to promote Taylor's checkerspot recovery. From our summary of CNLM-provided documents (e.g., annual reports, workplans, Working Group minutes, habitat monitoring checklists, and a synthesis of challenges and information needs identified by the Project Team) plus a selection of literature produced range-wide by researchers and agencies that was relevant to the Project's goals, we developed a survey with synthesized research questions which were assessments of butterfly responses to biotic and abiotic habitat variables (e.g., the influence on oviposition or on larval development and survival of species diversity of host plants or landscape-structure attributes). Our purpose was to evaluate the cooperator's assessments of data gaps, identified research needs, and existing knowledge to guide enhancement and assessment of unoccupied habitat to prepare for butterfly reintroduction in the south Puget Sound lowlands. Respondents included habitat restoration specialists, fire ecologists, lepidopterists, other biologists, prairie and oak woodland botanists, land managers, and others with extensive knowledge about Taylor's checkerspot and its habitat. Survey participants prioritized 30 questions based on "importance to recovery" and "contribution to knowledge" and then volunteered their own questions and research priorities. We ranked the responses, synthesized their assessments of current knowledge and data gaps, and included comments expressed by respondents during the survey with the results.

We compiled references for the original set of documents, specifically about Taylor's checkerspot and South Puget Sound prairie habitat. We obtained additional literature relevant to Project goals and added PDF files and keywords to our online searchable bibliographic database (Mendeley desktop and web software). Unpublished literature came directly from cooperators, colleagues, and collaborators, or was downloaded from agency websites. Journal articles were obtained using online searches of electronic databases of scholarly literature. Primary search criteria included key terms habitat or host plant or oviposition [and] *Euphydryas editha taylori* or *E. editha* spp. or *Euphydryas* spp. or grassland butterflies. Other search strategies were used to find recently published research that targeted prairie or grassland or savanna ecosystem restoration, and enhancement, conservation, assessment, or management techniques, including invasive species control methods (e.g., fire, herbicide). We included research about the behavioral responses of butterflies to habitat variables and landscape structure and the influence of topography, weather and climate change on habitat.

We investigated Taylor's checkerspots and closely related taxa, and relevant habitat enhancement strategies and associated metrics for butterflies in temperate grasslands. We included research

priorities identified by ACUB Project Cooperators, collaborators and colleagues; contributed research questions; topics discussed during site visits; comments respondents made during our survey; and recognized data gaps for habitat restoration, enhancement, and assessment. We then reviewed the literature and summarized highlights of information pertinent to habitat use and butterfly habitat enhancement standards in an annotated bibliography. We do not include entire journal article abstracts or executive summaries from reports. Where research is not specific to habitat enhancement efforts for Taylor's checkerspot in the South Puget Sound Lowlands, we include notes about potential implications. Keywords for each entry are relevant to the ACUB Taylor's Checkerspot Habitat Project. We use standard abbreviations. PNW is an acronym for Pacific Northwest.

Annotated Bibliography

- [1] Altman, B., 2000. Conservation strategy for landbirds in lowlands and valleys of western Oregon and Washington. American Bird Conservancy, prepared for Oregon-Washington Partners in Flight, pp. xii + 1-111 + appendices.

Conceptual flow-chart framework a useful model; emphasizes regional ecosystem management; provides structured conservation strategies for focal species strongly associated with high priority grassland-savanna habitat and key attributes critical for a functional ecosystem or in need of conservation (e.g., large patches, short grass with bare ground); complements other initiatives. Suggests use of population-based, landscape- or site-specific biological objectives based on species-habitat relationships to provide management targets for planning and implementation, and benchmarks for measuring success (lack of sufficient data precludes wildlife-habitat associations for many invertebrates, unlike checkerspots). Recommends integrated monitoring and research components to provide scientific data to evaluate assumptions upon which biological objectives are based, determine effectiveness of conservation actions, and guide adaptive management. Keywords: grasslands; habitat conservation; wildlife habitat.

- [2] Anderson, H.E., (Ed.), 2008. Proceedings Taylor's checkerspot workshop 2008. The Nature Conservancy, Olympia, WA, 121 pp.

Well-organized compilation of knowledge and expertise from Taylor's checkerspot conservation community in OR, WA, BC. Includes multiple documents assembled as one report; these are complete workshop presentations with some additional text. Updates of population status by region; policy issues; and monitoring are presented first. Many presentations relevant to habitat restoration and enhancement including a discussion of the ACUB Program and Taylor's Checkerspot habitat enhancement at Bald Hill Natural Area Preserve. Appendices include potential and known nectar plants by site and a comprehensive management matrix for coastal, bald, and lowland prairie habitat. Keywords: Euphydryas editha taylori; enhancement; fire; habitat; habitat quality; management; prairie; restoration; seed.

- [3] Anderson, H.E., (Ed.), 2011a. Taylor's checkerspot butterfly 2009 and 2010 Working Group meeting minutes. The Nature Conservancy, Olympia, WA, 57 pp.

*Comprehensive minutes from first and second Working Group meetings with representatives from the Taylor's checkerspot conservation community in OR, WA, BC. Includes multiple documents assembled as one report; some are included separately in this bibliography. Relevant to the ACUB Project for 2009: Separate sections on habitat management, habitat research, native plant propagation, and detailed action plans; appendices include a summary fact sheet for ACUB program enhancements for unoccupied sites, including questions for future research, and a South Sound seed production fact sheet. Relevant to the ACUB Project for 2010: research presentations on habitat characteristics, and other research needs and questions; an update on the ACUB habitat enhancement project; and occupied site updates on surveys and habitat management. Keywords: *Euphydryas editha taylori*; enhancement; fire; habitat; habitat quality; host plant; management; nectar resources; prairie; restoration; seed.*

- [4] Anderson, H.E., (Ed.), 2011b. Taylor's checkerspot 2011 range-wide Working Group meeting minutes. Center for Natural Lands Management, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife, Olympia, WA, 32 pp.

*Comprehensive minutes from third Working Group meeting with representatives from the Taylor's checkerspot conservation community in OR, WA, BC. Includes multiple documents assembled as one report; some are included separately in this bibliography. Relevant to the ACUB Project for 2011; reports on management activities at occupied sites range-wide; updates on current research (e.g., source-sink dynamics, oviposition habitat, Taylor's checkerspot and golden paintbrush); habitat restoration and enhancement efforts to prepare for reintroduction; and includes detailed action plans and additional research questions. Keywords: *Euphydryas editha taylori*; enhancement; fire; habitat; habitat quality; host plant; invasive species; management; nectar resources; prairie; restoration; seed.*

- [5] Anderson, R.C., 2006. Evolution and origin of the central grassland of North America: climate, fire, and mammalian grazers. *Journal of the Torrey Botanical Society* 133, 626–647.

Review; summarizes decades of research (1935–2005) on the structure and function of central North American prairies. Provides restoration insight; notes existing knowledge is often extensive but not adequately incorporated into restoration efforts; argues that critical roles of invertebrates in grassland ecosystems are underappreciated. Discusses co-evolution and adaptation of grasslands to fire, grazing animals, and drought; fire-grazing interactions that increase habitat heterogeneity; fire as the historic driver to maintain prairies; and effects of fire on plants, animals, and soils. Keywords: drought; fire; grasslands; grazing; prairie; restoration.

- [6] Anthes, N., Fartmann, T., Hermann, G., Kaule, G., 2003. Use of space and resources in a Mediterranean population of the butterfly *Euphydryas aurinia*. *Journal of Insect Conservation* 7, 175–185.

Evaluates conservation strategies and regional habitat quality with the emphasis on larvae and metapopulation dynamics rather than adult butterflies. Microhabitat analyses suggest host plant size determines oviposition choice; larval density correlates with host plant density; probability of patch occupancy increases with host plant density and habitat patch size and decreases with isolation from or lack of connectivity to nearby patches. Advocates management focused on both within-patch habitat quality and priority restoration of former habitat near occupied habitat to establish networks of suitable patches, particularly when the spatial configuration of extant colonies does not allow for population exchange. Keywords: Euphydryas spp.; habitat patch; habitat structure; host plant density; host plant preference; larval host plant use; oviposition.

- [7] Bachelet, D., Johnson, B.R., Bridgham, S.D., Dunn, P.V., Anderson, H.E., Rogers, B.M., 2011. Climate change impacts on western Pacific Northwest prairies and savannas. Northwest Science 85, 411–429.

Review; provides PNW-specific data generated by local climate change researchers; summarizes IPCC climate models and limitations; analyses results from experiments focused on community structure, productivity, and phenology. In general, higher summer temperatures and longer season predicted. Precipitation forecasts vary; high evapotranspiration will amplify summer drought, winters will be wetter. Grasslands unlikely to be adversely affected: established during warm dry Holocene, maintained by high frequency, low intensity fires and periodic drought. Other threats more consequential: prairie fragmentation, land conversion, human immigration. Strategies: adaptive-management, monitoring climate and biological community responses. Prairies occur across a range of vegetation, soil types, and weather; regional actions developed and tested now can respond to future uncertainties. Habitat heterogeneity and diverse micro-environments (e.g., mounds, swales, shady sites) can be exploited. Anticipating phenological shifts and plant community changes, annual forbs and non-native plants are being established as early food sources for larvae; butterflies and host plants (e.g., Castilleja levisecta) are being introduced to new and historically occupied sites. Restoration and management techniques (e.g., prescribed fire, herbicide) are more efficient under warm dry conditions. Prairie or savanna that replaces drought-stressed forests or abandoned fields will provide valuable ecosystem services. Entirely relevant; extensive references. Keywords: climate change; drought; Euphydryas editha taylori; fire; grasslands; habitat heterogeneity; host plant phenology; invasive species; prairie.

- [8] Baer, S.G., Blair, J.M., Collins, S.L., Knapp, A.K., 2004. Plant community responses to resource availability and heterogeneity during restoration. Oecologia 139, 617–629.

Explores the influence of N-availability on developing plant community dynamics in restored prairie ecosystems. Soil fertility can regulate community assembly, promote dominant grass, limit light, prevent recovery of floristic diversity, and affect restoration success. Forb diversity in native grasslands is maintained by high soil and vegetation heterogeneity, resulting from abiotic (i.e., topography, fire frequency) and biotic (e.g., plant spatial distribution, animal disturbance) factors; many studies find forbs much more difficult to reintroduce than native grasses. Relevant to enhancement and restoration efforts where N-deposition and invasive non-native legumes and tall grasses are problems; extensive references. Keywords: assembly rules; forbs; habitat heterogeneity; habitat structure; N-response; plant community; prairie; restoration.

- [9] Bale, J.S., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., Butterfield, J., Buse, A., Coulson, J.C., Farrar, J., Good, J.E.G., Harrington, R., Hartley, S., Jones, T.H., Lindroth, R.L., Press, M.C., Symrnioudis, I., Watt, A.D., Whittaker, J.B., 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biology* 8, 1–16.

Review. Recognizes predictions of future distributions and population dynamics are complex because life-cycle timing depends on site-specific responses to biotic and abiotic factors and involves distinct physiological stages, growth and diapause. Temperature affects life-history strategies; relative growth rates; phenological synchrony of insects with plants. Lepidopterans behaviorally manipulate responses to thermal cues and already adapt to large natural spatial and temporal variations. Conflicting effects are expected, e.g., fast-growing species that diapause at low temperatures may respond with range contraction, but higher summer temperatures may allow univoltine species to respond to climate warming by changing distribution. Ocean influence mitigates warming scenarios for PNW coastal environments, and precipitation and relative humidity are already high, but summer drought may increase. Species adapted to several host plants should fare best. Keywords: climate change; insect response; temperature.

- [10] Bennett, V.J., Smith, W.P., Betts, M.G., 2011. Evidence for mate guarding behavior in the Taylor's checkerspot butterfly. *Journal of Insect Behavior* 25, 183–196.

*Discusses previously undocumented behavior and resource use. Demonstrates mating system more complex than previously described; may be plastic; can be cryptic; is influenced by spatial and temporal variables; and employs multiple strategies. Observations of marked males at two sites support hypothesis that males locate and defend immature females yet to eclose, perching on the highest structure available (e.g., tall grass, flower heads, mounds), guarding territories for up to 10 days. Understanding habitat use is critical; identifying this behavior allows habitat suitable for pupation to be more effectively recognized. Keywords: *Euphydryas editha taylori*; behavior.*

- [11] Berendse, F., Elberse, W.T., Geerts, R.H.M.E., 1992. Competition and nitrogen loss from plants in grassland ecosystems. *Ecology* 73, 46–53.

Investigates grass adaptations to nutrient-poor environments, effects of N-enhancement and clipping on competitive balance between fescue and tall oatgrass. Fescue rapidly replaced oatgrass in low-nutrient soils; superiority enhanced when clipped. Mowing or grazing may help manage invasives, promote natives. Keywords: fescue; grazing; tall oatgrass.

- [12] Betzholtz, P.-E., Ehrig, A., Lindeborg, M., Dinnétz, P., 2006. Food plant density, patch isolation and vegetation height determine occurrence in a Swedish metapopulation of the marsh fritillary *Euphydryas aurinia* (Rottemburg, 1775) (Lepidoptera, Nymphalidae). *Journal of Insect Conservation* 11, 343–350.

*Argues that useful measures of habitat quality for *E. aurinia* vary by population and area. Investigates central-range breeding habitat in favorable condition by measuring patch variables area and isolation, and habitat quality variables related to microclimatic conditions (i.e.,*

vegetation structure, optimal vegetation height, insolation, overgrowth, humidity, and risk of summer floods) and host plants (i.e., total adult nectar supply, density of primary host, and density of host used by final instar). Supports earlier findings in other regions; suggests that a network of adjacent habitat patches with high host plant density and optimal-range vegetation height is the conservation goal. Keywords: Euphydryas spp.; habitat patch; host plant density.

- [13] Beyer, L.J., Schultz, C.B., 2010. Oviposition selection by a rare grass skipper *Polites mardon* in montane habitats: advancing ecological understanding to develop conservation strategies. *Biological Conservation* 143, 862–872.

Illustrates site-specific habitat preferences with respect to oviposition for a generalist grassland butterfly often sympatric with Taylor's checkerspot. Data collected for 50+ habitat variables (e.g., oviposition plant structure; community features; insolation; litter layers). Essential habitat ID confounded by large differences between meadows; within-site analyses revealed selectivity with respect to multiple components. Keywords: habitat; host plant preference; oviposition.

- [14] Black, S.H., Vaughan, D.M., 2005. Species profile: *Euphydryas editha taylori*, in: Shepherd, M.D., Vaughan, D.M., Black, S.H. (Eds.), Red list of pollinator insects of North America, The Xerces Society for Invertebrate Conservation, Portland, OR, digital, accessed 7/1/2012, <http://www.xerces.org/taylors-checkerspot/>.

Reference. Keywords: butterfly conservation; Euphydryas editha taylori.

- [15] Bonelli, S., Cerrato, C., Loglisci, N., Balletto, E., 2011. Population extinctions in the Italian diurnal Lepidoptera: an analysis of possible causes. *Journal of Insect Conservation* 15, 879–890.

Analysis of historical data (323 spp.) investigates extinctions due to changes in habitat quality rather than habitat loss. Vulnerability dependent on threat and ecological requirements (e.g., population stochasticity at range edges; moisture or temperature needs unmet). Concludes extant species undergoing declines for 'unknown causes' would benefit from enhanced knowledge and improved monitoring. Keywords: butterfly population; extinction; habitat quality; monitoring.

- [16] Bowers, M.D., 1986. Population differences in larval hostplant use in the checkerspot butterfly, *Euphydryas chalcedona*. *Entomologia Experimentalis et Applicata* 40, 61–69.

Compares responses (i.e., survival, growth rate, digestive efficiency of pre-diapause instars) of pre- and post-diapause larvae from two checkerspot populations reared on their own host plant and that of the other population. Responses differed by populations and by life stages. Keywords: Euphydryas spp.; host plant preference; larval host plant use.

- [17] Brereton, T., Roy, D.B., Middlebrook, I., Botham, M., Warren, M., 2011. The development of butterfly indicators in the United Kingdom and assessments in 2010. *Journal of Insect Conservation* 15, 139–151.

Discusses governmental indicators for UK biodiversity derived from butterfly abundance data. Multi-species trends for habitat specialists indicate significant long-term declines since 1970s; these represent large biodiversity losses because specialists are generally restricted to semi-natural habitats critically important for rare insect species. While not linked with specific environmental factors, declines point to a wider crisis. Keywords: biodiversity indicators; butterfly population.

- [18] Brooks, M.L., D'Antonio, C.M., Richardson, D.M., Grace, J.B., Keeley, J.E., DiTomaso, J.M., Hobbs, R.J., Pellant, M., Pyke, D., 2004. Effects of invasive alien plants on fire regimes. *BioScience* 54, 677–688.

Presents a conceptual model of relationships between invasive non-native plants, intrinsic and extrinsic fuel properties, and altered fire regimes (e.g., changes in their extent, type, frequency, intensity, and seasonality). Introduces a system to help land managers evaluate effects of invasive species, prioritize control, and restore native ecosystems and natural disturbance regimes. Keywords: disturbance; fire; invasive species; management; restoration.

- [19] Bullock, J.M., Franklin, J., Stevenson, M.J., Silvertown, J., Coulson, S.J., Gregory, S.J., Tofts, R., 2001. A plant trait analysis of responses to grazing in a long-term experiment. *Journal of Applied Ecology* 38, 253–267.

Presents results of a long-term study of plant community responses to grazing intensity; correlates plant traits with performance. With grazing, grasslands move towards dicot-rich communities valuable for grassland species conservation. Keywords: forbs; grasslands; grazing; management.

- [20] Burghardt, K.T., Tallamy, D.W., Philips, C., Shropshire, K.J., 2010. Non-native plants reduce abundance, richness, and host specialization in Lepidopteran communities. *Ecosphere* 1, article 11.

Compares species richness, abundance and host specialization for specialist and generalist Lepidoptera on native, non-native congener, and unrelated species of woody plants. Insect herbivores adapted to phytochemicals in native hosts accepted novel congeners; specialist abundance and richness were significantly greater on native plants. Keywords: host plant preference; invasive species; non-native host plant.

- [21] Caplow, F., 2004. Reintroduction plan for golden paintbrush (*Castilleja levisecta*). Prepared for U.S. Fish and Wildlife Service, Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia, WA, pp. 1–37 + appendices.

*Summarizes strategies for conservation and recovery of endangered golden paintbrush, a Taylor's checkerspot host plant. Well-written format includes guidelines, procedures, recommendations, plus rationales for implementation. Keywords: *Castilleja levisecta*; host plant; reintroduction.*

- [22] Caplow, F., Chappell, C., 2005. South Puget Sound site evaluations for reintroduction of golden paintbrush. Prepared for U.S. Fish and Wildlife Service, Washington Natural

Heritage Program, Washington Department of Natural Resources, Olympia, WA, pp. 1–30 + appendices.

Supplements reintroduction plan; ranks 16 south Puget Sound sites based on their similarity to Rocky Prairie, site of the only extant local population, using a generalized suite of ecological characteristics (e.g., vegetation, geology, soil, hydrology, topographic factors); discusses site management considerations for each. Keywords: Castilleja levisecta; host plant; reintroduction.

- [23] Carleton, A., Schultz, C.B., 2012. Restoration action and species response: oviposition habits of *Plebejus icarioides fenderi* (Lepidoptera: Lycaenidae) across a restoration chronosequence in the Willamette Valley, Oregon, USA. *Journal of Insect Conservation*, online early.

Quantifies larval host plant availability and reproductive response of specialist butterflies to assess whether animals respond favorably to prairie restoration measures. Argues that critical restoration efforts for degraded habitat often proceed without knowledge of effects upon at-risk species; or rely upon assessment metrics of community-level indicators (e.g., density, abundance) without demonstrating reproductive use; or assume that enhancement with host plant resources guarantees colonization; or presume animal responses correspond to vegetation metrics. Advises monitoring both oviposition and vegetation over a time period long enough to be ecologically relevant. Keywords: habitat; host plant; insect response; oviposition; restoration.

- [24] Carnicer, J., Brotons, L., Stefanescu, C., Peñuelas, J., 2012. Biogeography of species richness gradients: linking adaptive traits, demography and diversification. *Biological Reviews of the Cambridge Philosophical Society* 87, 457–79.

Review; focused on butterflies and birds. Considers how adaptive traits (e.g., related to host plant or resource use, phenology, dispersal) affecting demographic processes (e.g., reproduction, growth, or survival) continuously influence local species composition. Keywords: butterfly population; host plant phenology; host plant preference.

- [25] Chaney, M., 2006. Enhancing priority prairie habitat on a western Washington grassland reserve program easement with a grazing system. Poster. USDA-Natural Resources Conservation Service, Grassland Reserve Program, Olympia, WA.

Federal Grassland Reserve Program assists landowners, protects native prairies and maintains them as grazing lands; similar effect to an HCP. Resumed grazing on some lands may reduce impacts of non-native invasive grasses and enhance butterfly habitat. Poster integrates maps of historic (General Land Office surveys, 1853–1876), potential (NRCS soil surveys), and extant prairies and oak woodlands in Thurston and Pierce Counties, WA. Keywords: enhancement; grasslands; grazing; habitat; historical ecology; invasive species; prairie; restoration.

- [26] Chappell, C.B., 2006. Plant associations of balds and bluffs of western Washington. Washington Natural Heritage Program, Washington Department of Natural Resources, Natural Heritage Report 2006-02, Olympia, WA, 70 pp.

Details plant community associations of balds, meadow-like prairies on slopes with shallow soils atop bedrock, where grassland occurs in smaller patches within a forest matrix. Festuca roemerii predominates but forb composition differs from lowland South Sound prairies. Balds are critical habitat with high floral biodiversity; it is unclear why extirpation of Taylor's checkerspot from Bald Hills NAP occurred. Future reintroductions require restorations that include intensive long-term enhancement to establish a suite of native forbs and management for removal of non-native grasses and encroaching forest. Keywords: balds; disturbance; enhancement; fescue; flora; forbs; habitat patch; host plant; invasive species; nectar resource; plant community; restoration.

- [27] Chappell, C.B., Crawford, R.C., 1997. Native vegetation of the south Puget Sound prairie landscape, in: Dunn, P., Ewing, K. (Eds.), Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, WA, pp. 107–124.

Describes the distinctive species composition and physical environment of the few remaining (mid-1990s) grasslands dominated by native species. Restoration and management targets can be based on knowledge of disturbance and vegetation (e.g., fescue with mosses and a variable, regionally unique assemblage of forbs). Keywords: disturbance; enhancement; fescue; flora; forbs; host plant; invasive species; nectar resource; plant community; prairie; restoration.

- [28] Chappell, C.B., Crawford, R.C., Barratt, C., Kagan, J., Johnson, D.H., O'Mealy, M., Green, G.A., Ferguson, H.L., Edge, W.D., Greda, E.L., O'Neil, T.A., 2001. Wildlife habitats: descriptions, status, trends, and system dynamics, in: Johnson, D.H., O'Neil, T.A. (Managing Directors), Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR, pp. 22–114.

Reference; Westside Grasslands habitat. Conceptually, wildlife-habitat relationships refer to a single taxon, align with habitat niche it occupies, and include invertebrate wildlife. Specifically, refer to an area with the combination and arrangement of necessary resources (e.g., food, cover, water) and environmental conditions (e.g., temperature, precipitation) to meet the biological needs of a species (e.g., promote occupancy; allow individuals to survive and reproduce). From a systems perspective, provides a framework for the ecological role or function that an individual species plays within the environment. From a manager's perspective, the habitat concept needs to be tangible, scientifically supported, with clearly defined habitat features and species associations with them. Keywords: habitat conservation; invertebrate conservation; wildlife habitat.

- [29] Char, P., Boersma, P.D., 1995. The effects of prairie fragmentation on butterfly species in western Washington. Final report submitted to the Nature Conservancy, Washington Field Office and the U.S. Army, Fort Lewis, WA and Seattle, WA.

Concludes that isolated butterfly populations persisting in prairie fragments do not function as metapopulations; investigates sites with very large populations where checkerspots subsequently were extirpated (i.e., 13th Division prairie on JBLM); discusses concerns about herbicide use. First year of a study that was discontinued. Keywords: fragmentation; grassland butterflies; habitat; herbicide effects non-target; prairie.

- [30] Collinge, S.K., Prudic, K.L., Oliver, J.C., 2003. Effects of local habitat characteristics and landscape context on grassland butterfly diversity. *Conservation Biology* 17, 178–187.

Investigates effects of native plant community composition and proximity to urban development on butterfly diversity. Supports other research; concludes prairie type and habitat quality are of primary importance. Keywords: grassland butterflies; habitat quality; plant community.

- [31] Collins, S.L., Knapp, A.K., Briggs, J.M., Blair, J.M., Steinauer, E.M., 1998. Modulation of diversity by grazing and mowing in a tallgrass prairie. *Science* 280, 745–747.

Concludes that re-establishment of grazing or mowing enhances grassland biodiversity, based on long-term field experiments to assess combined effects of fire, N-addition, mowing and grazing on native prairie. Keywords: biodiversity; disturbance; fire; grasslands; grazing; prairie.

- [32] Crawford, R.C., Hall, H., 1997. Changes in the south Puget prairie landscape, in: Dunn, P., Ewing, K. (Eds.), *Ecology and conservation of the south Puget Sound prairie landscape*. The Nature Conservancy, Seattle, WA, pp. 11–15.

Details the magnitude of regional prairie ecosystem losses (in 1996) by comparing the extent of soils that historically supported grassland — shallow, sandy to gravelly well-drained loams with low water-holding capacity — with the actual extent of prairie as assessed by mapped soil and vegetation, aerial imagery, and field reconnaissance. Estimates native prairie species occupy ~8% of historical sites and intact prairie exists on ~3%; advocates immediate conservation measures. Historic distribution of suitable Taylor's checkerspot habitat presumably correlates closely with this. Keywords: conservation; grasslands; habitat; historical ecology; landscape scale; prairie.

- [33] Cushman, J.H., Boggs, C.L., Weiss, S.B., Murphy, D.D., Harvey, A.W., Ehrlich, P.R., 1994. Estimating female reproductive success of a threatened butterfly: influence of emergence time and hostplant phenology. *Oecologia* 99, 194–200.

Relative timing of adult emergence and host plant senescence strongly influenced reproductive success of female checkerspot butterflies in a study of lifetime reproductive success based on age-specific fecundity and survival. Keywords: Euphydryas editha bayensis; host plant phenology.

- [34] D'Aniello, B., Stanislao, I., Bonelli, S., Balletto, E., 2011. Haying and grazing effects on the butterfly communities of two Mediterranean-area grasslands. *Biodiversity and Conservation* 20, 1731–1744.

Compares butterfly species richness at meadows receiving different treatments; diversity indices were significantly higher at the site with cattle and sheep grazing rather than the site mown once a year and managed for haying. Keywords: disturbance; grassland butterflies; grazing.

- [35] D'Antonio, C., Meyerson, L.A., 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. *Restoration Ecology* 10, 703–713.

- Review of concerns and controversial issues raised when managing invasive species in ecological restorations (e.g., viewing disturbance as a fundamental process vs. producing target conditions quickly and then maintaining them with limited resources; circumstances where exotic species are desirable; or when removal threatens native species). Relevant to control of invasive grasses and shrubs; acceptance of non-native host plants. Keywords: disturbance; invasive species; seed bank.*
- [36] Davenport, R., 1997. Rocky Prairie restoration and native plant propagation project, in: Dunn, P., Ewing, K. (Eds.), Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, WA, pp. 191–197.
- Reports on Rocky Prairie NAP, a prairie fragment with high biodiversity, the largest population of golden paintbrush, high-quality fescue grassland, and an abundance of invasive non-native grasses and shrubs, notably Scotch broom. Describes results of initial efforts to grow native forbs and grasses to support regional prairie restorations, including selection criteria for commercial propagation candidates, seed collection, germination tests, and various phases of grow-out trials. Keywords: Castilleja levisecta, fescue; forbs; invasive species; prairie; restoration; seed.*
- [37] Davis, J.D., Hendrix, S.D., Debinski, D.M., Hemsley, C.J., 2008. Butterfly, bee and forb community composition and cross-taxon incongruence in tallgrass prairie fragments. Journal of Insect Conservation 12, 69–79.
- Argues that pollinator conservation is essential for sustaining remnant prairies. Focuses on the correspondence between butterfly and bee communities and the forbs they use for nectar and pollen sources; diversity between the two taxa is inversely correlated. Keywords: fragmentation; grassland butterflies; habitat; plant community; nectar resource; pollinator; prairie.*
- [38] Debinski, D.M., Ray, C., Saveraid, E.H., 2001. Species diversity and the scale of the landscape mosaic: do scales of movement and patch size affect diversity? Biological Conservation 98, 179–190.
- Examines effects of scale on butterfly movement and species diversity using satellite data, field surveys, and simulation models of landscape mosaics and habitat patches. Concludes that finer-grained landscapes permit more resources to be sampled and allow the matrix or patch context to have greater effects. Suggests that as ecological understanding of species-habitat relationships improves, conservation planning can incorporate more complex landscape-level analyses with incidence or abundance surveys. Keywords: butterfly distribution; habitat patch; landscape scale.*
- [39] Delvin, E., 2006. Voices of the Prairie. The Nature Conservancy, Olympia, WA, 22 pp.
- Landowners on the Mima Mounds prairie discuss life-long stewardship of a special landscape. Produced for education and outreach; persuasively illustrates multiple benefits of public-private collaboration and conservation partnerships. Keywords: conservation; prairie; stewardship.*

- [40] Dennehy, C., Alverson, E.R., Anderson, H.E., Clements, D.R., Gilbert, R., Kaye, T.N., 2011. Management strategies for invasive plants in Pacific Northwest prairies, savannas, and oak woodlands. *Northwest Science* 85, 329–351.

Draws on expertise of regional land managers. Recommends early detection, rapid response to new threats, prioritization, treatments to minimize impacts to native taxa and comprehensive restoration strategies to replant treated areas. Provides current best management practices, e.g., for Scotch broom and related taxa, gives mechanical, chemical, biological methods; discusses fire and grazing and the results of field trials; notes perpetual management efforts will be required. Keywords: disturbance; habitat; invasive species; management; prairie; restoration.

- [41] Dennis, R.L.H., Shreeve, T.G., Van Dyck, H., 2006. Habitats and resources: the need for a resource-based definition to conserve butterflies. *Biodiversity and Conservation* 15, 1943–1966.

*Challenges the validity of the habitat patch-matrix approach to defining butterfly habitats and the metapopulation model for understanding spatial dynamics of butterfly populations; both developed with research into checkerspot butterflies (e.g., Ehrlich and Hanski 2004). Argues that necessary larval and adult resources occur along a continuum rather than within vegetation-based patches; host plants are a key variable but not the sole critical factor to define habitat or the habitat patch for the butterfly; and that this is not unique to checkerspots but a fundamental issue critical for successful butterfly conservation and land management. Keywords: butterfly population; checkerspot; *Euphydryas editha bayensis*; habitat; habitat patch; habitat quality; landscape-scale; matrix; *Melitaea cinxia*; metapopulation; resources.*

- [42] Dickson, T.L., Busby, W.H., 2009. Forb species establishment increases with decreased grass seeding density and with increased forb seeding density in a northeast Kansas, U.S.A., experimental prairie restoration. *Restoration Ecology* 17, 597–605.

Investigates the lack of biodiversity seen in many restored prairies, compared with high-quality prairie remnants, by examining the effects upon forb species of variable grass-seeding densities using a replicated restoration experiment. Demonstrates that some grasses compete aggressively; high grass seed density decreases forb richness, cover, and biomass; forbs thrive when spatially separated from dominant grasses; seed availability limits establishment of some forbs; some late-successional forbs never become established; and higher forb seed densities increase forb richness. Recognizes expense/availability issues. Keywords: assembly rules; biodiversity; forbs; grasslands; plant community; prairie; restoration; seed; seed limitation.

- [43] Dobkin, D.S., Olivieri, I., Ehrlich, P.R., 1987. Rainfall and the interaction of microclimate with larval resources in the population dynamics of checkerspot butterflies (*Euphydryas editha*) inhabiting serpentine grassland. *Oecologia* 71, 161–166.

Examines the influence of extreme weather combined with microclimate differences due to topographic heterogeneity (i.e., slope and exposure); explains how two consecutive years of record rainfall led to near-extirpation the following year because delayed life stages led to greater than

normal near-100% larval mortality. Keywords: butterfly population; Euphydryas editha bayensis; host plant phenology; insolation; larval host plant use; microclimate; weather.

- [44] Dolek, M., Freese-Hager, A., Geyer, A., Balletto, E., Bonelli, S., 2012. Multiple oviposition and larval feeding strategies in *Euphydryas maturna* (Linné, 1758) (Nymphalidae) at two disjoint European sites. *Journal of Insect Conservation*, online early.

Concludes that the few remaining butterfly populations each require site-specific conservation measures adapted to different management, habitat structure, and female and larval host plant preferences. Keywords: Euphydryas spp.; host plant preference; larval host plant use; oviposition.

- [45] Dover, J., Settele, J., 2008. The influences of landscape structure on butterfly distribution and movement: a review. *Journal of Insect Conservation* 13, 3–27.

Review targets ecologists and land managers with an excellent analysis of literature pertaining to the influence of landscape scale and structure on butterfly dispersal and distribution, including human impacts, landscape-level processes and landscape elements (e.g., management schemes, succession, climate change, isolation, fragmentation, patches, and metapopulations). Keywords: butterfly distribution; habitat patch; habitat structure; landscape scale; matrix; spatial ecology.

- [46] Drake, D., Ewing, K., 1997. Germination requirements of 32 native Washington prairie species, in: Dunn, P., Ewing, K. (Eds.), *Ecology and conservation of the south Puget Sound prairie landscape*. The Nature Conservancy, Seattle, WA, pp. 181–191.

*Presents the results for pre-treatment and germination tests of native forb seeds from Fort Lewis prairie: for 25 species, maximum germination rates ranged from 2.3% — for *Castilleja hispida*, native host for Taylor's checkerspot — to 84.5%; 7 others had insignificant germination (0 to <1%) under all treatment combinations. Prairie habitat restoration requires large quantities of seed and plugs of specific native plants. To establish efficient propagation programs, replicated experiments on freshly-collected seed tested stratification regimes and temperature conditions. Keywords: *Castilleja hispida*; forbs; host plant; nectar resource; prairie; restoration; seed.*

- [47] Dunn, P., 1998. *Prairie habitat restoration and maintenance on Fort Lewis and within the south Puget Sound prairie landscape: final report and summary of findings*. The Nature Conservancy, Seattle, WA, pp. vi + 1–60.

Summarizes results of years of restoration and management in the south Puget Sound region under an agreement entitled “Prairie habitat restoration and management efforts on Fort Lewis,” whose primary objective was to “define, develop, and initiate management practices designed to preserve, restore, and rehabilitate native Puget Sound prairie grasslands and savannas” by accomplishing a suite of specific goals, modified over time, that included ecological research, restoration, management, and monitoring. Complements information presented in Dunn and Ewing (Eds.), 1997. ACUB Project builds on this effort. Keywords: conservation; habitat; landscape scale; management; prairie; restoration.

- [48] Dunn, P., Ewing, K. (Eds.), 1997. Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, WA.

Incorporates presentations made at a one-day symposium on prairie habitat conservation; includes research on historical ecology, land-use, distribution of native vegetation, butterflies; and restoration and maintenance strategies, including native plant propagation and the effects of prescribed fire and invasive-species control. Supplements Dunn, 1998. Keywords: conservation; habitat; landscape scale; management; prairie; restoration.

- [49] Dunn, P., Fleckenstein, J., 1997. Butterflies of the south Puget sound prairie landscape, in: Dunn, P., Ewing, K. (Eds.), Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, WA, pp. 75–85.

*Whulge (Taylor's) checkerspot (1996): "Current distribution in the South Puget Sound prairies includes two substantial and three minor populations. The largest populations occur within and adjacent to the 13th Division Prairie Research Natural Area at Ft. Lewis and at the Mima Mound-Black River-Glacial Heritage Park of Thurston County. Other sites containing Whulge checkerspots include the Bald Hills NAP, Mima Mounds NAP and Scatter Creek Wildlife Area." By 2006, checkerspots remained extant at Ft. Lewis, but the five population mentioned in this report were extirpated. Keywords: butterfly distribution; *Euphydryas editha taylori*.*

- [50] Dunn, P.V., Fimbel, C., 2011. Unoccupied butterfly habitat enhancement annual progress report to ACUB Cooperators. The Nature Conservancy, Seattle, WA, pp. 1–15 + appendices A–J.

Describes the project goal and objectives, methods used to achieve those targets; presents results and a discussion, future plans, and questions for future research. The primary goal of the Unoccupied Butterfly Habitat Enhancement project is to support reintroduction of Taylor's checkerspot and mardon skipper. Primary funding from Joint Base Lewis McChord ACUB and additional funding from the U.S. Fish and Wildlife Service has supported efforts of a multi-disciplinary Butterfly Habitat Enhancement Team to design and implement a strategic approach to enhance habitat on non-JBLM lands, identify suitable reintroduction sites, and develop restoration targets and site-based work plans updated annually to implement invasive species treatments and enhancements with native plant and seed additions. Explains many formerly occupied prairie sites do not currently support appropriate habitat for either species; butterfly resources have declined, while non-native grasses and forbs established dense stands. Habitat enhancement is achieving success supporting reintroduced populations of Taylor's checkerspot butterflies; future efforts will continue use of fire to prepare sites for intensive herbicide treatments and subsequent plantings concentrated into enhancement patches within a semi-native prairie matrix with lower restoration inputs. Keywords: disturbance; enhancement; habitat; invasive species; management; prairie; restoration.

- [51] Dunn, P.V., Fimbel, C., 2012. ACUB unoccupied butterfly habitat enhancement: 2011/2012 work plan for all sites. Center for Natural Lands Management, Olympia, WA, 40 pp.

Consolidates work plans for six individual sites in Thurston County targeted for enhancement to facilitate future re-introductions of Taylor's checkerspot or mardon skipper. The sites are: Glacial Heritage Preserve, Mima Mounds NAP, Scatter Creek North, Scatter Creek South, Tenalquot Prairie Preserve and West Rocky Prairie; five are known historical sites for Taylor's checkerspot. Individual plans provide background information on historic and current occupancy by rare butterflies. Evaluations of existing habitat include assessments of invasive species presence and density; microhabitat heterogeneity; connectivity/adjacency to other sites/units; and projected management activities. Habitat enhancement actions specify locations; detail treatment and monitoring requirements for control of invasive species and for enhancement plantings; provide a schedule by task matrix and maps showing past management actions and current objectives; and include an enhancement area habitat evaluation form that categorizes vegetative habitat features (e.g., host plant and nectar resource abundance, presence of invasive grasses or Scotch broom). Completed by representatives from site owner/manager agencies; each presents the required information in the same format differently. Keywords: disturbance; enhancement; habitat; invasive species; management; prairie; restoration.

- [52] Dunwiddie, P., Alverson, E., Stanley, A., Gilbert, R., Pearson, S., Hays, D., Arnett, J., Delvin, E., Grosboll, D., Marschner, C., 2006. The vascular plant flora of the south Puget Sound prairies, Washington, USA. *Davidsonia* 17, 51–69.

Compiles a comprehensive floristic inventory for the remaining prairies in south Puget Sound; provides data on abundance, distribution, and diversity of forbs and guidance for ecosystem conservation and restoration projects. On 15 prairies, 278 species were recorded; 59% were native taxa; 70% were perennials. Keywords: flora; habitat; plant community; prairie.

- [53] Dunwiddie, P., Delvin, E., 2002. Inadvertent selection in the propagation of native plants: a cautionary note. *Native Plants Journal* 7, 121–124.

*Case study of a prairie restoration and a chain of contributing factors that led inadvertently to using *Festuca rubra* instead of *Festuca roemerii*. Recommends awareness of local ecotypes and of native taxa with invasive relatives; common sense; and the use of standard accepted practices to avoid hazards that could compromise native restorations. Keywords: fescue; prairie; restoration.*

- [54] Dunwiddie, P.W., 1991. Comparisons of aboveground arthropods in burned, mowed, and untreated sites in sandplain grasslands on Nantucket Island. *American Midland Naturalist* 125: 206–212.

Examines effects on invertebrate biodiversity of management to maintain vegetation structure and composition in grasslands on sandy glacial outwash soils. Treatments were two years apart, April fire and August fire and mowing; arthropods sampled pre- and post-burn the second year were compared with those in nearby reference plots. Results were inconsistent, but Lepidoptera numbers in the August burn and mow treatment were higher in treated vs. reference plots prior to burning the second year, and their abundance declined post-fire. Notes that before effects of prescribed fire on arthropod populations can be accurately anticipated, many more studies are

needed that include different methodologies with a range of locations, timing, duration, and types of burns. Keywords: fire; grasslands; insect response; mowing; restoration.

- [55] Dunwiddie, P.W., 2009. Evaluating suitability of prairies for golden paintbrush (*Castilleja levisecta*) recovery by experimental outplanting in south Puget Sound. Final report prepared for the U.S. Fish and Wildlife Service, The Nature Conservancy, Seattle, WA, 17 pp.

Describes a project designed to advance recovery of golden paintbrush and provide information for assessing suitability of sites for reintroduction by: 1) experimentally planting plugs and seed into a variety of microclimates across multiple prairies identified as potential reintroduction sites; 2) gathering data on germination rates, survival, and growth; and 3) relating success of seeding and planting experiments to vegetation and soil at each site. Outplanting was very successful; in-the-field seed germination rates were extremely low; and factors other than physical site characteristics, i.e., enhanced soil fertility after fire appear to be important. Overall, the results led to targeted recommendations for future research to identify indicators of suitable microsites for reintroduction. Keywords: Castilleja levisecta; experiment; reintroduction.

- [56] Dunwiddie, P.W., Bakker, J.D., 2011. The future of restoration and management of prairie-oak ecosystems in the Pacific Northwest. *Northwest Science* 85, 83–92.

Provides the introduction for a collection of papers (many included in this list) that summarize scientific research and management presented at a regional conference on ecosystem conservation. Reviews the historical context, current conservation efforts, future threats, strategic conservation priorities, and future challenges; recommends collaborate, creative, and innovative research and management; and suggests a conceptual framework and specific principles for restoration goals. Keywords: conservation; habitat; management; prairie; restoration.

- [57] Ehrlich, P.R., 1992. Population biology of checkerspot butterflies and the preservation of global biodiversity. *Oikos* 63, 6–12.

*Reviews three decades of research on combined effects of environmental-quality factors on the population dynamics of checkerspots; and contrasts conservation concerns specific to invertebrates with those affecting vertebrates — all with the intent to convince conservation biologists at large that intensive single-species approaches are not the appropriate response to the crisis of global biodiversity loss — ‘quick and dirty’ sampling to rapidly assess ecosystems, plan reserves, and monitor results is instead required. At all levels, relevant to Taylor’s checkerspot. Keywords: biodiversity; butterfly population; conservation; *Euphydryas editha bayensis*; rapid assessment.*

- [58] Ehrlich, P.R., Hanski, I. (Eds.), 2004. On the wings of checkerspots: a model system for population biology. Oxford University Press, Oxford, 371 pp.

*Reference; synthesizes long-term research of both scientists and many colleagues on the population biology of checkerspot butterflies in California and in Finland. Keywords: butterfly population; conservation; *Euphydryas editha bayensis*; *Melitaea cinxia*; metapopulation.*

- [59] Ehrlich, P.R., Murphy, D.D., 1987. Conservation lessons from long-term studies of checkerspot butterflies. *Conservation Biology* 1, 122–131.

Highlights findings of specific importance to conservation biology and reserve design and management from decades of research in the western U.S. on the ecology and population biology of checkerspots. Of most relevance to habitat enhancement and assessment and reintroduction of butterflies: understand population scale and structure; topographic heterogeneity, other aspects of habitat diversity are crucial to habitat suitability; if options limited, prioritize conservation of demographic source units that can replenish other habitat; and attempt to identify subtle habitat requirements that could play key roles in long-term population persistence. Keywords: butterfly conservation; habitat; habitat heterogeneity; metapopulation; microclimate; topography.

- [60] Ehrlich, P.R., Murphy, D.D., Singer, M.C., Sherwood, C.B., White, R.R., Brown, I.L., 1980. Extinction, reduction, stability and increase: the responses of checkerspot butterfly (*Euphydryas*) populations to the California drought. *Oecologia* 105, 101–105.

*Describes variable and unpredicted responses of different checkerspot populations to a two-year drought, related to site-specific interactions between the butterflies and their host plants. Under most climate change scenarios, PNW summer drought will be exacerbated. Keywords: butterfly population; *Euphydryas* spp.; climate; drought; host plant; weather.*

- [61] Ehrlich, P.R., Raven, P.H., 1964. Butterflies and plants: a study in coevolution. *Evolution* 18, 586–608.

*Seminal paper on phytochemically-based affiliations between butterflies and host plants: “Melitaeini are often associated with Acanthaceae, Scrophulariaceae and their wind-pollinated derivatives Plantaginaceae, and with Compositae and Verbenaceae. Nymphalini feed on plants of the same families as Melitaeini, but also very prominently on the Ulmaceae-Urticaceae-Moraceae group and the Convolvulaceae, Labiatae, Portulacaceae, and Verbenaceae.” (cf. TCB resource matrix; Olmstead, 2002). Keywords: butterfly conservation; *Castilleja hispida*; *Castilleja levisecta*; *Collinsia grandiflora*; *Collinsia parviflora*; forbs; host plant preference; *Plantago lanceolata*; *Plectritis congesta*; restoration.*

- [62] Eichel, S., Fartmann, T., 2007. Management of calcareous grasslands for Nickerl’s fritillary (*Melitaea aurelia*) has to consider habitat requirements of the immature stages, isolation, and patch area. *Journal of Insect Conservation* 12, 677–688.

*Analyzes habitat preferences of adult butterflies and larvae; finds that host plant quantity and structure determine oviposition choice; habitat quality, patch area and isolation explain patch occupancy; concludes that adults need habitat disturbance to promote host plants (*Plantago* spp.), larvae need abundant host plants and low disturbance intensity, and that a rotational grazing system would supply both. Supports earlier research on related grassland butterflies. Keywords: disturbance; grassland butterflies; grazing; habitat; host plant preference; oviposition.*

- [63] Ejrnæs, R., Bruun, H.H., Graae, B.J., 2006. Community assembly in experimental grasslands: suitable environment or timely arrival? *Ecology* 87, 1225–1233.

Presents results of a succession experiment manipulating soil/climate, productivity, disturbance, and colonization sequence in two seed groups: specialist perennials restricted to semi-natural grasslands, and opportunists from disturbed habitats, primarily highly-competitive annuals. Assembly order controlled species composition; species richness and invasibility were affected by environmental factors (i.e., disturbance, fertilizer). Although a short-term experiment in a synthetic community, supports the importance of assembly order in grassland restorations. Keywords: assembly rules; experiment; grasslands; invasive species; plant community.

- [64] Farruggia, A., Dumont, B., Scohier, A., Leroy, T., Pradel, P., Garel, J.-P., 2012. An alternative rotational stocking management designed to favour butterflies in permanent grasslands. *Grass and Forage Science* 67, 136–149.

Notes agricultural intensification plays a key role in butterfly species declines; specialized species with a short summer flight season are affected most by changes that have shifted grassland use away from late-harvested hay meadows. Discusses a cattle grazing scheme designed to meet objectives for productivity and increase butterfly diversity by removing animals from subplots of a rotation during main flowering periods. Keywords: butterfly conservation; grazing.

- [65] Fazzino, L., Kirkpatrick, H.E., Fimbel, C., 2011. Comparison of hand-pollinated and naturally-pollinated Puget balsamroot (*Balsamorhiza deltoidea* Nutt.) to determine pollinator limitations on south Puget Sound lowland prairies. *Northwest Science* 85, 352–360.

Demonstrates that self-incompatible plants, inadequate pollinator populations, and additional limitation due to inability of pollinators to travel between habitat fragments may all contribute to small population sizes of Puget balsamroot, a nectar resource for Taylor's checkerspot. Keywords: balsamroot; experiment; forb; nectar resource; pollinator; prairie.

- [66] Fenn, M.E., Allen, E.B., Weiss, S.B., Jovan, S., Geiser, L.H., Tonnesen, G.S., Johnson, R.F., Rao, L.E., Gimeno, B.S., Yuan, F., Meixner, T., Bytnerowicz, A., 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. *Journal of Environmental Management* 91, 2404–2423.

Extends initial research (Weiss, 1999) on effects and management of N-deposition in serpentine grasslands — Bay checkerspot habitat — later applied to seven major California vegetation types. Reviews management options essential for maintaining biodiversity in grasslands where rates of N-deposition exceed critical loads and exotic annual grasses have invaded. Recommends cattle grazing to remove biomass accumulation, physically disturb soil to provide germination sites for native forbs, preferably a mosaic of grazing regimes to spread risks across years with different weather conditions. Where degraded habitats are too small, rotational mowing can be used for successful restoration; prescribed fire can reduce annual grass cover where permitted.

Innovative mitigation agreements and habitat conservation plans are discussed. Keywords: grasslands; grazing; invasive species; management; N-deposition; N-response.

- [67] Fimbel, C., 2004. Habitat enhancement for rare butterflies on Fort Lewis prairies. The Nature Conservancy, Seattle, WA, 69 pp.

Report identifies habitat requirements for four target butterfly species (i.e., Taylor's checkerspot, mardon skipper, zerene fritillary, Puget blue), and proposes strategies for habitat enhancements on prairies that target those requirements. Identifies three prairies as high priority sites on which to enhance the composition, structure, and processes of prairie habitat: the Artillery Impact Area (AIA), Johnson Prairie, and 13th Division Prairie Research Natural Area; two secondary sites: Weir Prairie complex, Training Area 7S. High-priority sites chosen based on historic and recent butterfly use, prairie vegetation, diverse structure, and compatible land uses; Taylor's checkerspot restricted to restricted-access AIA, historically present at all sites. Focuses on three enhancement strategy components: 1) vegetation composition, includes control of invasive species and planting of native grasses and forbs; 2) habitat structure, targets diverse structural and edaphic features including sloping topography, edge habitats or tree islands, and prairie-riparian ecotones; and 3) process, incorporating a 'butterfly-sensitive' fire regime at a meaningful scale. Details specific considerations for Taylor's checkerspot that include: at least two host plant species and abundant nectar plants, distributed on open sites near all structurally diverse habitat features described, plus presence of rodents that till the soil. Provides specific actions to implement strategies and emphasizes this is an ambitious proposal; should be implemented slowly, with a strong research component, with existing management adapted to incorporate butterfly-sensitive actions. Relevant when written; enhancement strategies are relevant now. Keywords: fire; habitat; habitat structure; invasive species; management; plant community; prairie; restoration.

- [68] Fimbel, C., 2009. Investigation of Taylor's checkerspot diapause habitat characteristics. The Nature Conservancy, Olympia, WA, 3 pp.

*Taylor's checkerspot larvae enter diapause in mid-July and remain there until mid-February; knowledge of their location is critical information for land management activities in their prairie habitat, particularly prescribed fire or herbicide application to control invasive plant species. Captive-reared larvae were released into study plots or containers to explore what microhabitats are used during diapause. Observations found the majority of larvae spend early diapause above ground in plant litter and duff, sometimes at the base of forb stems; others find more-protected locations below ground in soil cracks or the tunnels of ground-nesting bees or ants. Indicates a diverse invertebrate community that creates microhabitats within the upper layer of the prairie soil may be beneficial for Taylor's checkerspot by providing protection from disturbance. Keywords: diapause; *Euphydryas editha taylori*; habitat; larvae; prairie.*

- [69] Fimbel, C., Linders, M., 2008. Taylor's checkerspot diapause phase habitat pilot investigation. The Nature Conservancy and Washington Department of Fish and Wildlife, Olympia, WA, 3 pp.

Describes the pilot project to test methods to gain information about habitat used by Taylor's checkerspot larvae in the diapause phase. Results indicate diapause state may be more dynamic than expected. Keywords: Euphydryas editha taylori; diapause; experiment; habitat; larvae.

- [70] Fitzpatrick, G.S., 2004. Techniques for restoring native plant communities in upland and wetland prairies in the Midwest and west coast regions of North America. White paper prepared for City of Eugene, The Nature Conservancy, Eugene, OR, 52 pp.

Review of prairie restoration literature. Discusses differences between Midwest and west coast ecosystems, including climate and weather patterns (i.e., continental, wet spring–summer vs. maritime, wet fall–spring, dry summer) that favor warm-season grasses vs. cool-season grasses; historically deep vs. generally shallow soils; fire regimes (i.e., ignition by native Americans and lightning spring–fall vs. intentional fall fires); grazing (i.e., high-intensity bison grazing vs. lower pressure from elk and deer), and how these affect restoration timing and technique. Site preparation; invasive-species management; seeding and planting; improving competitive environments for natives; and short-term and long-term management (e.g., herbicides, grazing, mowing, and burning) are topics considered. Keywords: fire; herbicide; prairie; restoration.

- [71] Fleckenstein, J., Potter, A.E., 1999. Project summary, Puget prairie butterfly surveys 1997, 1998.

Surveys done near tipping-points for extirpation of multiple Taylor's checkerspot populations: a population at "Mima Mound-Black River-Glacial Heritage Park of Thurston County," was described in 1996 as one of two very important populations (Dunn and Fleckenstein, 1997); surveys at Glacial Heritage Preserve recorded 131 butterflies in 1997, 9 in 1998, and none in 1999. Keywords: butterfly distribution; Euphydryas editha taylori; monitoring

- [72] Flick, T., Feagan, S., Fahrig, L., 2012. Effects of landscape structure on butterfly species richness and abundance in agricultural landscapes in eastern Ontario, Canada. *Agriculture, Ecosystems & Environment* 156, 123–133.

Examines patterns of butterfly distribution across sample sites in agricultural landscapes with high configurational heterogeneity (i.e., spatial complexity; measured by patch density, number of patches in the landscape) or high compositional heterogeneity (i.e., more cover types, measured as patch richness). Butterfly species richness was related to higher patch density; abundance was high with lower patch richness, meaning fewer cover types, possibly due to limited availability of individual types. Suggests that detection of any effects of landscape heterogeneity is "remarkable" given environmental variability and uncontrolled factors influencing observations. Keywords: biodiversity; butterfly distribution; fragmentation; habitat heterogeneity; habitat patch.

- [73] Forister, M.L., McCall, A.C., Sanders, N.J., Fordyce, J.A., Thorne, J.H., O'Brien, J., Waetjen, D.P., Shapiro, A.M., 2010. Compounded effects of climate change and habitat alteration shift patterns of butterfly diversity. *Proceedings of the National Academy of Sciences of the United States of America* 107, 2088–2092.

Studies combine negative effects of habitat destruction and climate change; notes invertebrate taxa declines often underestimated. Long-term butterfly dataset (159 spp.; presence-absence; sampled biweekly for 19–35 years along elevational gradient 0–2775m in biodiversity hotspot): indicates species richness declines most severe at low elevations where habitat alteration, lost connectivity, and host and nectar plants losses are greatest; only highest-elevation site had an increase (but less abundant alpine specialists). Contrary to other studies, disturbance-associated ruderal species that tend to be good dispersers were affected far more than specialists; generalists also tended not to shift upslope, while specialists made significant range shifts. Climate change and habitat alteration drive complex changes at all low-elevation sites along the Pacific coast. Keywords: biodiversity; butterfly conservation; butterfly distribution; climate change; habitat.

- [74] Forister, M.L., Scholl, C.F., Jahner, J.P., Wilson, J.S., Fordyce, J.A., Gompert, Z., Narala, D.R., Alex Buerkle, C., Nice, C.C., 2012. Specificity, rank preference, and the colonization of a non-native host plant by the Melissa blue butterfly. *Oecologia*, online early.

Examines inter-population geographical variations in oviposition preference for a native vs. non-native host plant, and the evolution of behavioral preferences over time, either through an increased tendency to use multiple host plants (specificity), or a change in the order in which plants are preferred (rank preference). Preferences for three kinds of hosts were compared experimentally. Keywords: host plant; non-native host plant; oviposition.

- [75] Foster, B.L., Tilman, D., 2003. Seed limitation and the regulation of community structure in oak savanna grassland. *Journal of Ecology* 91, 999–1007.

Tests the importance of seed availability in regulating colonization dynamics and species richness in local habitat patches; determines that initial effects of sowing persist for years; assesses long-term impacts of sown species on the abundance of existing non-sown species. Keywords: assembly rules; experiment; grasslands; plant community; prairie; seed.

- [76] Foster, J.R., Shaff, S.E., 2003. Forest colonization of Puget lowland grasslands. *Northwest Science* 77, 283–296.

Studies successional patterns since exclusion of fire from prairies; examines changes in grassland ecosystem associated with forest encroachment, colonization by Douglas-fir. Initial assumptions were that plant composition of grasslands and direction/magnitude of ecological processes has remained the same since cessation of regular burning. Research shows two types of disturbance have altered successional processes: invasion of fescue-dominated grasslands by aggressive non-native species (e.g., Scotch broom, grasses) and changes in military training intensity at Fort Lewis (now JBLM). Keywords: Douglas-fir; disturbance; GIS; grasslands; historical ecology; invasive species; prairie.

- [77] Funk, J.L., Cleland, E.E., Suding, K.N., Zavaleta, E.S., 2008. Restoration through reassembly: plant traits and invasion resistance. *Trends in Ecology & Evolution* 23, 695–703.

Reviews assembly processes in the context of ecological restoration to create invasion-resistant communities, specifically in degraded ecosystems or after removal of invasive species; notes most principles also apply to efforts targeted towards improving habitat quality. Suggests functional composition may be more important than species diversity; advocates decision frameworks that incorporate relevant functional traits (e.g., resource-use, phenology, flammability) to assess native species by similarity to existing or potential invasives; use of ecological filters (e.g., biotic, dispersal, environmental) at multiple spatial scales (e.g., seeding native species, manipulating resource availability, fire, herbicide use). Recognizes debates about community ecology theory, science-driven restoration. Relevant to local, regional restoration and enhancement efforts. Keywords: assembly rules; invasive species; plant community; restoration.

- [78] Gamon, J., 1997. Rare vascular plants of the south Puget Sound prairie landscape, in: Dunn, P., Ewing, K. (Eds.), Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, WA, pp. 85–91.

*Discusses six grassland forb species; suggests conservation efforts overall will benefit from more research on prairie ecosystem function, response of rare species to management and disturbance. Keywords: *Castilleja lewisecta*; forbs; prairie; conservation; fragmentation.*

- [79] Garry Oak Ecosystem Recovery Team Society, 2011. Species at risk in garry oak and associated ecosystems in British Columbia: *Euphydryas editha taylori*. Garry Oak Ecosystem Recovery Team, Victoria, BC, 4 pp.

*Field guide pages, available online, provide concise descriptions, photos, life history details, BC-specific conservation information. Education and outreach; format and information likely to appeal to varied audiences. Keywords: butterfly conservation; *Euphydryas editha taylori*.*

- [80] Gould, P.J., Harrington, C.A., 2008. Evaluation of landscape alternatives for managing oak at Tenalquot Prairie, Washington. USDA Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-745, Portland, OR, 56 pp.

Presents alternative scenarios for oak management in an area that encompasses several prairies that are historic and potential Taylor's checkerspot habitat. Landscape-level evaluations meld digital techniques: a geographic information system, a forest-growth model with individual stand and tree data, and a landscape visualization using a LiDAR-derived digital elevational model. Prairie models might have multiple scales. Keywords: GIS; model; prairie; restoration.

- [81] Graves, S.D., Shapiro, A.M., 2003. Exotics as host plants of the California butterfly fauna. Biological Conservation 110, 413–433.

Discusses negative and positive impacts of non-native species used as host plants and nectar resources; 34% of CA butterfly spp. (in 2001) used non-native hosts for oviposition or larval feeding. Keywords: host plant preference; invasive species; non-native host plant; oviposition.

- [82] Gripenberg, S., Mayhew, P.J., Parnell, M., Roslin, T., 2010. A meta-analysis of preference-performance relationships in phytophagous insects. *Ecology Letters* 13, 383–93.

Meta-analysis supports preference-performance hypothesis: female preference for plant types reflects offspring performance. Keywords: host plant preference; oviposition; larval survival.

- [83] Grosboll, D.N., 2004. Proceedings of the Species at Risk 2004 Pathways to Recovery Conference: captive rearing the endangered mardon skipper (*Polites mardon*) and Taylor's checkerspot (*Euphydryas editha taylori*) butterflies: initial results (Lepidoptera, Nymphalidae). Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, BC, 18 pp.

*Presents results from initial captive-rearing trials for Taylor's checkerspot. Pre-diapause larvae fed two host plants, *Castilleja hispida* and *Plantago lanceolata*, with equal success. Survival to diapause > 80% for larvae reared from eggs laid by captive females. Keywords: butterfly conservation; *Castilleja hispida*; *Euphydryas editha taylori*; *Plantago lanceolata*; reintroduction.*

- [84] Grosboll, D.N., 2011. Taylor's Checkerspot (*Euphydryas editha taylori*) oviposition habitat selection and larval hostplant use in Washington State. M.E.S. Thesis, The Evergreen State College, Olympia, WA, pp. ix + 1–71 + appendices.

Argues that understanding oviposition preferences, larval survival and differential performance on host plants, and development of methods to enhance host plant resources are key to recovery of Taylor's checkerspot. Various oviposition site parameters were measured within occupied habitat; oviposition was significantly associated with high density host plant patches at three of four sites. Demonstrates that in areas with suitable grassland structure, high host plant density sites are located for oviposition. Concludes that assessments of habitat and restoration objectives should consider high density host plant areas more important than site-level host plant abundance or cover. Keywords: butterfly conservation; host plant preference; larval host plant use; oviposition.

- [85] Grundel, R., Pavlovic, N.B., 2007. Resource availability, matrix quality, microclimate, and spatial pattern as predictors of patch use by the Karner blue butterfly. *Biological Conservation* 135, 135–144.

Reviews performance of two major paradigms that predict habitat patch use: 1) differences in quality and quantity of larval and adult resources and in environmental conditions determine use (e.g., microclimatic differences affect thermoregulation or synchrony between insect and host plant development; insolation gradients affect abundance or plant chemical composition); or 2) the spatial configuration of habitat patches determines use, and recolonization is affected by connectivity or isolation. Examines extent to which grassland butterfly habitat patch use was affected by three sets of predictors: 1) larval host availability, 2) matrix characteristics, and 3) factors affecting thermal environment. Patch area, an indicator of host availability, accounted for 30% of variation; spatial trends, resource availability, matrix quality and microclimate each accounted for similar amounts of variation in occupancy. Concludes each should be incorporated

into habitat management planning. Keywords: grassland butterflies; habitat patch; habitat quality; host plant; management; matrix; microclimate.

- [86] Guppy, C.S., Kondla, N.G., Schaeffer, L., 2003. Draft national recovery strategy for Taylor's checkerspot *Euphydryas editha taylora* (W.H. Edwards). British Columbia Ministry of Water, Land, and Air Protection, Victoria, BC.

Presents recovery strategies for British Columbia; Taylor's checkerspot listed as Endangered in Canada. Most historical records are from southern Vancouver Island, near Victoria. Believed extirpated in 2000; see Page et al., 2009 for more recent distribution data. Keywords: conservation; Euphydryas editha taylora.

- [87] Guppy, C.S., Shepard, J.H., 2001. Butterflies of British Columbia: including Western Alberta, Southern Yukon, the Alaska Panhandle, Washington, Northern Oregon, Northern Idaho, and Northwestern Montana. University of British Columbia Press, Vancouver, BC, 413 pp.

Regional reference; extensive natural history information for Taylor's checkerspot. Keywords: butterfly biology; butterfly conservation; butterfly distribution; Euphydryas editha taylora.

- [88] Habel, J.C., Schmitt, T., 2012. The burden of genetic diversity. *Biological Conservation* 147, 270–274.

With respect to butterflies, increasing habitat fragmentation, and continual land-use changes, discusses advantages of low genetic diversity (i.e., found in ecological specialists, geographically restricted populations adapted to reduced gene flow that survive in isolation); and disadvantages of high genetic diversity (i.e., found in once-widespread common species adapted to strong gene flow between populations). Argues that intermediate species on a specialist-generalist continuum appear to be particularly sensitive to sudden habitat loss: they have high genetic diversity, but no longer have habitat patch networks to maintain that diversity in a fragmented environment. Keywords: biodiversity; butterfly conservation; Euphydryas spp.; habitat fragmentation.

- [89] Haddad, N.M., Tilman, D., Haarstad, J., Ritchie, M., Knops, J.M.H., 2001. Contrasting effects of plant richness and composition on insect communities: a field experiment. *The American Naturalist* 158, 17–35.

Demonstrates that two types of plant diversity, plant functional group richness, and plant species richness, have significant positive effects on insect species richness but contrasting effects on insect abundance. Negative effects of functional group richness on abundance attributed to sampling effect of productive but poor-quality grasses. Higher plant diversity may increase availability of alternate resources, such as host plants; diverse plots may be more structurally complex, providing more suitable habitat. Keywords: biodiversity; butterfly distribution; plant community.

- [90] Halder, I., Barbaro, L., Corcket, E., Jactel, H., 2007. Importance of semi-natural habitats for the conservation of butterfly communities in landscapes dominated by pine plantations. *Biodiversity and Conservation* 17, 1149–1169.

Concludes that preservation of semi-natural habitat remnants, maintenance of soil moisture levels, and management of the forest understory are of primary importance for conservation of butterflies in simplified pine plantation landscapes. Among 7 habitat types, Euphydryas spp. most abundant in herbaceous firebreaks, which had highest plant species richness. Relevance to balds in forest matrix. Keywords: butterfly conservation; Euphydryas spp.; habitat conservation.

- [91] Hamman, S.T., Dunwiddie, P.W., Nuckols, J.L., McKinley, M., 2011. Fire as a restoration tool in Pacific Northwest prairies and oak woodlands: challenges, successes, and future directions. *Northwest Science* 85, 317–328.

Discusses the increased use of prescribed fire with other techniques (e.g., herbicide, seeding native species) to restore and manage native habitat; variable results due to differential fire intensity, caused by fuels, weather and application technique; and solutions to control for these by altering pre-fire treatments, and fire season, frequency, and extent. Identifies challenges to overcome, collaborative strategies, and future research (e.g., species-specific responses to fire) to help refine fire management for optimal effectiveness. Keywords: fire; invasive species; restoration.

- [92] Hanski, I., 1994. Patch-occupancy dynamics in fragmented landscapes. *Trends in Ecology & Evolution* 9, 131–135.

Summarizes observational data on habitat patch occupancy patterns in fragmented landscapes; outlines an approach to modeling data to answer questions about ecological processes that produce patterns in specific metapopulations. Keywords: habitat patch; Melitaea cinxia; metapopulation.

- [93] Hanski, I., Singer, M.C., 2001. Extinction-colonization dynamics and host-plant choice in butterfly metapopulations. *The American Naturalist* 158, 341–353.

Shows that spatial variation in adult host plant preference influences movement of ovipositing females; females with different preferences perceive relative patch quality differently, which influences their likelihood of colonizing patches with particular host composition. Two host plant species are used; they vary in abundance among habitat patches in a highly fragmented network. Keywords: habitat patch; host plant preference; Melitaea cinxia; metapopulation; oviposition.

- [94] Harrington, T.B., 2011. Quantifying competitive ability of perennial grasses to inhibit Scotch broom. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Research Paper PNW-RP-587, Portland, OR, 15 pp.

Perennial grasses suppressed biomass development and cover of non-native invasive Scotch broom (Cytisus scoparius) by at least 72% in two greenhouse studies that evaluated competitive abilities of three native perennial grasses. Prescribed fire can be used to control existing plants, reduce the seed bank, and create a grass seedbed. Keywords: grass; invasive species; Scotch broom.

- [95] Hays, D.W., 2011. Conservation of Taylor's checkerspot on the Olympic Peninsula. Project final report submitted to the U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, Olympia, WA, 38 pp.

Reports on a three-year project to identify management needs at four Taylor's checkerspot sites on the Olympic Peninsula (i.e., Eden Valley, Dan Kelly Peak, Striped Peak, and Graysmarsh) that resulted in a management plan for lands managed by WDNR in Clallam County that includes site-specific management to minimize and mitigate impacts to Taylor's checkerspot from timber harvest, silviculture, road maintenance, fire management, and other activities, working with landowners to cooperatively manage and enhance habitat. At the three occupied sites on private and state lands, butterfly habitat was enhanced by controlling non-native invasive vegetation, removing trees and shrubs to maintain meadows and protect larval food plants, and establishing larval food and adult nectar plants by direct seeding or propagation and outplanting. Keywords: enhancement; invasive species; management; restoration.

- [96] Hays, D.W., Potter, A.E., Thompson, C.W., Dunn, P. V, 2000. Critical habitat components for four rare south Puget Sound grassland butterflies. Final report, Washington Department of Fish and Wildlife and The Nature Conservancy, Olympia, WA, 38 pp.

*Describes results of a two-year study of life history requirements for Taylor's checkerspot and three other rare Puget Sound butterflies to provide information on relationships between butterflies, grassland plants, and microhabitats to enhance prairie restoration efforts. Designed to capture data for two populations for each species; low butterfly numbers made this impossible. Focuses on adult feeding behavior and habitat selection; documents species used for oviposition, as larval food sources, and nectar species; assesses habitat quality by quadrats, estimating cover of native fescue, other native and non-native grasses and forbs, and open space, including cryptogams. Checkerspot surveys were on the 13th Division Prairie at Fort Lewis; nectar observations were so few that no vegetation data were collected and evaluations were not made; reports *Camassia quamash* used most often, *Lomatium triternatum* was the secondary nectar source. Documents the use of edge habitat where partial shade extends resources. Records oviposition on *Plantago lanceolata* and *Castilleja hispida*; suggests augmenting *Castilleja* populations at checkerspot sites. Recommends that management and restoration efforts emphasize areas with abundant nectar species, especially along edges between grasslands and trees. Stresses that butterflies need access to resources, thus controlling tall non-native grasses and Scotch broom is essential. Keywords: *Euphydryas editha taylori*; habitat; invasive species; prairie; nectar resources; host plants.*

- [97] Hellmann, J.J., 2002. The effect of an environmental change on mobile butterfly larvae and the nutritional quality of their hosts. *Journal of Animal Ecology* 71, 925–936.

*Examines interactions between Bay checkerspot larvae and host plants *Plantago erecta*, *Castilleja exserta*, and *C. densiflora* to assess 1) larval food plant choice and dependence of diet on oviposition; 2) host nutritional differences; and 3) impact on larval survivorship and growth of conditions that accelerate host plant death (i.e., temperature-caused senescence). Shows larvae used hosts independent of natal plants, ate a varied diet, foraged widely, and steadily increased*

consumption of nutritionally-variable but longer-lasting C. exserta; and larvae using both host plants enjoyed a survivorship advantage. Results suggest that larval diet choice and movement may be an adaptive strategy for foraging on declining food resources. Keywords: Euphydryas editha bayensis; host plant phenology; host plant preference; larval host plant use.

- [98] Hellmann, J.J., Byers, J.E., Bierwagen, B.G., Dukes, J.S., 2008. Five potential consequences of climate change for invasive species. *Conservation Biology* 22, 534–43.

As a starting point for future research, based on a conceptual model of invasion pathways and transitions between invasion stages, identifies 5 possible consequences of climate change (both temperature and precipitation) for invasive species that involve alteration of 1) mechanisms of transport and introduction; 2) climatic constraints; 3) distribution and 4) impact of existing invasives; and 5) effective management strategies. Keywords: climate change; invasive species.

- [99] Henry, E.H., Schultz, C.B., 2012. A first step towards successful conservation: understanding local oviposition site selection of an imperiled butterfly, mardon skipper. *Journal of Insect Conservation*, online early.

Investigates oviposition site selection, sampling vegetation at oviposition and random locations and measuring habitat variables with respect to the oviposition plant, vegetation structure, and vegetation cover; analysis revealed site selection based on habitat structure; eggs laid in small bunchgrass tufts in sparsely vegetated areas of the prairie. Results then used to assess habitat quality at a restored site with reintroduction potential, measuring variables most important for oviposition at occupied site and proposed reintroduction site. Assessments indicated habitat quality differences between sites; suggested further habitat management required prior to reintroduction; stressed importance of understanding local habitat use of a rare species; increased ability to target management of habitat for reintroduction. Keywords: grassland butterflies; habitat quality; host plant preference; oviposition; reintroduction.

- [100] Holdren, C.E., Ehrlich, P.R., 1982. Ecological determinants of food plant choice in the checkerspot butterfly *Euphydryas editha* in Colorado. *Oecologia* 417–423.

*Demonstrates — for this checkerspot population — that the primary factor in larval host plant preference (for *Castilleja linariifolia* vs. *C. chromosa* or *Penstemon strictus*) is not nutritional value or enhanced taste, but environmental characteristics including phenology, late availability due to drought tolerance, and potentially its response to mammalian herbivory (less consumed; regrowth is fast and dense). A Nevada population, however, feeds exclusively on *C. chromosa* although *C. linariifolia* is abundant. Keywords: *Euphydryas editha* spp.; host plant phenology; host plant preference; larval host plant use.*

- [101] Holl, K.D., Crone, E.E., Schultz, C.B., 2003. Landscape restoration: moving from generalities to methodologies. *BioScience* 53, 491.

Review of large-scale (i.e., extensive, expensive) restoration efforts. Relevant conclusions: success varies substantially between sites—attributed in part, to differences in hydrology, microclimate,

movements of biota, disturbance regimes; comparison of predictions of multiple models, followed by empirical testing is desirable; a suite of statistical techniques used in other branches of ecology to address lack of replication can be used in restoration; academic ecologists are encouraged to test large-scale processes in natural systems —can be facilitated by targeted funding to scientific studies coupled with management actions, rather than either/or funding. Restoration efforts more useful to ecological understanding if long-term monitoring data are collected using standardized methods, detailed restoration protocol records are kept, and scientists are consulted in the early stages of planning. Capitalizing on existing collaborations between academic researchers and management personnel will improve understanding of landscape processes, ecosystem dynamics, and successful restoration. Keywords: landscape scale; restoration.

- [102] Howe, H.F., 1994. Managing species diversity in tallgrass prairie: assumptions and implications. *Conservation Biology* 8, 691–704.

Raises a reference ecosystem question: “what is being conserved or restored?” – a prairie climax community, multiple historically plausible grasslands, or maximized species diversity? Recommends experimental approach, varied regimes of prescribed fire and grazing to promote species diversity, more realistically represent historical grassland communities (cf. Fitzpatrick, 2004, prairie ecosystem differences). Keywords: biodiversity; grasslands; prairie; restoration.

- [103] Hulme, P.E., 2006. Beyond control: wider implications for the management of biological invasions. *Journal of Applied Ecology* 43, 835–847.

Suggests three successive steps, prevention, eradication, control, as best management practices for invasive species to restore ecosystems, preserve or re-establish native biodiversity and function. Recommends comprehensive approach that considers the 1) expected impacts; 2) technical options available; 3) ease with which the species can be targeted; 4) risks; 5) likelihood of success; and 6) extent of public concern and stakeholder interest. In addition to targeting an individual species, management must incorporate an appreciation of other environmental pressures, landscape structure, role of existing management activities and restoration efforts. Keywords: biodiversity; invasive species; management; restoration.

- [104] Huntzinger, M., 2003. Effects of fire management practices on butterfly diversity in the forested western United States. *Biological Conservation* 113, 1–12.

Tests adult butterfly response to reintroduction of fire. Species richness and diversity monitored on replicated transects; compared with controls, 2–3 times as many butterfly species occur in forest burns, 13 times as many in fuel breaks, and twice as many in riparian burns. Area and density of forest canopy gaps after fires explained most variation in butterfly richness, likely related to increase in host plant availability stimulated by fire. Results suggest reintroduction of diverse fire management methods will benefit butterfly diversity. Management implications for balds, habitat in a forest matrix. Keywords: biodiversity; butterfly distribution; fire.

- [105] Ibbe, M., Milberg, P., Tunér, A., Bergman, K.-O., 2011. History matters: impact of historical land use on butterfly diversity in clear-cuts in a boreal landscape. *Forest Ecology and Management* 261, 1885–1891.

Demonstrates that historical land-use in remnant plant communities leaves a legacy that can affect butterfly diversity in later clear-cuts over a timescale of a full tree rotation of 70–90 yrs. Clear-cuts historically managed as meadows were: 1) richer in individuals, 2) more species-rich, 3) contained many more grassland specialists than clear-cuts with history as forest. Replanting clear-cuts on land that was previously meadows with deciduous trees or allowing the forest to regenerate naturally would preserve a greater diversity of habitats. Management implications for balds, habitat in a managed forest matrix. Keywords: butterfly conservation; restoration.

- [106] Isaac, N.J.B., Girardello, M., Brereton, T.M., Roy, D.B., 2010. Butterfly abundance in a warming climate: patterns in space and time are not congruent. *Journal of Insect Conservation* 15, 233–240.

Compares predictions of two different butterfly distribution models under similar climate change scenarios for northern temperate climates. Space-for-time substitutions are used by climate envelope and species-distribution models; correlations between present-day occurrences and environmental gradients are projected onto future conditions to predict future distributions. With data from ~10,000 populations, this model predicts domination by a few species and severe declines of all others. Results were compared with a time-based population model of Roy et al. (2001) that predicted generally positive population responses to warming climate due to lower winter mortality, rapid development, extended flight seasons, and shifts to multivoltinism. Concludes that a better assessment of local adaptations is essential for more accurate predictions. Keywords: butterfly distribution; climate change; model.

- [107] James, D.G., Nunnallee, D., 2012. Life histories of Cascadia butterflies. Oregon State University Press, Corvallis, OR, 447 pp.

Reference. Unique among regional treatments in its illustrations of life stages, egg through adult. Brief descriptions of adult and immature stages; general discussion. Keywords: butterfly biology.

- [108] James, J.J., Smith, B.S., Vasquez, E.A., Sheley, R.L., 2010. Principles for ecologically based invasive plant management. *Invasive Plant Science and Management* 3, 229–239.

Synthesizes current knowledge of the mechanisms and processes that drive plant community succession into ecological principles for ecologically based, invasive plant management (EBIPM). Demonstrates how ecological principles can be incorporated into a holistic EBIPM framework that includes necessary steps to assess needs, formulate strategies, identify appropriate tools and actions, and quantify and adjust outcomes for invasive plants. Keywords: invasive species; management; restoration.

- [109] James, J.J., Svejcar, T., 2010. Limitations to postfire seedling establishment: the role of seeding technology, water availability, and invasive plant abundance. *Rangeland Ecology and Management* 63, 491–495.

Experiments compared hand-seeding, drill-seeding and unseeded controls; portions of grassland plots were weeded and given supplemental water; invasive plant abundance was generally low. Substantial increases in seedling establishment were achieved with moderate improvements in seeding technology. Keywords: fire; invasive species; management; restoration; seed.

- [110] Junker, M., Schmitt, T., 2009. Demography, dispersal and movement pattern of *Euphydryas aurinia* (Lepidoptera: Nymphalidae) at the Iberian Peninsula: an alarming example in an increasingly fragmented landscape? *Journal of Insect Conservation* 14, 237–246.

Examines effects of habitat structure and heterogeneity on dispersal behavior and population densities; chosen as an indicator to reveal regional effects and consequences of fragmentation to provide conservation guidance. E.aurinia ssp. have colonized a wide variety of habitats; most populations are declining due to habitat loss; study populations not yet threatened but beginning to be affected by land-use changes. Keywords: biodiversity; butterfly conservation; dispersal; Euphydryas spp.; fragmentation; habitat heterogeneity; habitat structure; metapopulation.

- [111] Kaye, T., Menke, C., Michaud, M., Schwindt, R., Wischert, L., 2010. Benton County Prairie Species Habitat Conservation Plan. Prepared for Benton County, OR, submitted to U.S. Fish and Wildlife Service and Oregon Department of Agriculture, Institute for Applied Ecology, Corvallis, OR, 160 pp. + appendices.

HCP helps Benton County to comply with endangered species regulations; protects at-risk species through long-term planning, avoiding and minimizing impacts, and mitigating for losses. Vision is to achieve long term viability of rare species populations, compatible with essential public services, public and conservation land management, home, farm and forest construction on private lands. Incidental take permit in effect for 50 years covers Fender's blue butterfly, Taylor's checkerspot butterfly, Willamette daisy, peacock larkspur, Kincaid's lupine, Nelson's checkermallow and Bradshaw's lomatium. Keywords: ESA; Euphydryas editha taylori; habitat conservation; HCP; prairie.

- [112] Kaye, T.N., Stanley, A.G., Ross, D., 2011. Dispersal behavior and habitat variation of Taylor's checkerspot butterfly: Progress report. Institute for Applied Ecology and U.S. Fish and Wildlife Service, Corvallis, OR and Lacey, WA, 27 pp.

Project devised to provide information about Taylor's checkerspot habitat and dispersal behavior range-wide to support management of existing populations, habitat connectivity, reserve design, and overall recovery. Observations of dispersal behavior investigated movements through habitat patches and responses to edges of four different populations, one in OR and three in WA. Edges were meadow/forest or prairie/forest boundaries, roads, patches of shrubs at the edge of prairies, or slope breaks; forest edges were the most substantial barriers. Physical and biological

attributes of habitat were measured at nine sites; the matrix of data represented habitat from a broad latitudinal and elevational gradient across the range; it was summarized in two different ways using ordination to assess differences between sites and regions: 1) using raw species data to document differences in plant communities; and 2) combining species into functional groups to determine variation in overall vegetation structure. Results indicate Taylor's checkerspot populations occur in plant communities that differ in terms of species and primary functional groups; bare ground and litter are variable and do not appear to be strong determinants of habitat quality; and primary host and nectar plants vary, indicating the butterfly may be able to adapt to new environments. Keywords: dispersal; habitat patch; habitat quality.

- [113] Kennedy, T.A., Naeem, S., Howe, K.M., Knops, J.M.H., Tilman, D., Reich, P., 2002. Biodiversity as a barrier to ecological invasion. *Nature* 417, 636–638.

Investigates mechanisms that regulate susceptibility to invasion in plant communities under the diversity resistance hypothesis (i.e., diverse communities are highly competitive, easily resist invasion). Demonstrates that greater species diversity in experimental grassland plots increases crowding and species richness in localized plant neighborhoods used to sample communities; and also reduces the number, size, and total cover of invading plants, independent of the amount of bare ground. Suggests that local biodiversity enhances invasion resistance. Keywords: biodiversity; experiment; grasslands; invasive species; management; plant community.

- [114] Kettenring, K.M., Adams, C.R., 2011. Lessons learned from invasive plant control experiments: a systematic review and meta-analysis. *Journal of Applied Ecology* 48, 970–979.

Review of invasive plant control experiments (through 2009). Examines success of control efforts and what research translates best into successful restoration application. Identifies common limitations to successful control including minimal focus on revegetation with natives after invasive removal; limited spatial and temporal scope of invasive plant control research; and incomplete evaluation of costs and benefits associated with invasive species management actions, including impacts on native species; suggests management can be better informed if researchers specifically address these limitations and involve managers in research through adaptive management. Relevant in part because PNW researchers and land managers are ahead of the curve on this issue. Keywords: invasive species; management; meta-analysis; restoration.

- [115] Krämer, B., Kämpf, I., Enderle, J., Poniowski, D., Fartmann, T., 2012. Microhabitat selection in a grassland butterfly: a trade-off between microclimate and food availability. *Journal of Insect Conservation*, online early.

Assesses microhabitat preferences for oviposition to define habitat quality for grassland butterfly using two hosts; as at many sites for many species, environmental conditions vary depending on selected host plant, oviposition pattern is a trade-off between microclimate and food availability (e.g., prefers warm, dry conditions; but in warm-weather years, the preferred host desiccates). Keywords: grassland butterflies; habitat quality; oviposition; microclimate.

- [116] Krämer, B., Poniowski, D., Fartmann, T., 2012. Effects of landscape and habitat quality on butterfly communities in pre-alpine calcareous grasslands. *Biological Conservation* 152, 253–261.

Investigates effects of habitat area, functional connectivity, landscape context and habitat quality on species richness and density of grassland butterfly communities; results show impact of habitat quality is greater than landscape effects. Contrary to expectations, surrounding forest vs. non-habitat grassland increased species richness of habitat specialists in the habitat patch. Keywords: butterfly distribution; connectivity; fragmentation; grassland butterflies; habitat patch; matrix.

- [117] Krauss, J., Bommarco, R., Guardiola, M., Heikkinen, R.K., Helm, A., Kuussaari, M., Lindborg, R., Ockinger, E., Pärtel, M., Pino, J., Pöyry, J., Raatikainen, K.M., Sang, A., Stefanescu, C., Teder, T., Zobel, M., Steffan-Dewenter, I., 2010. Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels. *Ecology Letters* 13, 597–605.

Results indicate management strategies maintaining fragmented habitats are insufficient; time-delayed extinctions and co-extinctions will lead to further biodiversity loss in the future. Keywords: extinction debt; fragmentation; grassland butterflies; plant community

- [118] Kuefler, D., Haddad, N.M., 2006. Local versus landscape determinants of butterfly movement behaviors. *Ecography* 29, 549–560.

Examines butterfly movement across different scales; tests relative importance of landscape attributes and local habitat attributes related to food plants and plants influencing habitat structure; across species, tests relative importance of organism size and habitat specificity to explain response variation. Responses to landscape features more universal than responses to local features; help explain landscape-level variation in population distribution among species. Keywords: butterfly distribution; landscape scale.

- [119] Kuefler, D., Hudgens, B., Haddad, N.M., Morris, W.F., Thurgate, N., 2010. The conflicting role of matrix habitats as conduits and barriers for dispersal. *Ecology* 91, 944–950.

Addresses how landscape features affect dispersal by quantifying two behaviors that determine dispersal rates across complex landscapes, conductivity of major habitat types and behavior at boundaries between habitat types; finds strong negative relationship between probability of entering a habitat and speed of movement through it; notes that determining connectivity within complex landscapes is difficult if habitats that facilitate dispersal differ from those where animals normally are found or enter. Keywords: connectivity; habitat; matrix.

- [120] LaBar, C.C., Schultz, C.B., 2012. Investigating the role of herbicides in controlling invasive grasses in prairie habitats: effects on non-target butterflies. *Natural Areas Journal* 32, 177–189.

Examines non-target effects of grass-specific herbicide on four grassland butterfly species and their habitat resources on a JBLM prairie. Results indicate herbicide had little to no effect on flower species, larval success, or oviposition, but adult butterflies spent significantly less time in sprayed plots than in controls. Suggests more research on larval survival and adult behavior, cumulative effects and combination treatment (i.e., herbicides and fire), duration of treatment regimens. Recommends rotation of treatment areas to ensure adequate refugia so individuals from unsprayed areas can recolonize the habitat; assumes complete mortality in sprayed areas. Keywords: butterfly conservation; herbicide; herbicide effects non-target; invasive species.

- [121] Langenfeld, C., 2009. The value of ecological restoration volunteer programs: a case study in western Washington State. M.E.S. Thesis, The Evergreen State College, Olympia, WA, pp. vi + 1–111.

Focuses on the South Sound Prairie Volunteer Group, who conduct ecological restoration work on public lands, under the management of a professional environmental organization. Reasons that successful initiatives that connect people to their natural environment and inspire stewardship of the land provide multiple benefits for everyone who helps to achieve local restoration goals: land managers, grassroots volunteers, professional environmental organizations, and government agencies. Argues, convincingly, that lessons from this case study can provide beneficial guidance to other ecological restoration efforts. Keywords: conservation; prairie; restoration; stewardship.

- [122] Launer, A.E., Murphy, D.D., 1994. Umbrella species and the conservation of habitat fragments: a case of a threatened butterfly and a vanishing grassland ecosystem. *Biological Conservation* 69, 145–153.

*Describes how the conservation umbrella over an ESA-listed species extends protection for a butterfly and its habitat to all other elements of a fragmented grassland community threatened by non-native plant species and human development. Examines distribution of Bay checkerspot butterfly and native plants across 27 habitat patches to determine the butterfly's value as an 'umbrella species'; finds 98% of native spring-flowering plant species receive some measure of protection. Taylor's checkerspot and streaked horned lark listing would strengthen protection for listed, unlisted, and undiscovered prairie plants and animals. Keywords: conservation; prairie; ESA; *Euphydryas editha bayensis*; habitat conservation; habitat fragmentation.*

- [123] Lawrence, B.A., Kaye, T.N., 2006. Habitat variation throughout the historic range of golden paintbrush, a Pacific Northwest prairie endemic: implications for reintroduction. *Northwest Science* 80, 140–152.

Like Taylor's checkerspot, golden paintbrush historically inhabited grasslands that extended from western OR through WA and BC; recovery criteria require new populations throughout the species' historic range. Compares vegetation and soil characteristics of southern recovery sites with extant Puget Trough populations; soils are ecologically distinct, related to differences in geology, climate, ocean proximity, and land-use history, leading to plant community divergence. Suggests using a plant functional group approach to compare vegetation assemblages among sites, which allows comparison of taxonomically distinct communities that share ecological

characteristics. Functional groups can define forb variance in checkerspot habitat. Keywords: Castilleja levisecta; forbs; plant community; prairie; reintroduction.

- [124] Lawrence, B.A., Kaye, T.N., 2008. Direct and indirect effects of host plants: implications for reintroduction of an endangered hemiparasitic plant (*Castilleja levisecta*). *Madroño* 55, 151–158.

Examines effect on hemiparasitic Castilleja levisecta of different host combinations in the greenhouse and in the field. Results emphasize the importance of basing conservation decisions on experimental research conducted under conditions similar to those of the intended application, as greenhouse results were a poor predictor of field performance. Keywords: Castilleja levisecta; plant community; reintroduction.

- [125] Leach, M.K., Givnish, T.J., 1999. Gradients in the composition, structure, and diversity of remnant oak savannas in southern Wisconsin. *Ecological Monographs* 69: 353–374.

Examines composition, structure, and horizontal patterning of lower layers of grassland plant communities; findings have implications for restoration that could extend to west coast prairies adjusted for perennial vs. annual grasses. Contrary to previous reports, communities are forb dominated, except sandiest or sunniest microsites. Diverse distributions of plants with different adaptations for energy capture, large variation among sites in soil texture and within sites in ground-layer light regime (photon flux density estimated from hemispherical photographs) suggest that partitioning of light and soil gradients maintains high plant diversity within mosaic communities. Keywords: biodiversity; forbs; plant community; prairie; restoration.

- [126] Leon-Cortes, J.L., Lennon, J.J., Thomas, C.D., 2003. Ecological dynamics of extinct species in empty habitat networks. 2. The role of host plant dynamics. *Oikos* 102, 465–477.

Explores relative effects of host plant dynamics and butterfly-related parameters on butterfly persistence to determine whether a reintroduction scheme might succeed; considers an empty habitat network where a rare butterfly was extirpated in 1939. Visits surviving southern populations to assess host plant use, calibrate habitat suitability and carrying capacity in the empty network. Data used to deduce that a portion (~20%) of the northern host plant network was highly suitable for oviposition. Model system persisted in simulated metapopulations in the empty network; host plant dynamics appeared to be primary determinant of extirpation. Persistence after reintroduction likely to be successful if carried out in conjunction with host plant management. Keywords: butterfly conservation; host plant; metapopulation; reintroduction.

- [127] Linders, M.J., 2007. Development of captive rearing and translocation methods for Taylor's checkerspot (*Euphydryas editha taylori*) in south Puget Sound, Washington. 2006–07 Annual Report. Washington Department of Fish and Wildlife, Olympia, WA, 32 pp.

*Explains that the primary goal of this project is to reduce the probability of extinction of Taylor's checkerspot in south Puget Sound by developing captive rearing and translocation techniques, and using experimental releases to learn about potential limiting factors. Activities relevant to habitat enhancement included measurements of relative growth and survival of pre-diapause larvae on two different host plants: those fed *Castilleja hispida* weighed less at initiation of diapause than those fed *Plantago lanceolata*, with no statistical difference in survival rate; concludes *Plantago* will be an important component at translocation sites to maximize chances of survival but native host plants may also be suitable. Tests of egg translocation by wild females established both hosts were recognized although only *Plantago* is present in large quantities at their source site. Release of >600 pre-diapause larvae onto plots with both hosts available and of suitable quality as assessed by stem count and % cover produced poor results; only 6 larvae were located post-diapause, thought to be due to both very dry conditions at the time of release and the experimental strategy of releasing them separately rather than in groups; suggests earlier release dates and maintaining cohorts. Another release used post-diapause larvae and survival rates were low. Keywords: butterfly conservation; data; *Euphydryas editha taylori*; host plant preference; reintroduction.*

- [128] Linders, M.J., 2009a. Development of captive rearing and translocation methods for Taylor's checkerspot in south Puget Sound. 2007–2008 ACUB Project Progress Report. Washington Department of Fish and Wildlife, Olympia, WA, 12 pp.

*Project goal is to establish new populations of Taylor's checkerspot in south Puget Sound and reduce extinction likelihood. Activities relevant to habitat enhancement include a zoo experiment with post-diapause larvae to evaluate host plant quality: to test cut vs. live plants during captive-rearing larvae were provided with *Plantago lanceolata* and native *Castilleja hispida*, *Collinsia parviflora* and *Plectritis congesta*; presumably they ate them all. Results indicate those fed cut plants had a significantly higher likelihood of entering a second diapause; those fed live plants were more likely to pupate. Keywords: butterfly conservation; data; *Euphydryas editha taylori*; host plant preference; reintroduction.*

- [129] Linders, M.J., 2009b. Development of captive rearing and translocation methods for Taylor's checkerspot in south Puget Sound. 2009 ACUB Project Progress Report. Washington Department of Fish and Wildlife, Olympia, WA, 9 pp.

Project goal is to establish new populations of Taylor's checkerspot in south Puget Sound and reduce extinction likelihood. Activities relevant to habitat enhancement relate to release and monitoring of captive-reared post-diapause larvae: prior to release of ~750 at each site in March, nectar resources and ground cover were assessed at two plots at three release sites, Scatter Creek North, Scatter Creek South (SCS), and Pacemaker Airstrip on JBLM; nectar resources were enhanced in one plot the prior fall and the second was a control. During the 2009 flight season, nectar abundance and habitat variables associated with adults were assessed at transect and distance-sampling scales to detect similarities and differences between plots, with an emphasis on butterfly behavior; at two sites with trees, behavior near trees was recorded. Few adults were observed, however; two adults were observed at Scatter Creek North, and one at Pacemaker Airstrip. At SCS, distance sampling surveys (n=7) recorded 48 adults, with a

maximum of 19 during a single survey; behaviors recorded suggest habitat recognition. At all sites, butterflies were attracted to lone conifers. Due to captive-breeding success, a release of ~5,400 pre-diapause larvae was made in dense host plant patches at SCS and Range 50 in June. Keywords: *Euphydryas editha taylori*; butterfly conservation; data; enhancement; host plant; nectar resources; reintroduction.

- [130] Linders, M.J., 2011. Development of captive rearing and translocation methods for Taylor's checkerspot in south Puget Sound: 2009–2010 and an update for 2010–2011. 2010 ACUB Project Progress Report. Washington Department of Fish and Wildlife, Olympia, WA, 15 pp.

*Project goal is to establish new populations of Taylor's checkerspot in south Puget Sound and reduce extinction likelihood. Activities relevant to habitat enhancement include observations of a flight season at Scatter Creek South (SCS), evidence for on-site reproduction. Searches for pre-diapause larvae at SCS and Range 50 indicated reproduction occurred at both sites, and both *Plantago lanceolata* and *Castilleja hispida* were used for oviposition. Release plot selection is based on a qualitative assessment of host plant abundance; with secondary consideration given to nectar abundance and diversity; general prairie quality a factor. Sites with open ground, lower grass and moss density, some nectar and host plants selected; to increase habitat quality in ~15 x 30m plots *Plantago* are added to insure a minimum of one mature plant per 1–3 post-diapause larvae; nectar spp. are enhanced by planting plugs or seeding desirable spp. (e.g., *Lomatium* spp., *Balsamorhiza deltoidea*, and *Armeria maritima*), with invasive species control for Scotch broom or grasses as needed. In March, ~2,000 post-diapause larvae were released in dense host plant patches at SCS and Range 50 only; three enhancement sites, SCS, SCN, and Pacemaker, were monitored using distance sampling. Keywords: *Euphydryas editha taylori*; butterfly conservation; data; enhancement; host plant; nectar resources; reintroduction.*

- [131] Linders, M.J., 2011. Captive rearing and translocation of Taylor's checkerspot in south Puget Sound: 2010–2011. 2011 ACUB Project Progress Report. Washington Department of Fish and Wildlife, Olympia, WA, 22 pp.

*Project goal is to establish new populations of Taylor's checkerspot in south Puget Sound and reduce extinction likelihood. Sixth year of multi-year recovery project; results to date for captive rearing and translocation portions of the project are summarized and include analyses of 2010 distance sampling data for all reintroduction sites (SCS, R50, PCM, and SCN) and raw data for R76 source site. Habitat enhancement at release plots at SCS and Range 50 included seeding larval hosts *Collinsia parviflora*, *Plectritis congesta* and *Castilleja hispida*; planting or seeding nectar sources *Lomatium* spp., *Balsamorhiza deltoidea*, and *Armeria maritima*; with invasive species control for Scotch broom or grasses as needed. New activities highly relevant to habitat enhancement include quantifying the percent cover of functional plant groups in release plots (see Table 5, e.g., host by species, non-host forb, bunchgrass, moss, fern, bare ground, rock) and the frequency of host plants (see Table 6, host plant frequency per m²). Keywords: *Euphydryas editha taylori*; butterfly conservation; data; enhancement; host plant; nectar resources; reintroduction.*

- [132] Linders, M.J., 2012. Work plan for Taylor's checkerspot captive rearing and reintroduction in 2012. Washington Department of Fish and Wildlife, Olympia, WA.

*Report details field and lab methods; three items are critically relevant to habitat enhancement: 1) Criteria for selection of reintroduction sites and for enhancement of those sites; 2) Obtain measures of habitat condition and host plant availability during the post-diapause feeding period; and 3) Monitor success of the reintroduction. Criteria for site selection and enhancement have evolved over the life of the project and have been addressed previously. Methods are detailed for sampling schemes first used in 2011 for assessment of release plots to quantify the percent cover of functional plant groups (e.g., host by species, non-host forb, bunchgrass, moss, fern, bare ground, rock) and the frequency of host plants (host plant frequency per m²). Success is monitored by documenting post-release persistence, evaluating short-term success based on adult abundance and reproduction; and long-term monitoring. Keywords: butterfly conservation; data; enhancement; *Euphydryas editha taylori*; habitat quality; host plant; plant community; rapid assessment; reintroduction; restoration.*

- [133] Linders, M.J., 2012. Captive rearing and translocation of Taylor's checkerspot in south Puget Sound: 2011–2012. 2012 ACUB Annual Progress Report. Washington Department of Fish and Wildlife, Olympia, WA, 42 pp.

*Notes that native seed resources became available for the first time in 2011, and production still lags behind what land managers need for restoration. Reports two new sites were selected for reintroduction, Pacemaker and Glacial Heritage Preserve; enhancements have been made as reported elsewhere; two sites have received multiple sequential releases of Taylor's checkerspot, Scatter Creek South (since 2007) and Range 50 (since 2009). An initial assessment of percent cover of vegetation functional groups (Table 1) and host plant abundance (Table 2) suggests all reintroduction sites appear comparable to occupied plots at Range 76 (extant site) although host plant quantities at Glacial Heritage Preserve may be lower than desired. Report includes mapped distance sampling data. Keywords: butterfly conservation; data; enhancement; *Euphydryas editha taylori*; habitat quality; host plant; plant community; rapid assessment; reintroduction; restoration.*

- [134] Linders, M., Olsen, G., Potter, A., 2009. Taylor's checkerspot habitat characteristics selected for oviposition on Range 76, Artillery Impact Area, Fort Lewis, Washington. Final ACUB Project Report. Washington Department of Fish and Wildlife, Olympia, WA, 20 pp.

*Reports on a project devised to gather data on habitat characteristics specific to oviposition sites in extant Taylor's checkerspot habitat. Data collected using a stratified sampling design based on pre-existing host plant cover data at two spatial scales that relate to oviposition and small plots. Data includes vegetation cover, host plant counts, distance to nearest nectar and host plant, and condition of inflorescences at used and unused plots. Three sampling schemes, random, systematic, and haphazard, were used to locate small plots. Notes a late, wet spring delayed data collection and ~45% of what had been anticipated was collected; conclusions were that females are capable of identifying *Plantago* patches even within areas with less *Plantago* overall. Recommendations*

that could inform future habitat selection studies are detailed and drawn from multiple studies. Keywords: data; Euphydryas editha taylori; habitat quality; host plant; restoration.

- [135] Liu, W., Wang, Y., Xu, R., 2006. Habitat utilization by ovipositing females and larvae of the marsh fritillary (*Euphydryas aurinia*) in a mosaic of meadows and croplands. *Journal of Insect Conservation* 10, 351–360.

Assesses effects of mixed land use on butterfly occurrence. Examines habitat use of ovipositing females and larvae within a small metapopulation. Importance of habitat type varied by life stage: cultivated land important for eggs and pre-diapause larvae, due to female preference for large-sized host plants; meadows important for development of post-diapause larvae; implies patchy land use typical of traditional agriculture facilitates long-term persistence. Keywords: butterfly conservation; Euphydryas spp.; habitat patch; host plant preference; oviposition.

- [136] Longcore, T., Mattoni, R., Pratt, G.F., Rich, C., 1997. On the perils of ecological restoration: lessons from the El Segundo blue butterfly, in: Keeley, J.E. (Ed.), 2nd interface between ecology and land development in California, Occidental College, 6 pp.

Argues that ecological restoration goals should be the preservation of biodiversity in historically accurate and historically complete systems that require minimal human management. Illustrates critical dangers affecting target butterfly species when historical inaccuracy, ecotype conversions, lack of ecological redundancy, and the use of non-local native plant ecotypes affect the integrity of regional conservation efforts. Keywords: butterfly conservation; host plant; restoration.

- [137] Longcore, T., Murphy, D.D., Deutschman, D.H., Redak, R., Fisher, R., 2003. A management and monitoring plan for Quino checkerspot butterfly (*Euphydryas editha quino*) and its habitats in San Diego County, Advisory Report to the County of San Diego, pp. iii + 1–51.

Presents a monitoring and management plan for Quino checkerspot, once abundant in southern California and northern Baja California, now extirpated from most of its historical range, but present in areas where it was thought to have disappeared. Notes a biological lesson learned: the butterfly can survive environmental challenges by sustaining in diapause for years. Keywords: butterfly conservation; ESA; Euphydryas editha quino; habitat conservation; monitoring.

- [138] Longley, M., Sotherton, N.W., 1997. Factors determining the effects of pesticides upon butterflies inhabiting arable farmland. *Agriculture, Ecosystems & Environment* 61, 1–12.

Discusses accidental or intentional contamination of butterflies from pesticide application in farmland habitats. Reviews early (1997) literature on effects of insecticides and herbicides upon Lepidoptera (e.g., direct mortality, sublethal changes in fecundity and longevity, removal of adult nectar and larval host plants), factors determining exposure and susceptibility to particular compounds (e.g., chemical properties of the compound, intrinsic susceptibility and species-dependent ecological factors determining behavior and dispersal). Could inform newer site-species-product-specific research. Keywords: butterfly conservation; herbicide effects non-target.

- [139] Looney, C., Caldwell, B.T., Eigenbrode, S.D., 2009. When the prairie varies: the importance of site characteristics for strategising insect conservation. *Insect Conservation and Diversity* 2, 243–250.

Recommends explicitly incorporating an invertebrate community–structure component to prairie conservation measures; recognizes variability within biological communities and patterns in associated with soil characteristics; supports other research on these topics and on species richness of insects and vascular plants in other fragmented grassland ecosystems; emphasizes importance of disturbance history. Relevant overall, and with respect to diapausing Taylor’s checkerspot larvae. Keywords: habitat conservation; invertebrate conservation; larval survival; prairie.

- [140] Maccherini, S., Bacaro, G., Favilli, L., Piazzini, S., Santi, E., Marignani, M., 2009. Congruence among vascular plants and butterflies in the evaluation of grassland restoration success. *Acta Oecologica* 35, 311–317.

Suggests the use of community composition of different taxa as a valuable tool for evaluation of restoration and management success. Three years after grassland restoration, larval host plants were significantly correlated with the composition of non-migratory butterflies and the butterfly community was significantly correlated with the entire plant community data set. Keywords: butterfly distribution; grasslands; plant community; restoration

- [141] MacDougall, A.S., Turkington, R., 2005. Are invasive species the drivers or passengers of the change in degraded ecosystems? *Ecology* 86, 42–55.

Examines impact of two invasive perennial grasses on community structure in a fragmented and fire-suppressed BC oak savanna. Tests alternative models: whether invasives drive change (i.e., invaded communities are highly interactive; natives are limited or excluded by competition from exotic dominants) or are passengers (i.e., invaded communities are structured by noninteractive factors like environmental change or dispersal limitation that constrain exotics less). Reduction and removal treatments conducted at different seasons, soil depths; seed addition tested dispersal limitation vs. competition. Forbs and woody plants functionally distinct from grasses responded most significantly to treatments; suggests relative abundance influenced by trade-offs relating to environmental conditions (i.e., long-term fire suppression) more than traits relating to resource capture which should most impact functionally similar species, points towards the passenger model as the underlying cause of exotic dominance, although combined effects (suppressive and facilitative) are substantial. Keywords: invasive species; grasslands; plant community.

- [142] MacDougall, A.S., Turkington, R., 2007. Does the type of disturbance matter when restoring disturbance-dependent grasslands? *Restoration Ecology* 15, 263–272.

Argues that reintroduction of fire is usually viewed as critical for grassland restoration, but its ecological necessity is often untested; fire may be irreplaceable because it suppresses dominant competitors, eliminates litter, and modifies resource availability; or, its impacts could be replaced by other disturbances that suppress dominants without risks associated with burning. Tests impacts of fire, cutting and raking, and weeding on two factors: controlling dominant invasive

grasses and increasing subordinate native flora. No significant difference found in a 5-year field experiment—all treatments as effective at suppressing exotics, increasing native plant growth; light is the primary limiting resource for many native species, each increased its availability. Effectiveness of disturbance for restoration depended more on site factors and timing than type of treatment; positive responses by native species were significantly greater on shallow soils but these areas had high native diversity prior to treatment. Likely not applicable to all disturbance-dependent ecosystems, but results emphasize importance of testing the effectiveness of alternative restoration treatments. Keywords: disturbance; fire; grassland; invasive species; restoration.

- [143] Mahmoud, A., Grime, J.P., 1976. An analysis of competitive ability in three perennial grasses. *New Phytologist* 77, 431–435.

Investigates competitive interactions between three perennial grasses by measuring effects of paired species upon each other. Under both productive conditions and severe N-stress, each pairing resulted in total elimination of one species; order of competitive ability was Arrhenatherum elatius > Agrostis tenuis > Festuca ovina. Suggests competitive abilities above and below ground are interdependent and covariable and that ability to compete for nutrients may be of relatively minor importance for [locally invasive] species colonizing naturally infertile soils. Keywords: bent grass; fescue; grasslands; invasive species; N-response; tall oatgrass.

- [144] Maret, M.P., Wilson, M.V., 2005. Fire and litter effects on seedling establishment in western Oregon upland prairies. *Restoration Ecology* 13, 562–568.

Reviews factors that affect seedling establishment on western prairies, most specific to plant litter (e.g., litter tends to depress germination and establishment, but also can conserve moisture which can promote seedling establishment during drought conditions; litter removal increases light penetration and temperature fluctuation, reduces pathogens and barriers to seedling emergence) and fire (e.g., canopy cover reduction; decreased competition; altering soil nutrients). Examines how fire used in restoration efforts affects litter and establishment of native and exotic forbs and grasses (sown after burning) at sites dominated by 1) non-native annual grasses; 2) non-native perennial grasses (particularly tall oatgrass); and 3) native bunchgrass. Where non-natives predominated, burning significantly improved establishment of native, but not non-native grasses; litter removal had a significant effect, often creating favorable microsites. At sites with primarily native bunchgrass, fire increased establishment of short-lived non-native species only — not the expected result. Suggests fire followed by seeding native species is effective as a restoration strategy at sites where exotics predominate but either treatment alone would not be productive. Keywords: fire; grasslands; invasive species; prairie; restoration; review; seeds.

- [145] Mattoni, R., Longcore, T., Novotny, V., 2000. Arthropod monitoring for fine-scale habitat analysis: a case study of the El Segundo sand dunes. *Environmental Management* 25, 445–452.

Demonstrates that a broad taxonomic approach that samples a range of arthropod communities can be used for habitat evaluation; supports the use of invertebrates for monitoring purposes in conservation biology. Arthropod community structure reflects disturbance history and species

assemblages differ between habitats; this can be used to evaluate success or failure of restorations as revegetated sites move closer towards undisturbed sites over time. Samples of ground-dwelling arthropods within prairie communities could be used to assess restoration progress (vs. success or failure) or could be used to assess subtle soil differences within and between sites to detect areas that are more likely to benefit from habitat enhancement, perhaps to select areas to concentrate additional host plants in conjunction with more knowledge of where larvae diapause. Keywords: grassland butterflies; invertebrate conservation; monitoring; restoration.

- [146] Mattoni, R., Pratt, G.F., Longcore, T., Emmel, J.F., George, J., 1997. The endangered Quino checkerspot butterfly, *Euphydryas editha quino* (Lepidoptera: Nymphalidae). *Journal of Research on the Lepidoptera* 34, 99–118.

*Reviews systematics and distribution; details butterfly natural history with references to applicable research on Bay checkerspot; discusses conservation planning. Quino checkerspot is distributed in extreme southern California and northern Baja California. Extirpated from most of its historical range, it was listed as federally endangered under ESA in 1997. Quino is not found in open grasslands, unlike Taylor's and Bay checkerspots; it occurs in patches and clearings within several fragmented plant communities (e.g. oak woodland, chaparral, coastal sage scrub, pinyon-juniper woodland); community structure rather than composition is critical. Keywords: butterfly conservation; ESA; *Euphydryas editha quino*; fire; habitat conservation; monitoring.*

- [147] McBride, C.S., Singer, M.C., 2010. Field studies reveal strong postmating isolation between ecologically divergent butterfly populations. *PLoS Biology* 8, e1000529.

*Checkerspot butterfly *Euphydryas editha* consists of numerous populations at different stages of adapting to different host plants. Examines two allopatric populations evolved to lay eggs on only one of two alternative host plants that grow closely intermingled, annual *Collinsia torreyi* and perennial *Pedicularis semibarbata*. Populations have diverged in 6 host-related traits, 2 larval (i.e., foraging height, performance) and 4 expressed in adult females (i.e., oviposition preference, preference for old or young *Collinsia* when only given that host, height of oviposition site and clutch size variability). Hybrids between populations show no differences in the lab, but in their interactions with host plants have intermediate traits that don't work well with either host, and they have reduced survival and reproduction. This situation is thought to be typical of divergence in populations at early stages of speciation, where there is ecological selection against hybrids. Keywords: *Euphydryas editha*; host plant preference; larval host plant use; oviposition.*

- [148] McIntire, E.J.B., Schultz, C.B., Crone, E.E., 2007. Designing a network for butterfly habitat restoration: where individuals, populations and landscapes interact. *Journal of Applied Ecology* 44, 725–736.

Argues that restoring habitat networks to ensure persistence of many at-risk species surviving in highly fragmented environments requires detailed knowledge of species behavior and landscape complexities. Presents a spatially explicit simulation model based on 14 years of data to assess the ability of potential restored landscapes to create persistent and connected populations for federally endangered Fender's blue butterfly in OR. Model improves upon previous metapopulation and

population models, supports earlier predictions about large patch persistence, expands inference to include connectivity and persistence of small patches, and finds emergent network properties, including stepping-stone patches, asymmetric connectivity and reciprocal effects of connectivity and population dynamics. Assuming no large disturbances, concludes that restoring all currently degraded and potentially available habitat patches to high quality native prairie would be sufficient for long-term persistence of the butterfly in the western OR study area. Keywords: connectivity; fragmentation; habitat; habitat patch; metapopulation; model; prairie; restoration.

- [149] McLaughlin, J.F., Hellmann, J.J., Boggs, C.L., Ehrlich, P.R., 2002. Climate change hastens population extinctions. *Proceedings of the National Academy of Sciences of the United States of America* 99, 6070–6074.

*Models two checkerspot populations to show that increasing variability of precipitation amplified butterfly population fluctuations, leading to accelerated extinctions. Notes few other extinction events have been linked mechanistically to climate change although predictions of climate-induced extinctions are supported by geographic range shifts corresponding to climatic warming. Keywords: butterfly population; climate change; *Euphydryas editha bayensis*; precipitation.*

- [150] Middleton, E.L., Bever, J.D., Schultz, P.A., 2010. The effect of restoration methods on the quality of the restoration and resistance to invasion by exotics. *Restoration Ecology* 18, 181–187.

Investigates effect of restoration method on plant community structure and reduction of exotic plant density. Compares 1) distributing seed over fallow fields and 2) planting established seedlings in combination with seeding with a naturally colonized post-agricultural field and remnant grassland. Finds greater resemblance to remnant grassland plant community (i.e., floristic quality, native species richness, and native diversity) with the introduction of seedlings during the first 4 years of restoration and negative correlation between native plant diversity and density of exotic plants in the restoration. Keywords: plant community; restoration.

- [151] Miller, J.C., Hammond, P.C., 2007. Butterflies and moths of Pacific Northwest forests and woodlands: rare, endangered, and management-sensitive species. USDA USFS Forest Health Technology Enterprise Team, Corvallis, OR, iii + 234.

Reference. Keywords: butterfly conservation; butterfly distribution.

- [152] Miskelly, J.W., 2004. Habitat requirements and conservation of the butterflies *Euchloe ausonides insulanus* (Pieridae) and *Euphydryas editha taylori* (Nymphalidae) in southwestern British Columbia.

Synthesizes information on the natural history of two butterfly species believed to be extirpated from BC, island large marble and Taylor's checkerspot, documents habitat requirements, and assesses feasibility of habitat restoration and reintroduction. Indicates that host and nectar plant density is likely not limiting for TCB at potential reintroduction sites, but host plants senesce too early to support butterfly population. Mesic areas where senescence would be delayed have been

eliminated by forest encroachment; reintroduction cannot succeed until habitat can be restored by conifer removal; experimental control has led to invasion of non-native species; recommends active reintroduction of native plants after tree removal. Keywords: butterfly conservation; Euphydryas editha taylori; habitat; invasive species; reintroduction; restoration.

- [153] Moles, A.T., Flores-Moreno, H., Bonser, S.P., Warton, D.I., Helm, A., Warman, L., Eldridge, D.J., Jurado, E., Hemmings, F.A., Reich, P.B., Cavender-Bares, J., Seabloom, E.W., Mayfield, M.M., Sheil, D., Djietror, J.C., Peri, P.L., Enrico, L., Cabido, M.R., Setterfield, S.A., Lehmann, C.E.R., Thomson, F.J., 2012. Invasions: the trail behind, the path ahead, and a test of a disturbing idea. *Journal of Ecology* 100, 116–127.

Review of invasion biology. Synthesis of conclusions: disturbance is a weak predictor of invasion; neither disturbance per se nor changes in disturbance regime explained > 7% of variation in the % cover or species richness contributed by introduced species (global data, 200 sites). Searches for traits that make ecosystems susceptible to invasion or species good invaders yield idiosyncratic results; suggests a greater range of data about introduced species, and communities and habitats they are invading is needed, or that it may never be possible to predict which species are likely to become problems based on traits alone. Keywords: disturbance; invasive species.

- [154] Morgenweck, M., 2003. Butterfly populations on Fort Lewis: a historic perspective. The Nature Conservancy, Olympia, WA, 30 pp. + appendices.

Illustrates the distribution over time of rare prairie-dependent butterfly species on Fort Lewis by using historical and recent survey data and multiple informational reports (i.e., databases for observations made 1937–1994 and extensive details from 1995–2003 survey reports) along with interviews with lepidopterists with extensive experience in the south Puget Sound region. Observes that not coincidentally, rare butterfly species on Fort Lewis are found near-exclusively on training areas protected from disturbance — either by live munitions on the ground on the AIA, or by Research Natural Area status (i.e., TA15's Triangle on the 13th Division Prairie; Johnson and Weir Prairies); reiterates previous suggestions that land managers prioritize efforts to maintain and enhance high-quality habitat (i.e., fescue-dominant, abundant nectar sources and less cover of invasive vegetation) based on an area's demonstrated ability to support butterfly populations. Concludes that for Taylor's checkerspot, however, habitat quality is not the only management consideration, given the disappearance of the species from other prairies in the south Puget Sound region. Notes that since the late-1990s population crash, surveyors hope butterflies have entered diapause if not observed, which may not be entirely unrealistic given an early spring flight season and access constraints that may preclude additional surveys. Keywords: butterfly population; butterfly conservation; data; habitat; habitat quality; monitoring; prairie.

- [155] Morgenweck, M., Dunn, P., 2003. Fort Lewis butterfly survey. The Nature Conservancy, Olympia, WA, 24 pp. + appendices.

Presents results of a well-coordinated comprehensive survey to determine distribution of prairie-dependent butterflies on Fort Lewis, with priority targets four rare species including Taylor's checkerspot; intended to serve as a baseline for locating butterfly populations by species, inform

management and habitat enhancement actions, and complement regional butterfly conservation and survey efforts. Early spring through summer surveys visited 13 prairies and observed 32 of ~48 species known from south Puget Sound. Taylor's checkerspots seen once; 33 observed in their previously documented location along the southwestern edge of the AIA; none were observed at other historic sites. Report discusses habitat at survey sites; includes survey schedule organized by prairie sector with survey dates highlighted by flight seasons, and mapped data. Keywords: butterfly population; butterfly conservation; data; habitat; habitat quality; monitoring; prairie.

- [156] Munguira, M.L., Martín, J., García-Barros, E., Viejo, J.L., 1997. Use of space and resources in a Mediterranean population of the butterfly *Euphydryas aurinia*. *Acta Oecologica* 18, 597–612.

Studies a large population of marsh fritillary butterflies in oak woodlands in central Spain; traditional land management includes charcoal production and extensive grazing by cattle and goats. Adult abundance was correlated with presence of larval food plants and was higher where woodland habitat met open areas with abundant nectar resources. Nectar sources used by adults were different in both study years and were correlated with the most abundant plants available during the flight period. Keywords: Euphydryas spp.; grazing; larval host plant use.

- [157] Münzbergová, Z., 2012. Seed density significantly affects species richness and composition in experimental plant communities. *PloS One* 7, e46704.

Demonstrates effects of seed density on species richness and composition in a series of experimental grassland communities composed of the same 44 perennials in the same proportions, established on 2 substrates using 3 different seed densities. Results show density (seed rain intensity) affected species richness at the beginning of the experiment; effects on composition persisted for the 3-year study period. Suggests seed addition experiments need to consider the amount of seed added so it reflects amounts naturally found in the field; seed density differences may explain variation in the composition of natural communities that cannot be attributed to habitat conditions. Keywords: forbs; grassland; plant community; seed.

- [158] Murphy, D.D., Launer, A.E., Ehrlich, P.R., 1983. The role of adult feeding in egg production and population dynamics of the checkerspot butterfly *Euphydryas editha*. *Oecologia* 56, 257–263.

Shows nectar feeding plays a critical role in Bay checkerspot butterfly fitness. Assesses effects of water, sugar, amino acids on reproduction and maintenance of body weight; water in nectar is usually the only moisture available for this species; water alone played no direct role. Amino acids in nectar lead to heavier eggs more likely to survive; carbohydrate intake increases body weight, egg production, and longevity in adult females. Females fed nectar produce more eggs late in the season than females that are not fed, and these larvae only reach diapause during very wet years, but this infrequent population increase may be essential for long-term survival. Notes Euphydryas spp. are most conservative with respect to adult resource needs because they emerge with mature eggs and can produce them in large numbers without feeding, thus if nectar use is

important in population dynamics for this butterfly it may be even more critical for others.
Keywords: butterfly biology; butterfly population; Euphydryas editha bayensis; nectar resource.

- [159] Murphy, D.D., Menninger, M.S., Ehrlich, P.R., 1984. Nectar source distribution as a determinant of oviposition host species in *Euphydryas chalcedona*. *Oecologia* 62, 269–271.

Shows that distribution of nectar resources affects the distribution of adult butterflies and their offspring. Egg distribution is constrained by the proximity of nectar sources to oviposition plants where those species are spatially separated. Suggests influence of nectar distribution may extend from the selection of individual host plants to the selection of oviposition host species. Keywords: butterfly distribution; Euphydryas spp.; host plant preference; nectar resources; oviposition.

- [160] Murphy, D.D., Weiss, S.B., 1988. Ecological studies and the conservation of the bay checkerspot butterfly, *Euphydryas editha bayensis*. *Biological Conservation* 46, 183–200.

Reviews the historical decline of the bay checkerspot butterfly, presents relevant ecological data obtained from 25 years of intensive research, and explains its conservation status: butterfly distribution has become highly restricted; development has destroyed its habitat; its numbers have been reduced by severe drought and the effects of other extreme weather events; and habitat loss and fragmentation has disrupted the ability of habitat patches to support populations as key topographic features are eliminated. Continued survival of the butterfly is dependent on a reservoir population which provides colonists for smaller habitat patches. Keywords: butterfly conservation; Euphydryas editha bayensis; fragmentation; habitat conservation; habitat patch.

- [161] Myers, J.A., Harms, K.E., 2009. Seed arrival, ecological filters, and plant species richness: a meta-analysis. *Ecology letters* 12, 1250–60.

Meta-analysis of 28 studies examines effects of seed dispersal and arrival on plant species richness under different intensities of ecological filters (e.g., limited resource availability, disturbance). Seed arrival increased species richness in a range of communities (>75% of studies are grasslands or savannas); effect was 70% higher in disturbed vs. undisturbed communities, suggesting that disturbance increases recruitment opportunities for immigrant species. In seed-addition experiments, effect positively correlated with species and functional diversity within the pool of added seeds (species evenness and seed-size diversity), primarily in disturbed communities. Provides experimental support for the general hypothesis that species pools and local environmental heterogeneity interactively structure plant communities. Keywords: assembly rules; biodiversity; disturbance; meta-analysis; plant community; seed.

- [162] New, T.R., Pyle, R.M., Thomas, J.A., Thomas, C.D., Hammond, P.C., 1995. Butterfly conservation management. *Annual Review of Entomology* 40, 57–83.

Review presents examples of conservation needs of butterflies as flagship taxa for invertebrate conservation. Highlights recent developments emphasizing species and habitat management based on sound ecology, examples of recovery plans, and studies in many countries that show the complexity of management needs for single species. Notes long-term studies on population

dynamics are the ideal background for understanding the parameters of successful management, and studies of the Bay checkerspot in CA can serve as the model for such projects. Keywords: butterfly conservation; Euphydryas editha bayensis; habitat; management.

- [163] Noland, S., Carver, L., 2011. Prairie landowner guide for western Washington. ESA and The Nature Conservancy, Olympia, WA, 72 pp. + appendices.

Provides information specifically about western Washington prairies in a well-designed, comprehensive and accessible format that effectively targets private landowners and encourages their participation in land stewardship, active management, and prairie restoration. Explains current best management practices to reduce impacts on prairie lands; applies to residential lands and to working lands that produce fiber or food; gives details on incentive programs and sources for resources and assistance. Keywords: habitat conservation; prairie; restoration; stewardship.

- [164] Nyamai, P.A., Prather, T.S., Wallace, J.M., 2011. Evaluating restoration methods across a range of plant communities dominated by invasive annual grasses to native perennial grasses. *Invasive Plant Science and Management* 4, 306–316.

Evaluates techniques for eastern PNW prairie restoration that include removing annual grasses and supplementing native species recruitment with native grass and forb seeds; assesses soil moisture and seed predation as specific factors affecting recruitment. Combination of broadcast herbicide application and seeding with mulching was most effective in reducing annual grasses and enhancing establishment of native grass species in predominately annual and mixed annual and perennial communities. Spot herbicide application was effective in predominately perennial communities; only seeding native species did not improve recruitment. Suggests decision support tool for each plant community. Keywords: invasive species; plant community; restoration

- [165] Olmstead, R.G., 2002. Whatever happened to the Scrophulariaceae? *Fremontia* 30, 13–22.

Butterfly and host plant phylogeny – who eats what (cf. Ehrlich and Raven, 1964), and why it makes more sense after DNA sequencing determined evolutionary relationships that led to reorganization of species and families — and a better understanding of butterfly ecology. Keywords: butterfly conservation; Castilleja; forbs; host plant preference; Plantago; restoration.

- [166] Olson, G.S., 2007. Legacy Prairie Assessment Progress Report November 2007. Wildlife Program, Science Division, Washington Department of Fish and Wildlife, Olympia, WA, 29 pp. + appendix.

Limited-term project to assess south Puget Sound prairie sites with respect to five species of interest, including Taylor's checkerspot. Main prairie sites include: Mima Mounds NAP, Scatter Creek, Rocky Prairie, West Rocky Prairie, Glacial Heritage Preserve, Tenolquot Preserve, Wolf Haven International, and Bald Hill NAP. Vegetation assessment intended to be compatible and coordinate with Fort Lewis' ITAM program (see U.S. Army, 2005); includes soil sampling.

“Prairie Legacy Data Framework” draft is a third component; developed to be a resource for access and storage of south Puget Sound prairie-related data. Keywords: data; habitat.

- [167] Olson, G.S., 2008. Legacy Prairie Assessment Progress Report November 2008. Wildlife Program, Science Division, Washington Department of Fish and Wildlife, Olympia, WA, 30 pp.

Continuation of assessment project with vegetation surveys and soil sampling; vegetation surveyed at two sites. Some survey techniques based on recommendations from a “prairie quality protocol beta test”; listed in references as “prepared for an interagency group” by Fort Lewis ecologist Jeff Foster; this does not appear elsewhere and could be useful. Main objectives of vegetation component are assessing spatial distribution, abundance, and site-specific trends of important invasive and native plants; determining whether the structure and composition of prairie sites are appropriate for species of interest, and assessing site-specific trends in habitat suitability. Includes frequency distributions by cover class and maps of abundance categories for plants surveyed by 25m grids. Keywords: data; habitat.

- [168] Olson, G.S., 2009. Legacy Prairie Assessment Progress Report October 2009. Wildlife Program, Science Division, Washington Department of Fish and Wildlife, Olympia, WA, 42 pp.

The primary focus for 2009 data collection was completion of vegetation assessments for all sites except Bald Hill; results for the four completed sites describe intensive surveys with numerous plant species recorded that were not in evidence when the recent flora for the area was prepared (see Dunwiddie, 2006). Includes frequency distributions by cover class and maps of abundance categories for plants surveyed by 25m grids. Keywords: data; habitat.

- [169] Oregon Biodiversity Information Center, 2010. Rare, threatened and endangered species of Oregon. Portland, OR, 105 pp.

Reference; describes animal and plant programs in OR; lists animals and plants with status and distribution. Keywords: biodiversity; conservation; data.

- [170] O’Shea, C., 2008. Mima Mounds Natural Area Preserve butterfly guide. Washington Department of Natural Resources and The Nature Conservancy, Olympia, WA, 8 pp..

Encourages prairie habitat stewardship; includes concise descriptions and excellent photographs of local butterflies and is a well-produced outreach and education effort targeted towards a range of people; the interpretive display at Mima Mounds NAP is another example from the same site that inspires a conservation ethic. Keywords: habitat conservation; prairie; stewardship.

- [171] Page, N., Lilley, P.L., Heron, J., Kroeker, N., 2009. Distribution and habitat characteristics of Taylor’s checkerspot on Denman Island and adjacent areas of Vancouver Island (2008). Report prepared for B.C. Ministry of Environment and Parks Canada Agency by Raincoast Applied Ecology, Vancouver, B.C., v + 32 pp.

*Reports methods and results of surveys for Taylor's checkerspot conducted in 2008 to determine its BC distribution and assess habitat characteristics; extensive photographs and maps. Post-diapause surveys recorded larval activity, host plant use in habitat known to be occupied. Larvae were found in disturbed and undisturbed habitats; most were resting or basking, confirming the importance of thermal habitat features; almost all observed feeding were on *Veronica scutellata*; other hosts are *Veronica* spp. and *Plantago* spp. Adult surveys conducted in occupied habitat on Denman Island to re-assess distribution patterns of stable interconnected subpopulations; in a search for new populations, one butterfly observed in potential habitat on Vancouver Island is the only recent record here. A detailed assessment made during pre-diapause indicated disturbed, seasonally wet areas were highest quality habitat; presence and abundance were related to host plant abundance; host plant use was similar, primarily one *Veronica* spp. Occupied habitats threatened by forest and wetland succession and inappropriate disturbance. Keywords: butterfly conservation; habitat quality; larval host plant use; monitoring.*

- [172] Panzer, R., 2002. Compatibility of prescribed burning with the conservation of insects in small, isolated prairie reserves. *Conservation Biology* 16, 1296–1307.

Examines response and recovery of insect populations after fire within small, isolated tallgrass prairie remnants; entomologists have expressed concern that prescribed burning is incompatible with the conservation of insect species richness on small sites. Research over seven seasons focused on species-level responses, distinguished between remnant-dependent and remnant-independent species, and included multiple fire events and sites. Overall results for butterflies indicate lesser fire sensitivity than other research (cf. Swengel 2001); notes that differences in experimental design and data analysis make it difficult to account for contrasting results; supports rotational cool-season burning. Keywords: fire; insect response; management; prairie.

- [173] Parker, I.M., 2002. Safe site and seed limitation in *Cytisus scoparius* (Scotch broom): invasibility, disturbance, and the role of cryptogams in a glacial outwash prairie. *Biological Invasions* 3, 323–332.

*Finds significant effects of surface treatment on *Cytisus scoparius* germination and on its final seedling density: fewest seedlings were in plots where the cryptogamic crust had been removed. Suggests that in contrast to expectations that disturbance enhances invasive species, certain types of disturbance may inhibit *C. scoparius*. In addition, its prevalence throughout prairies in western WA may be best explained not by disturbance but by favorable conditions of undisturbed vegetation. Notes that cryptogams have been observed to facilitate establishment of plants in other ecosystems; protect soils; prevent erosion; increase infiltration; increase other nutrients to plants; increase surface topography; and may provide excellent mossy, moist 'safe sites' for seed germination. Keywords: disturbance; invasive species; prairie; Scotch broom.*

- [174] Parker, I.M., Harpole, W., Dionne, D., 1997. Plant community diversity and invasion of the exotic shrub *Cytisus scoparius*: testing hypotheses of invasibility and impact, in: Dunn, P., Ewing, K. (Eds.), *Ecology and conservation of the south Puget Sound prairie landscape*. The Nature Conservancy, Seattle, WA, pp. 149–163.

Investigates relationships between plant community characteristics and invasibility using studies of prairie plant diversity and of Scotch broom (Cytisus scoparius) demographics. Rate of growth of C. scoparius population positively correlates with prairie species richness, failing to support biotic resistance theory; growth rate negatively correlates with proportion of total cover occupied by other exotics, suggests competition from other aggressive invaders might reduce success of actively expanding Scotch broom population. Prairie indicator species Festuca [idahoensis] roemerii declined dramatically related to presence of C. scoparius. Only two prairies had enough native species to compare: native richness and cover declined with increasing C. scoparius cover in one prairie but not the other; proportion of total native cover declined and total cover of non-natives increased significantly with Cytisus cover in both sites, suggesting N-fixation may facilitate invasion. Keywords: invasive species; plant community; prairie; Scotch broom.

- [175] Pennekamp, F., Monteiro, E., Schmitt, T., 2012. The larval ecology of the butterfly *Euphydryas desfontainii* (Lepidoptera: Nymphalidae) in SW-Portugal: food plant quantity and quality as main predictors of habitat quality. *Journal of Insect Conservation*, online early.

Investigates roles of habitat quality, habitat patches and other factors that affect the presence of immature life-stages of regionally threatened grassland butterfly Euphydryas desfontainii. Assesses habitat quality at two spatial scales: at landscape-level by determining presence-absence of caterpillars at host plant patches; and at within-patch levels to study oviposition selection, comparing host plants with egg clutches to a random sample of unoccupied host plants. Overall occupancy then related to various predictors for each scale (e.g., patch size, host plant abundance; host plant morphology, topography). At landscape-level occupied and unoccupied patches only differed in host plant abundance. At within-patch level, host plant features (i.e., large plants with inflorescences; lower grass around plants) and microclimate variables (i.e., inclination, exposition, and insolation — like Bay checkerspot) differed significantly between occupied and unoccupied plants. Keywords: Euphydryas spp.; habitat fragmentation; habitat patch; habitat quality; landscape scale; larval host plant use; oviposition; microclimate; topography.

- [176] Pfeifer-Meister, L., Roy, B.A., Johnson, B.R., Krueger, J., Bridgham, S.D., 2012. Dominance of native grasses leads to community convergence in wetland restoration. *Plant Ecology* 213, 637–647.

Presents results from a wetland prairie restoration in western OR where initial site preparation treatments intended to eliminate exotic species and favor native plant establishment were tested; 10 treatments (e.g., herbicide, solarization, tilling) were based on restoration practitioners' input. Each plot was densely-sown with mixed native perennial and annual forbs and grasses. Although initial site preparations produced large differences in plant communities, after three years they were no longer apparent; increasing dominance by native bunchgrasses led to similar plots with low diversity but high native and low non-native plant cover. Supports conclusions from other recent grassland studies that found competitive effects of native bunchgrasses continue for at least five years; native forbs may have difficulty becoming established if bunchgrasses are planted first; and that seeding rates with lower initial grass densities favor forbs. Keywords: assembly rules; biodiversity; experiment; forbs; grass; plant community; prairie; restoration.

- [177] Piessens, K., Adriaens, D., Jacquemyn, H., Honnay, O., 2009. Synergistic effects of an extreme weather event and habitat fragmentation on a specialised insect herbivore. *Oecologia* 159, 117–126.

Argues that habitat fragmentation decreases the ability of populations to resist and recover from environmental disturbances like extreme weather events, expected to occur at an increasing rate as a result of global change. Investigates how fragmentation amplified impacts of an extremely hot dry summer on egg deposition rates, population size fluctuations, and survival of a grassland butterfly restricted to one food plant. Immediately after a 2003 summer heat wave, host plant populations declined; this paralleled decreases in population size of the butterfly and altered egg deposition rates. At the end of the monitoring period in 2006, most host plant populations had recovered and only one population was lost; in contrast, several butterfly populations had gone extinct between 2003 and 2006. Concludes that extinction probability was significantly related to the initial population size, with small populations having a higher risk of extinction than large populations, and that results support predictions that higher trophic level species are more susceptible to extinction due to habitat fragmentation and severe disturbances; similar responses have been shown earlier for Bay checkerspot. Keywords: butterfly population; climate change; disturbance; grassland butterflies; habitat fragmentation.

- [178] Piper, J.K., Schmidt, E.S., Janzen, A.J., 2007. Effects of species richness on resident and target species components in a prairie restoration. *Restoration Ecology* 15, 189–198.

Tests a prediction that persistent and diverse plant communities are more likely to be created in restorations by increasing the number of species initially sown and by including representatives from different functional groups. Experimental prairie plots were planted with up to 16 species of perennial grasses and wildflowers representing 4 groups in 12 treatments with 5 replicates. Target community establishment rates and target species richness were highest using the most species-rich seed mixtures, while cover of resident species emerging from the seed bank was lowest; implications for management are that increasing the number of native species in the original mix speeds up the establishment of relatively diverse prairie that contains fewer weeds that emerge from the seed bank. Keywords: biodiversity; forbs; grass; prairie; restoration; seed.

- [179] Porter, K., Ellis, S., 2010. Securing viable metapopulations of the marsh fritillary butterfly, *Euphydryas aurinia*, (Lepidoptera: Nymphalidae) in northern England. *Journal of Insect Conservation* 15, 111–119.

Explains that due to land use changes and the loss of isolated habitat patches in semi-natural grasslands in northern UK, extirpations of this butterfly between 1990 and 2000 amounted to 66% of the local populations. Describes recovery actions to restore habitat and populations within the known historical patch network where butterflies thrived in past decades, including: seeding host plants; reinstating grazing regimes; captive breeding efforts with the last wild caterpillars (250 to 50,000 in 2 years); reintroductions that were apparently successful at three of four sites, albeit with very different population trends; and future plans to establish viable metapopulations across larger landscapes. Habitat quality and the patch pattern within a

landscape are believed to be the critical factors for viable long-term population persistence. Keywords: Euphydryas spp.; landscape scale; metapopulation; reintroduction.

- [180] Potter, A., 2008. Monitoring Taylor's Checkerspot in the Bald Hill Area of Thurston County, WA. 2007-2008 ACUB Project Progress Report, Washington Department of Fish and Wildlife, Olympia, WA, 8 pp.

Report summarizes fieldwork to monitor Taylor's checkerspot at Bald Hill, one of two extant sites in the south Puget Sound region where the butterfly occupies grassy, herbaceous vegetation typically found on prairies or balds; monitoring has been conducted by distance sampling in the patches of upland prairie. Despite intensive effort, only two checkerspots were observed at one site in 2007 (134 visits); and in 2008 (71 visits) none were recorded. Keywords: data; Euphydryas editha taylori; monitoring.

- [181] Potter, A., 2009. Monitoring Taylor's checkerspot butterfly in the Bald Hill landscape. 2009 ACUB Project Progress Report, Washington Department of Fish and Wildlife, Olympia, WA, 3 pp.

Report summarizes fieldwork to monitor Taylor's checkerspot at Bald Hill, one of two extant sites in the south Puget Sound region; during each survey visit, monitors systematically traversed and visually inspected entire balds, fragile upland prairie sites within a prairie matrix that are non-forested, grass and or forb-dominated areas. Surveys were conducted at 15 balds previously determined occupied and five neighboring balds by WDFW with the support of ACUB. No checkerspots were recorded. Keywords: data; Euphydryas editha taylori; monitoring.

- [182] Potter, A., 2010. Monitoring Taylor's checkerspot butterfly in the Bald Hill landscape. 2010 ACUB Project Progress Report, Washington Department of Fish and Wildlife, Olympia, WA, 4 pp.

Report summarizes fieldwork to monitor Taylor's checkerspot at Bald Hill, one of two extant sites in the south Puget Sound region. No checkerspots were observed in 2010; no habitat observations included; weather observations indicate cold, cloudy conditions, which would depress any extant populations. It is possible that the butterfly persists in the landscape; it is also possible that it has been extirpated. Keywords: data; Euphydryas editha taylori; monitoring.

- [183] Potter, A., 2011. Monitoring Taylor's checkerspot in the Bald Hill landscape. ACUB Project Progress Report. Washington Department of Fish and Wildlife, Olympia, WA, 4 pp.

Taylor's checkerspot surveys at Bald Hill are part of a consecutive multi-year effort to determine the occupancy status for balds previously found occupied, and some balds that are adjacent to those previously occupied; 2011 was the final year of an intensive, consecutive, multi-year effort to relocate Taylor's checkerspot in the Bald Hill landscape. Occasional, incidental monitoring of these sites for Taylor's checkerspot may occur in the future; however at this time there are no plans for further intensive surveys. Keywords: data; Euphydryas editha taylori; monitoring.

- [184] Potter, A., 2012. DRAFT Thurston County Habitat Conservation Plan Taylor's checkerspot species narrative. Washington Department of Fish and Wildlife, Olympia, WA, 10 pp.

Recent review of Taylor's checkerspot conservation status, population trends and distribution, life history and ecology, habitat characteristics, threats and reasons for decline. Incorporates rangewide information and regional data specifically in the context of the Thurston County, WA HCP. Keywords: Euphydryas editha taylori; habitat conservation; HCP.

- [185] Potter, A., Fleckenstein, J., Richardson, S., Hays, D., 1999. Washington State status report for the mardon skipper. Washington Department of Fish and Wildlife, Olympia, WA, 32 pp.

Includes some data about whulge (Taylor's) checkerspot; roughly maps areas of suitable habitat and describes associations with maritime prairies and shorelines, open island prairies, and post-glacial outwash prairies. Notes concentrations are declining although "locally bountiful"; and describes limiting factors for persistence: development within its habitats, grazing, agricultural practices, disturbance, and host plant community succession. Recommends maintaining grazing as a component of management; notes it may be necessary where not currently employed. Keywords: conservation; Euphydryas editha taylori; grassland butterflies; grazing.

- [186] Pöyry, J., Lindgren, S., Salminen, J., Kuussaari, M., 2005. Responses of butterfly and moth species to restored cattle grazing in semi-natural grasslands. Biological Conservation 122, 465–478.

Studies effects of restorative grazing on abundance of butterfly and moth species in semi-natural grasslands differing in management history: old and continuously grazed; restored with ~5 years of reinitiated grazing; and abandoned former pastures. In 5 out of 11 species, the successional stage preferred differed markedly between this Finland study and previous research in Central Europe. Concludes that ~5 years of grazing is insufficient for old-pasture species to colonize restored grasslands sites; different management intensities are needed across the region for the maintenance of grassland insect diversity; and application of the knowledge on successional preferences of different species in conservation management, even in climatically similar regions, should be made with caution. Keywords: grasslands; grazing; insect response; restoration.

- [187] Pratt, G.F., Emmel, J.F., 2009. Sites chosen by diapausing or quiescent stage quino checkerspot butterfly, *Euphydryas editha quino*, (Lepidoptera: Nymphalidae) larvae. Journal of Insect Conservation 14, 1–8.

Investigates natural habitat choices made by postdiapause Quino checkerspot larvae that return to the dormant stage and examines frequency of larvae that return to diapause for two or more seasons, behavior that is most frequent in butterflies that are adapted to areas with highly variable rainfall. Checkerspots spend most of their lives in diapause, and where they choose to hide is critical for their survival; comparatively little is known about the field biology of Quino checkerspot. Creates an experimental habitat with larval host plants and nectar resources seeded

*amongst rocks and larger perennial shrubs; releases 1,000 captive-bred larvae; 31 develop into adults; 49 return to diapause. Finds that the majority of those that returned to diapause have chosen to shelter 2–5 cm aboveground within California buckwheat shrubs, not a food plant; suggests this plant may be important in checkerspot habitat restoration. Also notes that the experiment shows 91% of larvae were lost to unknown forms of mortality. Keywords: *Euphydryas editha quino*; habitat; larval survival; restoration.*

- [188] Preston, K.L., Redak, R.A., Allen, M.F., Rotenberry, J.T., 2012. Changing distribution patterns of an endangered butterfly: linking local extinction patterns and variable habitat relationships. *Biological Conservation* 152, 280–290.

*Evaluates population extinctions between 1930 and 1998 for endangered Quino checkerspot relative to agricultural history, human population growth, climate variability, topographical diversity, and wildflower abundance. Determines that a long history of intensive livestock grazing was the strongest agricultural predictor of extinction; land use was calculated for extinct and extant populations based on cultivation and grazing intensities averaged across time periods reflecting distinct practices from 1769 to present; extirpated populations were associated with more intensive agriculture and greater human population growth at time of extirpation. Based upon historic vegetation maps, extirpated populations were typically isolated from other known populations by 1930, in landscapes fragmented by cultivation and development. Nectar sources and wildflower host plants declined across the range because of invasive plants and habitat loss; years considered average or abundant in wildflowers declined significantly during extinction periods. Quino checkerspot has shifted in distribution from the coast into foothills and mountains; newly discovered higher-elevation populations experience more precipitation and are buffered from drought although topographical variability and precipitation were not important predictors of extinction. Recognizes that multiple processes are responsible for species' extinctions; efforts to conserve Quino checkerspot are enhanced by understanding that the butterfly's decline and shifting distribution is a complex multi-scale process related to agricultural history, human population growth, climate variability, and wildflower decline. Keywords: *Euphydryas editha quino*; grazing; host plant; nectar resources.*

- [189] Pryke, S.R., Samways, M.J., 2001. Width of grassland linkages for the conservation of butterflies in South African afforested areas. *Biological Conservation* 101, 85–96.

Maps flight behaviors of butterfly species to establish effects of different-sized grassland linkages and blocks of trees on localized movements. Knowledge of responses to varied landscape structures has important conservation and management implications. Movement rates were significantly faster in narrow highly-disturbed linkages than in wide and open grasslands, with the linkages acting as conduits between the preferred grassland patches; but only highly vagile species actually entered narrow grassland linkages. Wider linkages hosted significantly higher species diversity and functioned as habitats per se and not just as movement corridors, with butterflies frequently stopping to nectar, oviposit, drink and bask; recommends linkages wider than 250 m for these butterflies. Blocks of trees caused butterflies to change direction and move away from the edge; only 4 of 23 species crossed a grassland/pine edge; a grassland/indigenous forest edge had a higher

number of species, but very few entered the forest. Relevant to prairie linkages and encroaching forest between bald habitats. Keywords: edge; grassland butterflies; habitat patch.

- [190] Pyle, R.M., 1989. Washington butterfly conservation status report and plan. Washington Department of Wildlife, Nongame Program, Olympia, WA, 217 pp.

Lists distribution, habitats and potential threats to more than 200 Washington butterfly species. Keywords: butterfly conservation; butterfly distribution; Euphydryas editha taylori; habitat.

- [191] Pywell, R.F., Bullock, J.M., Tallowin, J.B., Walker, K.J., Warman, E.A., Masters, G., 2006. Enhancing diversity of species-poor grasslands: an experimental assessment of multiple constraints. *Journal of Applied Ecology* 44, 81–94.

Investigates biotic and abiotic constraints on increased grassland biodiversity by manipulating seed and microsite availability, soil fertility, resource competition, herbivory and deficiencies in soil microbes to develop and test practical solutions. Effectiveness of 13 restoration treatments was investigated over 4 years in an experiment established in two UK grasslands. Severe disturbance involving turf removal followed by seed addition was the most effective and reliable means of increasing grassland diversity; low-level disturbance by grazing was ineffective in increasing diversity; different grazing management regimes had little impact on diversity. Keywords: biodiversity; enhancement; grasslands; habitat quality; restoration; seed.

- [192] Reudler Talsma, J.H., Biere, A., Harvey, J.A., van Nouhuys, S., 2008. Oviposition cues for a specialist butterfly--plant chemistry and size. *Journal of Chemical Ecology* 34, 1202–1212.

Examines effects of Plantago lanceolata size and plant chemistry (i.e., iridoid glycosides known to deter feeding or decrease growth rates of generalist insect herbivores, but act as oviposition cues and feeding stimulants for specialized herbivores) on the oviposition behavior of specialist butterfly Melitaea cinxia. In cages, finds a positive association between iridoid glycoside level and number of ovipositions, reflecting butterfly selection; in the field, plant size appeared to be a more important stimulus than iridoid glycoside content, with bigger plants receiving more oviposition than smaller plants, regardless of secondary chemistry. Oviposition choice of an insect herbivore is based on a complex set of stimuli and responses; results illustrate that the rank of a cue used for oviposition may be dependent on environmental context. Keywords: oviposition.

- [193] Russell, C., Schultz, C.B., 2009. Effects of grass-specific herbicides on butterflies: an experimental investigation to advance conservation efforts. *Journal of Insect Conservation* 14, 53–63.

Discusses use of grass-specific herbicides to control non-native invasive plant species specifically for butterfly habitat restoration; notes selectivity and comparatively low toxicity. Investigates the effects on larvae of two PNW butterfly species by direct contact, residue, and ingestion of two grass-specific herbicides (commercial names Fusilade and Poast), with and without surfactants. Responses differs between herbicide formulas and species, producing lethal effects for one species

over days to weeks rather than direct mortality, and sub-lethal effects on both; results suggest that selective herbicides have different effects on different butterfly species. Presents several issues concerning potential impacts of herbicides on non-target butterflies: 1) studies of herbicidal effects are generally in an agricultural context (e.g., pollinators or pests) that may not generalize to species of conservation concern; 2) studies indicate terrestrial invertebrates exhibit adverse effects from some herbicides; 3) results generated from traditional toxicity tests for one invertebrate species may not transfer to another (i.e., U.S. tests mostly honeybees); 4) herbicides may compromise the nutrient quality of non-target host plants; and 5) studies suggest that lethal effects on non-target insects may result from the biochemical pathways which cause herbicides to kill plants. Keywords: grass; herbicide effects non-target; insect response; invasive species.

- [194] Sang, A., Teder, T., Helm, A., Pärtel, M., 2010. Indirect evidence for an extinction debt of grassland butterflies half century after habitat loss. *Biological Conservation* 143, 1405–1413.

Species richness in recently disturbed habitats is expected to reflect past rather than current habitat availability, with the set of species eventually going extinct representing extinction debt. Shows that species richness of habitat specialists correlates positively with past (75 years ago) and current habitat area, best explained by a model incorporating both variables. Response to habitat loss in specialist butterflies appears faster than in specialist plants. Keywords: butterfly conservation; extinction debt; grassland butterflies; habitat conservation.

- [195] Schuller, R., 1997. Vegetation response to fall prescribed burning within *Festuca idahoensis*-dominated prairie, Mima Mounds Natural Area Preserve, Washington, 1985–1992, in: Dunn, P., Ewing, K. (Eds.), *Ecology and Conservation of the South Puget Sound Prairie Landscape*. The Nature Conservancy, Seattle, WA, pp. 207–217.

*Experimentally evaluated vegetation response for individual species to two different seasons of prescribed burning (i.e., summer, fall, or unburned control) at Mima Mounds Natural Area Preserve. Fall burning was generally observed to be less damaging to native species, especially the dormant native grass *Festuca [idahoensis] roemerii*. Some nonnatives decreased slightly (not significant) under a fall burning regime. Keywords: fire; management; prairie; restoration.*

- [196] Schultz, C.B., 2001. Restoring resources for an endangered butterfly. *Journal of Applied Ecology* 38, 1007–1019.

Demonstrates a method to quantitatively link resource needs of target species (i.e., larval host plants and nectar resources) to habitat restoration efforts. Treatments include four soil options, two seeding rates (i.e., 50%:50% and 10%:90% forb to grass ratios); and two weeding schemes replicated at two degraded prairie sites; plants were monitored for four years; and resources were categorically evaluated (i.e., insufficient, sufficient, or ample). No treatment produced sufficient larval resources; one soil treatment with a 50%:50% forb to grass seed ratio produced sufficient nectar resources at both sites. Keywords: forbs; host plant; nectar resources; restoration; seed.

- [197] Schultz, C.B., Crone, E.E., 1998. Burning prairie to restore butterfly habitat: a modeling approach to management tradeoffs for the Fender's Blue. *Restoration Ecology* 6, 244–252.

Argues that fire is an excellent tool to control invasive species and stimulate native plant growth when managing grasslands, but it may eradicate the invertebrate fauna. Presents an empirically based mathematical model to rank potential burn strategies for Fender's blue butterfly habitat, where potential strategies include combinations of times between burn (i.e., 1–5 years) and fractions of habitat to burn in each fire (i.e., 1/8, 1/4, 1/3, or 1/2), as well as never burning; includes an uncertainty analysis. Recommends treating one-third of the occupied area at a time, which maximizes average annual population growth rate, and allows adults the option of moving between treated and untreated patches. Notes that strategies to manage rare species' habitats may involve tradeoffs that include negative short-term impacts to achieve positive long-term success. Keywords: fire; grassland butterflies; habitat; invasive species; restoration.

- [198] Schultz, C.B., Crone, E.E., 2005. Patch size and connectivity thresholds for butterfly habitat restoration. *Conservation Biology* 19, 887–896.

Investigates the potential of biologically-based heuristics and complex models as tools in making land acquisitions for butterflies that survive in fragmented habitat patches. Argues that existing reserve design methods to select sites for habitat restoration often involve too many options and too much uncertainty. Based on dispersal behavior and demography of Fender's blue butterfly, estimates appropriate distance from existing habitat and size for restored patches; compares these rules to results from two different modeling approaches, an incidence function model and a spatially-explicit simulation of demography and dispersal behavior; concludes that simple rules and complex models agree that large (>2 ha) connected (<1 km) patches have highest restoration value. Differences in model assumptions produced variable predictions for the importance of size (i.e., large, small) and isolation (i.e., connected, isolated); recommends selecting nearby sites when short-term colonization dynamics are expected to be an important aspect of a species' biology. Keywords: butterfly population; habitat patch; metapopulation; model; restoration.

- [199] Schultz, C.B., Franco, A.M.A., Crone, E.E., 2012. Response of butterflies to structural and resource boundaries. *Journal of Animal Ecology* 81, 724–34.

Investigates behavioral responses of male and female butterflies to habitat heterogeneity based on two aspects of landscape composition, physical structure of the landscape (i.e., prairie, open woods and dense woods) and abundance of key resources (i.e., presence or absence of larval host plant patches), and two types of movement (within-habitat movement vs. edge preference) across four habitat types and nine ecotones. Responses to physical structure and resource patches were not congruent; movements and responses to barriers varied. Concludes that if other species behave like Fender's blue, different 'habitat' definitions (physical structure vs. resources), aspects of movement (edge preference vs. within-habitat movement), and gender differences could lead to misleading conclusions about responses to different habitat types. Evaluates the extent to which movement reflects a simple response to habitat presence vs. absence as opposed to subtler responses

to structure or resources; highlights the importance of investigating responses; and provides a framework for separating them. Keywords: habitat; habitat heterogeneity; insect response.

- [200] Schultz, C.B., Henry, E., Carleton, A., Hicks, T., Thomas, R., Potter, A., Collins, M., Linders, M.J., Fimbel, C., Black, S., Anderson, H.E., Diehl, G., Hamman, S.T., Gilbert, R., Foster, J., Hays, D., Wilderman, D., Davenport, R., Steel, E., Page, N., Lilley, P.L., Heron, J., Kroecker, N., Webb, C., Reader, B., 2011. Conservation of prairie-oak butterflies in Oregon, Washington, and British Columbia. *Northwest Science* 85, 361–388.

*Reviews regional at-risk species including Taylor's checkerspot; discusses distribution and status; primary threats (i.e., habitat loss and fragmentation, invasive species, and lack of appropriate disturbance); management approaches (i.e., fire, herbicide, mowing, and habitat restoration); and challenges (i.e., invasive species management, understanding of species' basic biology, multi-species conservation, and adapting to climate change). Concludes that enhanced communication and collaboration between land managers and biologists and sharing diverse strategies and experiments already being implemented will aid PNW butterfly species recovery. Appendices include an overview of habitat enhancement strategies that discusses identifying and evaluating 15 management units at 12 sites; developing quantitative restoration targets; mapping nectar and host plants; controlling invasive species; propagating and planting native plants; and using standardized protocols to evaluate success. Notes the varied expertise and input of partners and agencies are essential elements. Keywords: butterfly conservation; *Euphydryas editha taylori*.*

- [201] Schultz, C.B., Russell, C., Wynn, L., 2008. Restoration, reintroduction and captive propagation efforts for at-risk butterflies: a review. *Israel Journal of Ecology & Evolution* 54, 41–61.

Comprehensive review of recent conservation efforts for at-risk butterflies. Surveys and compares strategies of British (e.g., reestablishing traditional management practices, active manipulation of habitat) and American (e.g., invasive plant eradication, restoring disturbance regimes, and seeding native plant species) conservationists. Offers four general recommendations applicable to planning restoration, reintroduction, and captive propagation: 1) Increase systematic recording of activities; all types of conservation efforts would benefit from additional data; 2) Review experimental design and monitoring; recommends connecting habitat management activities to species-specific responses, preferably through replicated experiments; 3) Augment use of ecological modeling; models have been used to understand basic butterfly biology and distribution and in population viability analyses, could be extended to restoration or reintroduction efforts, and are most useful when long-term or large-scale experimentation is not feasible; and 4) Improve species-specific knowledge; a relevant extension would be taxon-specific knowledge, although extensive information for closely related taxa or local species within the same habitat is valuable. Keywords: butterfly conservation; data; habitat; model; reintroduction; restoration.

- [202] Seabloom, E.W., 2007. Compensation and the stability of restored grassland communities. *Ecological Applications* 17, 1876–1885.

Demonstrates that the aggregated abundance of restored grasses was more stable than were the individual species in response to disturbance, drought, and succession in a large-scale experimental restoration of a California grassland community; quantifies potential importance of diversity–stability relationships to restoration ecology and in increasing the persistence of restored communities in the face of altered disturbance regimes, climatic variability, and over the course of succession. Keywords: biodiversity; fire; grasslands; invasive species; restoration.

- [203] Seabloom, E.W., Benfield, C.D., Borer, E.T., Stanley, A.G., Kaye, T.N., Dunwiddie, P.W., 2011. Provenance, life span, and phylogeny do not affect grass species' responses to nitrogen and phosphorus. *Ecological Applications* 21, 2129–2142.

Tests whether upland prairie native and non-native grasses along a latitudinal transect from BC to OR respond differently to management interventions due to differences arising directly from their origin (i.e., provenance) or indirectly due to biased representations of different life history types (e.g., annual vs. perennial life span) or phylogenetic lineages among provenance (i.e., native or exotic origin) groups, by determining whether the factors interact to determine species distributions along natural soil chemistry gradients (e.g., soil nitrogen and phosphorus). Determines nutrients and pH strongly control plant community composition but distributions are unrelated to provenance, life span, or phylogenetic groups. Measures grass response to N and P in a greenhouse experiment; natives with greatest ability to maintain biomass at low nutrient levels were most abundant in field surveys but there was no relationship between non-natives and abundance, indicating that reduced nutrient supplies do not favor native species, contrary to general belief, and that nutrient manipulation is unlikely to alter the balance between natives and non-native species. Keywords: grasslands; invasive species; N-deposition; restoration.

- [204] Severns, P.M., 2008. Exotic grass invasion impacts fitness of an endangered prairie butterfly, *Icaricia icarioides fenderi*. *Journal of Insect Conservation* 12, 651–661.

*Tall oatgrass *Arrhenatherum elatius* was removed from shortgrass prairies in OR, oviposition by Fender's blue butterfly increased 2.5–5 times. Reduction of grasses increases visibility of native plants and hosts and nectar resources and decreases competition with native species for resources. Keywords: grassland butterflies; habitat quality; invasive species; oviposition; tall oatgrass.*

- [205] Severns, P.M., 2009. Oviposition habitat in three sites at Beazell Monument, Benton Co., Oregon.

*Summarizes habitat characteristics at previously uncharacterized OR sites and suggests habitat attributes that favor Taylor's checkerspot oviposition. The three sites differed in grass species richness and abundance, butterfly resources, bare ground, and herbaceous cover, and provide an example of the broad floral community composition under which the butterfly can thrive. History and habitat conditions all sites suggest that prairies are not required for checkerspots to thrive. At all locations, the preferred oviposition sites were on *Plantago lanceolata* at variable densities surrounded by dense short grass, which may create a desirable thermal environment, whereas tall grasses discourage oviposition. Keywords: *Euphydryas editha taylori*; habitat; oviposition.*

- [206] Severns, P.M., Grosboll, D., 2011. Patterns of reproduction in four Washington State populations of Taylor's checkerspot (*Euphydryas editha taylori*) during the spring of 2010. Report submitted to The Nature Conservancy, 82 pp.

*Argues that identification of shared traits that influence butterfly reproduction across the Taylor's checkerspot range will provide site-specific management targets, metrics for site reintroduction assessments and a baseline to measure changes over time. Examines four WA sites in distinct ecosystems (i.e., on Puget Sound prairies, on balds, ridges and in stabilized coastal dune habitat) to identify and quantify reproductive habitat. Concludes that important site-specific information was gathered that will be valuable for site managers, however, few generalities could be drawn about oviposition habitat except at all sites, oviposition occurred on *Plantago lanceolata* associated with roads, even at sites where *Castilleja hispida* was the primary pre-diapause larval host plant. Keywords: *Euphydryas editha taylori*; habitat; oviposition*

- [207] Severns, P.M., Warren, A.D., 2008. Selectively eliminating and conserving exotic plants to save an endangered butterfly from local extinction. *Animal Conservation* 11, 476–483.

*Investigates effects of non-native plants on the last Taylor's checkerspot populations in OR. Decrease in larval host plant abundance and adult nectar resources correlates with increased cover of non-native grasses; concludes populations are at risk of extirpation because two very tall grasses that dominate remnant prairies and degrade structural conditions in native grasslands surround the last two known OR checkerspot sites, and are the dominant vegetation at seven historic locations where populations were extirpated. Argues that although invasive plants can displace key resources, degrade habitat and directly impact fitness, non-native plants thrive in degraded prairie sites and have become a critical component of native butterfly diets; these two populations are entirely dependent on non-native *Plantago lanceolata* as a larval host plant, with larval development timed to its growth. Tests oviposition choice; females choose larval host plants surrounded by abundant short-statured native bunchgrasses and adult nectar resources, indicating egg-laying site selection is based on habitat conditions rather than just host plant presence. Concludes that to prevent regional extinction of Taylor's checkerspot, land managers must accept that the anthropogenically-mediated switch to *P. lanceolata* must be conserved and that reintroductions or habitat enhancement with a potential native host plant species is unlikely to be effective. Keywords: conservation; *Euphydryas editha taylori*; habitat quality; host plant preference; invasive species; oviposition; *Plantago lanceolata*.*

- [208] Sheley, R.L., Half, M.L., 2006. Enhancing native forb establishment and persistence using a rich seed mixture. *Restoration Ecology* 14, 627–635.

Argues that establishing native forbs is crucial for long-term invasive plant management and restoration of a desirable grassland plant community. Experimentally determines (i.e., in pots under controlled greenhouse conditions) that increased forb seed density results in increased forb establishment; and that a species-rich forb mixture has greater establishment and survivorship than a single species. Concludes that using a mixture of forbs will enhance forb establishment in various and unpredictable environments because the mixture possesses a variety of traits that may match year-year and site-site conditions. Keywords: experiment; forb; seed.

- [209] Singer, M.C., 1972. Complex components of habitat suitability within a butterfly colony. *Science* 176, 75–77.

*First attributes independent fluctuations of population size of three adjacent Bay checkerspot colonies to spatial and temporal patterns of three larval resources: 1) survival was naturally very low due to unpredictable spatial and temporal patterns of larval development and senescence of host plants caused by microclimate differences resulting from topographic heterogeneity; larvae developed faster on south-facing slopes and host plants senesced later on north-facing slopes; when adults that developed on warm south-facing slopes oviposited in cooler sites, they increased the probability of larval survival; postdiapause larvae were spatially correlated with the location of long-lasting host resources from the previous spring; 2) *Plantago* senescence was delayed in small patches of soil disturbed by gophers; and 3) where two host plants species occur together, surviving larvae fed on edible *Castilleja* rather than senescent *Plantago*. Keywords: butterfly distribution; *Euphydryas editha bayensis*; larval host plant use; microclimate; weather.*

- [210] Singer, M.C., 2003. Spatial and temporal patterns of checkerspot butterfly-host plant association: the diverse roles of oviposition preference, in: Boggs, C.L., Watt, W.B., Ehrlich, P.R. (Eds.), *Butterflies: ecology and evolution taking flight*, pp. 207–228.

*Explains that it is difficult to identify traits that influence patterns of insect-plant associations because insect and plant traits both vary within and among populations. Defines preference as an insect trait; acceptability as the reciprocal plant trait; and electivity as the trait of the interaction, measuring use against relative abundance, here with respect to oviposition. *Euphydryas editha* research leads to insights and conclusions: insect populations vary in preference and electivity; genetic variation in both insects and plants substantially contributes to the spatial pattern of insect-plant association; and variations among plant populations in acceptability should be important in the evolution of insect-host plant associations. Host shifts are spatial and temporal. When an herbivorous insect population confronts a novel plant both larval performance traits and oviposition choice behavior traits can be used to investigate the response. Host shifts can be studied while in progress; change may be impeded by phenological barriers or various types of maladaptations to the novel host (e.g., finding the host, chemical or physical issues, number of eggs laid); change can be rapid, over six to eight generations; hosts can be adopted and abandoned several times; and adaptive behavior towards multiple hosts can be achieved. *E. editha* show genetic variability in host plant specificity and in preference rank order both among and within populations; evidence shows preferences can vary among individuals. Concludes that testing evolutionary predictions with butterflies is eminently suitable, and that larval performance and oviposition preference are equally important. Several relevant threads for Taylor's checkerspot. Keywords: *Euphydryas editha*; host plant preference; oviposition.*

- [211] Singer, M.C., Parmesan, C., 2010. Phenological asynchrony between herbivorous insects and their hosts: signal of climate change or pre-existing adaptive strategy? *Philosophical transactions of the Royal Society of London. Series B, Biological Sciences* 365, 3161–3176.

*Notes climate change alters phenological relations between interacting species, and expectations may be that the baseline for such effects would be a precise synchrony between the season when food is required and the time when resources are most available. Describes the case of the Bay checkerspot, where initial observations of the mismatch between the butterfly and its ephemeral annual host plants that results in starvation of most of the population through poor synchrony were made prior to the onset of anthropogenically driven climate change. Develops the idea that when phenological asynchrony with resources forms the starting point for effects of anthropogenic global warming, consumers are particularly vulnerable to impacts that intensify the mismatch, and this vulnerability likely contributed to extirpation of a well-studied metapopulation. Keywords: climate change; *Euphydryas editha bayensis*; host plant phenology.*

- [212] Singer, M.C., Wee, B., Hawkins, S., Butcher, M., 2008. Rapid natural and anthropogenic diet evolution: three examples from checkerspot butterflies, in: Tilmon, K.J. (Ed.), Specialization, speciation, and radiation: the evolutionary biology of herbivorous insects. University of California Press, Berkeley and Los Angeles, pp. 311–325.

*Discusses fairly rapid evolutionary host shifts by *Euphydryas editha*, which consists of numerous allopatric populations at different stages of adapting to different host plants. Indicates the first event was clearly anthropogenic, caused by a near-complete shift to non-native host *Plantago lanceolata*; the second was less-obviously human-caused, but followed changes in the distribution and quality of native host plants triggered by logging and the creation of novel habitat patches that evolved over several phases; and the third host shift was the result of a natural population extirpation, followed by a recolonization that led to the acceptance of a previously rejected host plant. Keywords: *Euphydryas editha*; host plant preference; oviposition.*

- [213] Smee, M., Smyth, W., Tunmore, M., Ffrench-Constant, R., Hodgson, D., 2010. Butterflies on the brink: habitat requirements for declining populations of the marsh fritillary (*Euphydryas aurinia*) in SW England. *Journal of Insect Conservation* 15, 153–163.

*Describes two management methods, including grazing, used to increase and improve grassland quality for *Euphydryas aurinia* over a 5-year period at a network of habitat patches in the UK, where it persists in subpopulations threatened by habitat fragmentation and degradation. Adult and larval densities indicate the butterfly favors habitat patches with higher larval food plant densities, higher grass height in the fall, and intermediate levels of stock grazing; management produced an improvement in habitat variables across patches; a quadratic relationship between grazing and important habitat variables has been found which will aid further improvement over all sites. Keywords: *Euphydryas* spp.; grazing; habitat quality; larval host plant use.*

- [214] Smith, R.S., Shiel, R.S., Millward, D., Corkhill, P., Sanderson, R.A., 2002. Soil seed banks and the effects of meadow management on vegetation change in a 10-year meadow field trial. *Journal of Applied Ecology* 39, 279–293.

Compares soil seed banks and vegetation in a long-term meadow trial (two fertilizer treatments; two seed treatments, no seeds vs. multiple species sown over three years) with species-rich meadows traditionally managed with disturbance by cattle and sheep grazing. After ten years, composition of seed banks and vegetation were distinct; traditionally managed control meadows were diverse; the trial meadow was more uniform and only seed addition increased species richness. Concludes development of soil seed banks lag behind increases in vegetation diversity initiated by seed sowing; emphasizes the need to introduce additional species as seed when enhanced plant species diversity is an objective for grassland restoration and management for wildlife conservation. Keywords: grasslands; grazing; restoration; seed banks; seed limitation.

- [215] Smith, S., 2007. Arbuscular mycorrhizal fungi of abandoned agricultural land and their implications for the restoration of Puget Sound prairies. M.Sc. thesis, University of Washington College of Forest Resources, 87 pp.

Demonstrates that mycorrhizal communities of agricultural lands are functionally equivalent to native prairies in the area; concludes that restoration of abandoned fields back to native prairie can proceed without concerns about dysfunctional fungal activity. Keywords: prairie; restoration.

- [216] South Puget Sound Prairies Working Group, 2002. South Puget Sound Prairies Site Conservation Plan. South Puget Sound Prairies Working Group, Olympia, WA, pp. 1-27 + appendices.

Introduces the planning process and the purpose of the regional conservation plan; describes the natural communities and species that are the focus of their concern, including prairie butterflies; analyzes and ranks relevant threats using two components, stresses and sources of stress; presents their vision; delineates planning areas (i.e., Mima Mounds NAP, Scatter Creek, Rocky and Weir Prairies, and Fort Lewis and McChord AFB); and formulates a conservation strategy. Working group was organized in 2000 specifically to improve natural resources of south Puget Sound oak woodland and prairie ecosystems by addressing conservation and management needs; members from private organizations and public agencies have expertise in natural area planning and management. Website (www.southsoundprairies.org; accessed 9/1/2012) explains the group operates primarily on consensus, and individuals actively help accomplish the group goals, but an informal structure allows members to cooperate on "renegade" ideas or actions that the entire group does not support. Keywords: conservation; habitat; prairie; restoration.

- [217] Spasojevic, M.J., Aicher, R.J., Koch, G.R., Marquardt, E.S., Mirotnick, N., Troxler, T.G., Collins, S.L., 2010. Fire and grazing in a mesic tallgrass prairie: impacts on plant species and functional traits. *Ecology* 91, 1651–1659.

Argues that although grazing and fire may have some comparable effects in grasslands, they do not have similar impacts on species composition and community structure; however, the concept of fire as a 'global herbivore' implies that fire and herbivory may have similar effects on plant functional traits. Tests whether trait composition between grazed and burned grassland plant communities would converge; if degree of convergence depended on fire frequency; and the effects on composition of eliminating or adding fire. Finds grazing and burning once every four years

showed the most convergence in traits; concludes that functional traits and species-based metrics should be considered when determining and evaluating goals for fire management in grassland ecosystems. Keywords: fire; grassland; grazing; prairie.

- [218] Stanley, A.G., Kaye, T.N., Dunwiddie, P.W., 2010. Regional strategies for restoring invaded prairies, final technical report. The Northwest Conservation Fund of the Priscilla Bullit Collins Trust, The Nature Conservancy and the Institute for Applied Ecology, Corvallis, OR and Seattle, WA.

Demonstrates that a combined treatment approach designed by managers and ecologists using a variety of strategies is an effective and efficient way to improve degraded grasslands. Reports on a cooperative project conducted over 5 years at 10 sites from British Columbia to the Willamette Valley, OR intended to improve methods for restoring prairies and oak savannas. Compares four different combinations of seed addition and disturbance treatments that include herbicide (grass-specific sethoxydim and systemic glyphosate), fire, and mowing; combinations targeted various limiting factors for ecosystem restoration, including invasive species, litter accumulation, and limited dispersal of native species. In all cases, disturbance treatments reduced non-native cover to varying degrees but had no positive impact on native diversity except when seeds were added. The most disturbance-intensive combination (application of sethoxydim, burning, and post-fire glyphosate) led to reduced abundance of non-native grasses and forbs without causing a decline in native species. Grass-specific sethoxydim combined with fall mowing reduced non-native grasses, caused no change in non-native forbs, and increased total cover of native plants. Keywords data; fire; herbicide; invasive species; prairie; restoration; seed; seed limitation.

- [219] Stanley, A.G., Kaye, T.N., Dunwiddie, P.W., 2011. Multiple treatment combinations and seed addition increase abundance and diversity of native plants in Pacific Northwest prairies. *Ecological Restoration* 29, 35–44.

One of three published versions of this study (see Stanley et al., 2010). Evaluates manager-recommended combinations of herbicide treatments, burning, and mowing in a collaborative experiment to develop and test treatment combinations to reduce non-native weeds and increase native species diversity and abundance in fragmented prairie remnants; all treatments were crossed with native seed addition. Tests strategies for widespread applicability in prairies across the region with replicated experiments; recommends seed addition at all sites to enhance native diversity and abundance; notes that even relatively high quality sites are strongly seed-limited. Degree of success varies across sites; results show best invasive grass controls without reducing native species abundance incorporate many techniques: application of grass-specific herbicide in the spring to target non-native grasses with minimal effects on native forbs and some native grasses, followed by burning in the fall to prepare for seeding, followed closely with a carefully timed post-fire broad spectrum herbicide application to control rapidly resprouting weeds that avoids impacting later-sprouting natives. Mowing did not increase bare soil, resulting in poor seedling establishment, and was ineffective at reducing herbaceous weed abundance. Keywords: data; fire; herbicide; invasive species; prairie; restoration; seed; seed limitation.

- [220] Stinson, D.W., 2005. Status report for the Mazama pocket gopher, streaked horned lark, and Taylor's checkerspot. Washington Department of Fish and Wildlife, Olympia, WA, 131 pp.

Summarizes and provides detailed knowledge about natural history, habitat, past and present population and habitat status, legal status and management activities, and factors affecting the continued existence of Taylor's checkerspot, along with information about two other species locally dependent on south Puget Sound prairies: Mazama pocket gopher and streaked horned lark. Discusses adult and larval habitat requirements: a plant community dominated by short-stature grasses; sufficient larval host plants and abundant and diverse spring nectar sources whose use by the butterfly varies by site and availability; a heterogeneous landscape with varied topography and microclimates; and while existence of water is not limiting for checkerspots, water sources may be important in years of extended drought, thus water may be of greater importance in a warming climate. Provides an introduction to the ecology of western WA grasslands; describes their development on gravelly glacial outwash soils during a warm dry period ~7,000–10,000 years BP; their historic extent; management by indigenous burning until permanent settlement led to fire suppression; and their current (1995) status: ~8% of the original prairie supports grassland vegetation and ~2–3% is dominated by native prairie vegetation. Keywords: butterfly conservation; data; Euphydryas editha taylori; habitat quality.

- [221] Stone, J.K., Severns, P.M., Miller, N., 2011. *Pyrenopeziza plantaginis* new to North America. North American Fungi 6, 1–4.

Reports presence of fungus Pyrenopeziza plantaginis from leaves of Plantago lanceolata from remnant native prairie sites in Benton Co., OR. Suggests associated leaf blight may impair restoration of populations of Taylor's checkerspot because pre-diapause larvae in most butterfly populations use P. lanceolata as a host. Keywords: Euphydryas editha taylori; larval host plant use; Plantago lanceolata.

- [222] Storm, L., Shebitz, D., 2006. Evaluating the purpose, extent, and ecological restoration applications of indigenous burning practices in southwestern Washington. Ecological Restoration 24, 256–268.

Reviews and evaluates ethnobotanical, archaeological, and ethnographic information about the prairies of western WA to better understand the extent to which prairie distribution and plant composition was managed by traditional ecological methods; synthesizes knowledge, provides a framework for reconstructing historic fire regimes and integrating indigenous burning practices to local restoration projects. Keywords: fire; prairie; restoration.

- [223] Suding, K.N., 2011. Toward an era of restoration in ecology: successes, failures, and opportunities ahead. Annual Review of Ecology, Evolution, and Systematics 42, 465–487.

Review; broadly examines research addressing ecological restoration success or failure according to four general paradigms, with thoughtful examples: 1) restoration to guide recovery of degraded

systems, typically with a historical reference point (e.g., restoration of a disturbance regime may do little to undo entrenched undesirable species; consider minimization of 'dark diversity,' the number of species belonging to the species pool but missing from an ecosystem; research confirms outcomes are equally split between complete, relatively quick recovery, mixed success with some improvement, and little to no recovery); 2) restoration as mitigation for habitat loss (e.g., estimates of likelihood of success are critical because immediate loss is permanent whereas future gain is uncertain; compensation seldom successfully restores structure, composition, or function); 3) restoration to deliver ecosystem services (e.g., when selecting methods to control post-fire grass invasion, an optimization model that focused on benefits of several ecosystem services and cost effectiveness of a range of treatments greatly enhanced restoration decision making; functional species redundancy may allow ecosystem processes to more feasibly be restored than biodiversity); and 4) restoration to ensure resilience (e.g., adaptive capacity and resilience should increase with management for increased genetic and species diversity; landscape factors like fragmentation, spatial heterogeneity and connectivity should affect resilience). Keywords: habitat; restoration.

- [224] Swengel, A.B., 1998. Effects of management on butterfly abundance in tallgrass prairie and pine barrens. *Biological Conservation* 83, 77–89.

Analyzes management effects for specialist and grassland butterfly species; most specialists showed significantly increased numbers associated with less frequent, less intrusive management but entirely unmanaged habitat was rarely optimal. Single occasional wildfires were typically more favorable for specialist abundance than regular rotational burning, which often produced very low numbers. No management type was clearly favorable for all specialists of a given habitat. Grassland species respond similarly to specialists except several favored more frequent or more intrusive management; mowing was not markedly better for their abundance than grazing or wildfire better than rotational burning. For conserving specialist butterflies, both consistency of management type within site and deliberate differences in management type among sites of like habitat is desirable. Keywords: butterfly conservation; fire; grasslands; grazing; mowing.

- [225] Swengel, A.B., 2001. A literature review of insect responses to fire, compared to other conservation managements of open habitat. *Biodiversity and Conservation* 10, 1141–1169.

Review and synthesis of literature about insect responses to fire compared with other types of habitat management (i.e., mowing, grazing) to maintain open habitats in habitat fragments. Declines may follow immediately after mowing, but of lesser degree and shorter duration than after a fire of comparable timing and size; niche and assemblage simplification result from heavy grazing. Characteristics associated with insect response to fire relate to insect mobility, degree of exposure to flames and lethal temperature, stress experienced in post-fire environments, habitat suitability of post-treatment vegetation, and ability to rebuild numbers from survivors or colonizers. Argues these factors are useful for explaining insect responses to other management, but the assumption that habitat-restricted species will be most adapted to ecological forces believed to be prevalent in that ecosystem appears less valuable for predicting insect management preferences. Maintains that providing specific needs of particular butterfly species, not just maintenance of general habitat types is essential, as is sufficient spatiotemporal variation among

sites of the same ecosystem type in the frequency of fire, grazing, and other management; reduced variation leads to simplified homogeneous sites lacking key niches and species. Keywords: fire; grassland; grazing; insect response; management.

- [226] Swengel, S.R., Schlicht, D., Olsen, F., Swengel, A.B., 2010. Declines of prairie butterflies in the midwestern USA. *Journal of Insect Conservation* 15, 327–339.

Presents data indicating numerous declines of butterflies in fire-managed preserves, including large high-quality ones. Suggests tallgrass prairie-specialist butterflies are not co-evolved with current fire regimes. Status and trends data pooled from long-term survey datasets collected in recent decades in four US states by 10 teams. Results replicate previous findings; indicate that management changes upon initiation of conservation actions affect specialists negatively and that butterfly declines can be as great on reserves as non-reserves; warns declines will likely continue unless conservation approaches change to include required resources and management tolerances of individual butterfly species. Argues against an ecosystem approach that assumes habitat specialists co-evolved with processes such as fires assumed to maintain those ecosystems. Alternate perspective views ecological processes as re-setting vegetation to current climate and landscape conditions; over geologic time, relict plant associations persist as outliers until an event resets them; in modern times, human disturbances can reset sites to favor generalist plants and butterflies found in prevailing, human-degraded landscapes. Species-specific management protocols, including permanent non-fire refugia, were more favorable for specialists. Keywords: butterfly conservation; fire; grasslands; insect response; management; prairie; restoration.

- [227] Swengel, S.R., Swengel, A.B., 1999. Correlations in abundance of grassland songbirds and prairie butterflies. *Biological Conservation* 90, 1–11.

Suggests that conservation programs benefitting grassland birds can be favorable for co-occurring prairie-specialist butterflies and that certain bird and butterfly species can be effective indicators of each other, within a habitat and a region. Although other studies have shown diversities of distantly related animal groups may not correlate well, correlations of three songbirds as a group with all observed butterfly individuals in each of three ecological groups (i.e., prairie specialists; grassland butterflies occurring widely in native prairies; generalist butterflies) showed similar patterns. Keywords: butterfly conservation; grassland butterflies; prairie.

- [228] The Nature Conservancy, 2005. January – December 2005 Annual Report Fort Lewis Conservation Project. The Nature Conservancy, Olympia, WA, 61 pp.

Provides an overview and details of conservation activities undertaken by TNC in partnership with Fort Lewis in 2005. Prairie restoration and other projects relevant to Taylor's checkerspot include habitat management at two priority areas, high-quality habitat severely impacted by Scotch broom on Johnson and Weir Prairies and a matrix of degraded and high-quality habitat on 13th Division Prairie. Road decommissioning, Muck Creek corridor restoration also affect prairie habitat. Describes actions to support all these projects, including invasive species control, prairie plant propagation, extensive enhancement plantings targeted at rare prairie butterflies,

and development of rare species recovery techniques in partnership with WDFW. Keywords: conservation; data; enhancement; habitat; invasive species; prairie; restoration.

- [229] The Nature Conservancy, 2006. January – December 2006 Annual Report Fort Lewis Conservation Project. The Nature Conservancy, Olympia, WA, 78 pp.

*Provides an overview and details of conservation activities undertaken by TNC in partnership with Fort Lewis in 2006. Conservation actions specifically affecting Taylor's checkerspot were mainly to enhance habitat, and included extensive invasive plant control for Scotch broom; strategic planting of native forbs on 13th Division, Johnson and Weir Prairies, at TNC's adjacent Morgan (Tenolquot) Prairie, and at Muck Creek Triangle; continuing propagation of multiple native species and evaluation of host plant *Castilleja hispida* trials. Keywords: conservation; data; enhancement; habitat; invasive species; prairie; restoration.*

- [230] The Nature Conservancy, 2007. January – December 2007 Annual Report Fort Lewis Conservation Project. The Nature Conservancy, Olympia, WA, pp.

Provides an overview and details of conservation activities undertaken by TNC in partnership with Fort Lewis in 2007. Ongoing actions included invasive species control for Scotch broom. New activity for Taylor's checkerspot included development of a butterfly habitat enhancement work plan based on prior work, field visits and collaborative discussions. The plan emphasizes creation of small resource plots containing dense concentrations of larval host and adult nectar plants within a high-quality fescue prairie matrix, and includes a Butterfly Habitat Evaluation form to be a framework for enhancement targets. Experimental plots were designed, baseline surveys were made of existing vegetation, and sites were prepared and planted with >11,000 seedlings and direct-seeded with native forbs; results will guide future habitat enhancement efforts, which have accelerated in response to the ACUB Project and with recent developments in captive rearing and translocation efforts of butterflies onto off-base Puget Sound prairies. Keywords: conservation; data; enhancement; habitat; invasive species; prairie; restoration.

- [231] The Nature Conservancy, 2008. January – December 2008 Annual Report Fort Lewis Conservation Project. The Nature Conservancy, Olympia, WA, pp.

Provides an overview and details of conservation activities undertaken by TNC in partnership with Fort Lewis in 2008. General butterfly enhancement and restoration efforts included invasive species control for Scotch broom; butterfly and nectar surveys and habitat mapping on Johnson Prairie; and planting of native forbs on 13th Division and Johnson Prairies. Efforts for Taylor's checkerspot in conjunction with regional programs to support reintroduction on- and off-base included dog training for checkerspot detection and more-extensive enhancement and restoration experiments (i.e., planting plugs vs. direct-seeding forbs) incorporating vegetation monitoring to evaluate the approach at three sites (i.e., TA 14, Pacemaker; TA 7S; TA 15, Muck Creek Triangle). First year results indicate site preparation techniques need refinement; planted seedling survivorship was high; establishment rates from direct-seeding were relatively low. Keywords: conservation; data; enhancement; habitat; invasive species; prairie; restoration.

- [232] The Nature Conservancy, 2009. January – December 2009 Annual Report Fort Lewis Conservation Project. The Nature Conservancy, Olympia, WA, pp.

Provides an overview and details of conservation activities undertaken by TNC in partnership with Fort Lewis in 2009. Reports that several programs on Fort Lewis benefitted from regional integration, including prescribed fire, prairie quality monitoring, invasive species control, and butterfly habitat enhancement; that TNC presented a summary of Fort Lewis and ACUB off-base butterfly enhancement work to the WA Wildlife Society; and that habitat enhancement efforts to support reintroductions of Taylor's checkerspot on-base continued at TA 14, Pacemaker; TA 7S; and TA 15, Muck Creek Triangle. Describes pilot techniques used to investigate larval habitat during diapause; observations indicate larvae spend at least some time on the ground surface amongst litter and duff at the base of forb stems, and take advantage of soil cracks. Keywords: conservation; data; enhancement; habitat; invasive species; prairie; restoration.

- [233] Thomas, J.A., 1995. Why small cold-blooded insects pose different conservation problems to birds in modern landscapes. *Ibis* 137, 112–119.

Argues that most early attempts to conserve butterflies within nature reserves set aside for birds or larger mammals failed because it was assumed insects, smaller vertebrates, and flora would thrive in protected areas, without considering that their specialized habitat often depends on ephemeral successional stages that remain suitable for limited periods of time, e.g., 3–10 years, and that many species are too sedentary to colonize new habitat patches farther than 300m–1km from old ones during the period for each that is suitable for reproduction and dispersal. Finds a pattern between endangered status of all UK terrestrial invertebrates and types of vegetation succession required (i.e., either very early or very late stages). Contends many declines attributed to other causes (e.g., inbreeding depression, severe weather, insecticides, various agencies, collectors) were instead the result of a combination of changes in the quality or dynamics of individual species' habitat niches. Keywords: butterfly conservation; habitat quality.

- [234] Thomas, J.A., Bourn, N.A.D., Clarke, R.T., Stewart, K.E., Simcox, D.J., Pearman, G.S., Curtis, R., Goodger, B., 2001. The quality and isolation of habitat patches both determine where butterflies persist in fragmented landscapes. *Proceedings. Biological Sciences /The Royal Society* 268, 1791–1796.

Demonstrates that habitat quality and site isolation are both important determinants of where butterfly populations persist in existing landscapes. Determines requirements of three grassland butterflies; quantifies carrying capacity variation within each butterfly's niche; conducts surveys to compare distribution and density of every population of each species with size, distance apart and quality of their specific habitats in all potential habitat patches in three UK landscapes. Within-site variation in habitat quality explained which patches supported a species' population 2–3 times better than site isolation; no correlation between occupancy and site area. Argues habitat quality and spatial effects operate at different hierarchical levels in the same process instead of being alternative paradigms; and habitat quality is a missing third parameter in metapopulation dynamics, contributing more to persistence than isolation or site area. Keywords: butterfly conservation; grassland butterflies; habitat quality; metapopulation.

- [235] Thomas, J.A., Simcox, D.J., Hovestadt, T., 2010. Evidence based conservation of butterflies. *Journal of Insect Conservation* 15, 241–258.

Review; concludes the most important factor determining the size and persistence of butterfly populations is variation in the intrinsic quality of the habitat preferred by larvae, based on “most better-studied species of temperate butterfly.” Argues scientists are competent at describing changes in species’ distribution and abundance but not in understanding mechanisms driving changes; and in spite of notable exceptions, unable to reverse trends in declining species with targeted conservation measures. Asserts that “it is sufficient for the practical conservationist to identify the preferred immature habitat for a valuable species [...] and manipulate sites to encourage the generation or persistence of near-optimum conditions.” Acknowledges this may vary over a species’ range or in different climates, but defines optimal habitat as correlating with a subset of food plants growing in a narrow successional stage, which can be manipulated by management. Then suggests that at any point above the level of medium-quality habitat, chances for persistence and establishment are high and do not greatly improve for optimum conditions, except to gain more emigrants. Concludes, based on “current incomplete knowledge” that it is more effective to spend limited resources to achieve adequate, upper-range quality habitat at several sites than to create the ultimate at one site. UK-centric; eccentric; relevant. Keywords: butterfly conservation; butterfly population; habitat quality; larval host plant use.

- [236] Thomas, T.B., Carey, A.B., 1996. Endangered, threatened, and sensitive plants of Fort Lewis, Washington: distribution, mapping, and management recommendations for species conservation. *Northwest Science* 70, 148–163.

Presents the results of a comprehensive survey to locate endangered, threatened and rare plants on Fort Lewis: seven habitat types were located on aerial imagery and on topographic maps; and then >3,000 ha of prairie, wetland, and moist-forest plant communities were systematically sampled, and rare plant species, their habitats, and associated species were mapped. Aster curtus, most abundant of four rare species, attained highest cover and frequency on fescue-dominated bunchgrass prairies, with other native forbs and grasses. Discusses major threats to prairie habitat; recommends protection of populations from damage from military training maneuvers, restoring degraded prairie, monitoring, propagation, and further research. Keywords: forbs; habitat conservation; military; plant community; prairie.

- [237] Thorpe, A.S., Stanley, A.G., 2011. Determining appropriate goals for restoration of imperilled communities and species. *Journal of Applied Ecology* 48, 275–279.

Review; focuses on challenges of defining appropriate conservation goals and restoration targets for PNW native ecosystems, given global changes, including species invasions, habitat loss, and climate change. Suggests restoration goals should be based on ecological principles that will lead to resilient, functioning ecosystems rather than focusing on historic benchmarks. Warns problems can arise when goals are to recreate pre-settlement conditions, with historical plant communities and disturbance regimes; quantitative data are sparse, and remnant communities are often an inadequate proxy for historic conditions. Mima Mounds Natural Heritage Preserve case study illustrates how seeding with native forbs became the controversial component of newly developed

*strategies which include burning, herbicide and mowing to restore degraded prairies. Techniques were still experimental, and managers were reluctant to let researchers add two local native species for which they had no records for occurring on site (i.e., *Balsamorhiza deltoidea* and *Plectritis congesta*; important resources for rare butterflies). Scientists documented that both were historically widespread nearby; that the Preserve had much lower diversity than predicted for its size; and that native forb diversity, particularly annuals, had declined sharply in prairie remnants in the absence of fire. Consensus was reached between scientists and managers and both species were incorporated into experimental plots. Provides other examples of collaborate efforts to define and test effective methods, including strategies to adapt to global change and defining targets for movement of genotypes based on population genetic theory, species biology, and experiments rather than assumptions based on remnant populations. Keywords: climate change; disturbance; historical ecology; management; restoration.*

- [238] Tveten, R., 1997. Fire effects on prairie vegetation, Fort Lewis, Washington, in: Dunn, P., Ewing, K. (Eds.), Ecology and conservation of the south Puget Sound prairie landscape. The Nature Conservancy, Seattle, WA, 9 pp.

*Compares three documented fire regimes with different return intervals in areas with uniform soils on three Fort Lewis prairies: fire suppression; annual burning of the Artillery Impact Area (ALA) triggered by exploding ordinance; and prescribed burning at 3–5 year intervals. Fort Lewis contains the largest high-quality remaining prairies in western Washington and has a long-term prescribed burning program. Argues that fire suppression negatively impacts large tracts of prairie and oak woodland, allowing unchecked growth of invasive or successional species (i.e., Scotch broom, Douglas-fir) and high fuel levels that threaten fire-adapted plants when very hot fires eventually burn. ALA fires occur nearly annually (for 50 years; now 65+), have changed native perennial bunchgrass prairies to sparsely-vegetated non-native forb and annual grass prairies; displacement of *Festuca [idahoensis] roemerii* as the dominant species and absence of several forbs and grasses indicates prairie is not adapted to annual fire. Shows prescribed fire at 3–5 year intervals maintains diverse prairies that approximate natural vegetation; sampled plant communities were well-distributed, ~40% fescue, ~22.5% mixed forbs with other native grasses, ~22.5% mosses and other cryptogams. Notes this response is similar to other prairie fire studies in the positive response of native fescue and in rapid post-fire growth; forb cover did not increase, however, which differs from several other studies. Keywords: conservation; fire; invasive species; management; military; plant community; prairie; restoration.*

- [239] U.S. Army, 2004. 2004 Range and Training Lands Assessment. U.S. Army Sustainable Range Program, Fort Lewis, WA, 141 pp.

Prairie habitat of high ecological value where substantial military training occurs exists on ~20,000 acres on Fort Lewis. Range and Training Land Assessment (RTLA; formerly Land Condition Trend Analysis) collects butterfly, bird, and vegetation data; monitors land resources; gives results to Range Division and Army trainers; prevents “detrimental consequences.” Includes workplan and multiple documents assembled as one report. LCTA Butterfly Survey presents results from 38 surveys on 4 transects; surveys began in 1997; Taylor’s checkerspot extirpations discussed; indicates none observed in 2004. States “butterflies have the potential to

impact training on FLMR more than any other species if federally listed”; recommends management strategies for butterfly habitat, coordination of land management, and education of military land users about sensitive species. Mapping Field Report incorporates survey data into GIS; maps give an overview of vegetative quality of individual prairies; guides land use decisions. Prairie Quality Ranking Protocol designed to quickly assess prairie habitat biodiversity value and protection priority on an annual basis using a uniform methodology to assess a series of ecological features and conditions across multiple prairies, which are ranked using coarse and fine ecological filters; vegetation and disturbance data collected in 10m² plots; species richness and abundance data from 1m² plots. Field tested on 13th Division and Lower Weir Prairies, and at Scatter Creek Prairie to compare with data from Fort Lewis. Keywords: butterfly conservation; conservation; data; disturbance; habitat; military; prairie; restoration.

- [240] U.S. Army, 2005. Fort Lewis Integrated Training Area Management (ITAM) Program 2005 Reports. Fort Lewis, WA, 149 pp.

Includes workplan and multiple documents assembled as one report. RTLA 2005 field reports include bird and butterfly surveys. The 2005 butterfly report states a new Taylor’s checkerspot colony on Range 74/76 was discovered in 2004 and that no more than 50 butterflies were observed on any given day; 2004 Report states NO checkerspots were observed. 2005 report indicates >1,000 individuals were observed on one day on Range 74/76 and hundreds were recorded on other days; also indicates search effort was greater this year than in 2004. Some checkerspots were observed adjacent to 74/76 but none were located at historically occupied sites; WDFW biologist Potter recommends refinements to make permanent transects and a database redesign. LRAM land condition mapping report explains Scotch broom removal procedures and native plant propagation. Keywords: conservation; data; disturbance; habitat; invasive species; military; prairie; restoration.

- [241] U.S. Army, 2007. Fort Lewis Integrated Training Area Management (ITAM) Program 2007 Reports. Fort Lewis, WA, 141 pp.

Includes workplan and multiple documents assembled as one report. Describes the Conservation Candidate Agreement (CCA) entered into with regional partners. RTLA 2007 butterfly report indicates distance sampling as an additional survey technique that estimates density and controls for differences in detectability between years was developed for Fort Lewis’ monitoring needs by WDFW biologists; they will be responsible for data analysis. Other methods used here include long-term transect monitoring, spot searches, and block counts. RTLA goals are to assist in developing an accurate and efficient regionally-accepted monitoring method for Taylor’s checkerspot; establish a minimum population estimate for the area surveyed to assess impacts of collecting animals for captive rearing; test the distance sampling method; and reduce the overall level for survey effort. Taylor’s checkerspots were present on the AIA in 2007; report explains a peak daily count of 637 for Range 74/76 does not represent a population estimate because the colony is using a larger area but further access is restricted. LRAM land condition mapping report discusses Scotch broom and tall oatgrass control, surveys for target species. Keywords: conservation; data; disturbance; habitat; invasive species; military; prairie; restoration.

- [242] U.S. Army, 2008. Fort Lewis Integrated Training Area Management (ITAM) Program 2008 Reports. Fort Lewis, WA, 194 pp.

Includes workplan and multiple documents assembled as one report; provides comprehensive reports about all conservation and restoration activities; considerably expanded for 2008. Selected quote: "Fort Lewis prairies provide essential habitat for the U.S. Army to meet its military mission of training combat forces for deployment throughout the world." Long-term transects, block counts, spot searches, and distance sampling used for butterfly surveys; Taylor's checkerspot observed on and adjacent to Range 76 during block counts and distance sampling. Reports that the continued decline in numbers over the past few years concerns biologists; notes that since data have been collected by RTLA since 2004, they are in an excellent position to guide training activities and recommend actions that are butterfly-neutral. Keywords: conservation; data; disturbance; habitat; invasive species; military; prairie; restoration.

- [243] U.S. Fish and Wildlife Service, 1999. Recovery plan for the Quino checkerspot butterfly (*Euphydryas editha quino*). U.S. Fish and Wildlife Service, Portland, OR, pp. x + 1–179.

*Recovery strategy focuses on landscape-level protections for Quino checkerspot metapopulations that experience marked fluctuations in density and geographic distribution on a scale of 5 to 10 years; threats include substantial habitat losses and declines in suitability throughout the species' range due to urban and agricultural development, habitat fragmentation and degradation, invasive non-native species and other human-caused disturbances; conservation needs include protection and management of connectivity between habitat patches and intervening areas, habitat restoration and enhancement, and development of a captive breeding program. Describes species' taxonomy; life history; distribution; habitat requirements and limiting factors; and current and evolving conservation measures. Notes long-term restoration and management efforts are required, possibly in perpetuity; discusses various issues related to habitat restoration, specific methods and requirements (e.g., larval habitat requirements; variety selection and seed collection of native forbs for revegetation; restoring cryptogamic crusts; implementing adaptive management techniques). Keywords: ESA; *Euphydryas editha quino*; habitat conservation.*

- [244] U.S. Fish and Wildlife Service, 2003. Recovery plan for the serpentine soil species of the San Francisco Bay area. U.S. Fish and Wildlife Service, Portland, OR, pp. xi + 1–330 + appendices.

Multi-objective multi-species community-level recovery strategy for Bay checkerspot butterfly, 13 listed plants, and 14 additional animals and plants of conservation concern occurring primarily or exclusively on CA serpentine soils and grasslands; explains the natural patchy distribution of serpentine environments, and that all species covered under the plan are threatened by loss of this specialized habitat and by fragmentation of the few larger remaining blocks of habitat. For the butterfly, describes historical and recent distribution; population trends; habitat, including the critical influence on multiple life-stages of topographic diversity; and extensive life history information. Discusses reasons for its decline, assesses threats to its survival (i.e., habitat loss and fragmentation; invasive plants; negative and positive impacts of grazing and fire – both recognized as important management tools to reduce non-native plants in grassland habitat;

effects of air pollution and excess N-deposition; effects of climate change; and impacts of research), and details ongoing conservation efforts and recommended strategies for recovery; lists specific recovery goals, objectives, and criteria, and recommended actions, including habitat protection and management in perpetuity. Distribution, threats, recommendations are directly relevant to Taylor's checkerspot and its habitat in fragmented prairie habitat. Keywords: ESA; Euphydryas editha taylori; grasslands; habitat conservation.

- [245] U.S. Fish and Wildlife Service, 2010a. Species assessment and listing priority: *Euphydryas editha taylori*. U.S. Fish and Wildlife Service, Lacey, WA, 24 pp.

Annual review. Comprehensive presentation of most relevant information available about Taylor's checkerspot, compiled by species lead at USFWS western Washington field office. Includes taxonomy and species description, habitat and life history, historical range and distribution, current range and distribution, and population estimates. Explains threats and the rationale for listing priority based on the magnitude and imminence of threats. Details conservation measures planned or implemented and recommends conservation measures. Keywords: ESA; Euphydryas editha taylori; habitat conservation; prairie.

- [246] U.S. Fish and Wildlife Service, 2010b. Recovery plan for the prairie species of western Oregon and southwestern Washington. U.S. Fish and Wildlife Service, Portland, OR, pp. xi + 1–241.

Multi-objective multi-species recovery strategy for Fender's blue butterfly and four listed plants that incorporates OR-specific recommendations for golden paintbrush, previously listed, and addresses five additional plants of conservation concern — and Taylor's checkerspot butterfly. The strategy to achieve recovery for these species "is to restore and maintain multiple viable populations [...] by protecting, restoring, maintaining, and connecting the remaining fragments of prairie habitats within their historical range. These areas should be restored to functional prairie ecosystems with management that restores and maintains a diversity of native species typical of these prairie communities." Provides information about prairie habitat and ecology; describes population trends, distribution, life history, ecology, habitat characteristics, threats and reasons for decline, and ongoing conservation; assesses the threats; and lists specific recovery goals, objectives, criteria, and actions recommended. Keywords: ESA; Euphydryas editha taylori; habitat conservation; prairie; restoration.

- [247] U.S. Fish and Wildlife Service, 2012a. Endangered and threatened wildlife and plants; listing Taylor's checkerspot butterfly and streaked horned lark and designation of critical habitat; proposed rule. Federal Register 77, 61938–62058.

Proposal to list Taylor's checkerspot as an endangered species and designate critical habitat under ESA. Provides a thorough review that augments and draws extensively on annual reviews (e.g., USFWS 2010a) and the USFWS candidate assessment (2001); includes habitat and life history, historical and current range and distribution, and population status. After a detailed review of threats, determines that the butterfly is presently in danger of extinction throughout its entire range, based on the immediacy, severity, and scope of threat factors and severe reduction of

its range and population size, and that it meets the ESA definition of an endangered species. Keywords: ESA; Euphydryas editha taylori; HCP; habitat conservation; prairie.

- [248] U.S. Fish and Wildlife Service, 2012b. Literature cited for listing Taylor's checkerspot butterfly and streaked horned lark and designation of critical habitat. Accessed 25 October 2012, <http://www.regulations.gov/#!documentDetail;D=FWS-R1-ES-2012-0080-0002>, U.S. Fish and Wildlife Service, Lacey, WA, 31 pp.

Reference, U.S. Fish and Wildlife Service, 2012a. Keywords: data; ESA; Euphydryas editha taylori; habitat conservation; prairie.

- [249] Van Dyck, H., 2012. Changing organisms in rapidly changing anthropogenic landscapes: the significance of the "umwelt"-concept and functional habitat for animal conservation. *Evolutionary Applications* 5, 144–153.

Argues that thought about habitat and habitat selection should be integrated with the umwelt concept from ethology, referring to the idea that different organisms live in different perceptual worlds dealing with specific subsets of the environment as a result of their evolutionary and developmental history. Believes this approach may offer new opportunities for conservation; help avoid failures with habitat restoration; and improve the realism of fragmentation models. Contends perception may be subject to adaptive change and may also constrain organisms from adaptive behaviors in rapidly changing environments. Discusses human interference with animal information processing (e.g., light pollution that alters habitat quality and ecological cues organisms use to deal with their environment; noise impact on the foraging efficiency of acoustic predators; reflective surfaces that attract insects that use polarized light to locate water surfaces). Illustrates perceptual differences for butterflies with results from field experiments: females scanned a landscape matrix well outside damp meadows where host plants grow, readily found and deposited large quantities of eggs on >70% of host plants placed far from 'suitable' habitat; and in a species whose distribution and abundance is expanding, wild-caught individuals from an agricultural landscape detected target habitat from a greater distance than forest butterflies. Notes structural habitat units (e.g., land cover types) as human constructs may not represent functional habitat units for other organisms; and habitat use is not a species-specific fixed trait but shows intraspecific variation. Acknowledges that conservationists may wonder about the practical relevance and feasibility of the umwelt concept; cites a growing recognition for the significance of behavioral studies and evolutionary thinking in conservation biology and ecology. Argues a directly relevant issue: accepted definitions of suitable habitat may constrain new opportunities for conservation and restoration in landscapes under intense human use. Keywords: butterfly conservation; conservation; habitat; restoration.

- [250] Van Dyck, H., Van Strien, A.J., Maes, D., Van Swaay, C.A.M., 2009. Declines in common, widespread butterflies in a landscape under intense human use. *Conservation Biology* 23, 957–965.

Reevaluates population trends of common, widespread species that are more typically unaffected while rare and localized butterflies show losses. Analyzes 16 years (1992–2007) of transect

counts from The Netherlands; study area has long history of intensive agriculture, urbanization, industrialization. Cumulative abundance declined by ~ 30%; 55% of common species (11 of 20) suffered severe declines in distribution and abundance. Some declining species were omnipresent in gardens and parks; 2 were former agricultural pests. Butterflies in urban, farmland, and woodland areas had the largest declines in abundance; species associated with vegetation types found mainly in nature reserves, including, to some extent, semi-natural grassland increased or remained stable. Notes that comparisons with life-history traits are beyond the scope, but most declining species are univoltine with less trait plasticity. Keywords: butterfly conservation.

- [251] Van Noordwijk, C.G.E., Flierman, D.E., Remke, E., WallisDeVries, M.F., Berg, M.P., 2012. Impact of grazing management on hibernating caterpillars of the butterfly *Melitaea cinxia* in calcareous grasslands. *Journal of Insect Conservation*, online early.

Measures effects of sheep grazing (i.e., high and low intensity grazing; ungrazed control treatment) on overwinter larval survival for a grassland butterfly (Melitaea cinxia) whose larvae hibernate in silk nests. Reports 64% of nests with high intensity grazing were damaged or missing compared with 12% at low intensity, 8% ungrazed; nest volume and larval survival were 50% lower at high intensity compared to ungrazed and low intensity treatments. Damage and increased mortality mainly caused by incidental ingestion of caterpillars by sheep. Concludes grazing may similarly affect other invertebrates, depending on location in plants, ability to avoid herbivores; and grazing impact strongly depends on timing of management in relation to species' phenology. Argues that for many insects, grazing is essential to conserve semi-natural grassland habitat, but greater focus on immature and inactive life-stages in conservation policy in general and particularly in endangered species action plans is required to effectively preserve invertebrate diversity. Keywords: grassland butterflies; grazing; larval survival; management.

- [252] Vanreusel, W., Van Dyck, H., 2007. When functional habitat does not match vegetation types: a resource-based approach to map butterfly habitat. *Biological Conservation* 135, 202–211.

Describes and tests a procedure to recognize and delineate habitat according to a resource-based approach instead of a vegetation-based approach. Argues that terrestrial habitat is often defined as physical patches of a certain vegetation type in a matrix of non-habitat but ecological resources that make up the habitat may only cover subsets of vegetation types or are spatially dispersed in a complex way over different vegetation types, thus recognition of a species' habitat is ambiguous. Selects zones that comprise essential resources, conditions, and key thermal constraints within a suitable spatial window; calculates larval, adult and combined habitat indices in a GIS, using variables retained in a logistic regression model; derives space-use measure from mark-release-recapture data to group different and scattered ecological resources into functional habitat zones; uses least-cost modeling to adapt the spatial window to the vegetation between sets of resources. Describes habitat using this approach that matches observed butterfly distribution significantly better than did a classic approach based on vegetation types with host plants only; useful output for conservation purposes; recognizes zones with the highest potential for habitat restoration. Keywords: butterfly conservation; butterfly distribution; GIS; habitat; model; restoration.

- [253] Verdasca, M.J., Leitão, A.S., Santana, J., Porto, M., Dias, S., Beja, P., 2012. Forest fuel management as a conservation tool for early successional species under agricultural abandonment: The case of Mediterranean butterflies. *Biological Conservation* 146, 14–23.

Examines long-term consequences of fuel management on butterfly communities. Focuses on regions where scrub and forest encroachment have led to homogenized landscapes and loss of early-successional habitats and where forestry practices to reduce fire hazard are primarily mechanical removal of understory vegetation (vs. prescribed fire) within oak stands. Consistent positive effects (richness and abundance) only observed for species with univoltine life cycles, herbaceous layer feeding, larval overwintering, and medium body size; for these butterflies, effects significant at $p < 0.001$. Overall species richness increased immediately after management; abundances peaked 2–3 years later; both then declined for about 10–20 years to pre-disturbance levels. Most life history groups showed similar trends. Most individual species were associated with recurrent management; a few specialists occurred in undisturbed stands. Suggests fuel management at <10 years intervals to promote habitat heterogeneity and landscape mosaics is strongly positive for butterfly assemblages; patches of undisturbed habitat should also be retained. Keywords: butterfly conservation; disturbance; fire; insect response; management; time.

- [254] Vesely, D.G., Rosenberg, D.K., 2010. Wildlife conservation in the Willamette Valley's remnant prairies and oak habitats: a research synthesis. Submitted to Interagency Special Status Sensitive Species Program, U.S. Forest Service/Bureau of Land Management, Portland, OR, Oregon Wildlife Institute, Corvallis, OR, 131 pp.

Review of wildlife studies, intended for managers and researchers to help guide conservation and restoration efforts in western Oregon prairie and oak communities. States invertebrate fauna are least understood; indicates their most striking finding was the large number of in-depth (i.e., with formal experimentation, statistically valid sampling designs) regional studies of butterfly responses to restoration (mostly for Fender's blue), in contrast to observational studies for vertebrates. Discusses challenges of selecting indicator variables; notes butterfly studies generally measure response to restoration using a variety of metrics rather than relying on measures of abundance. Keywords: butterfly conservation; habitat; insect response; prairie; restoration.

- [255] Vogel, J.A., Debinski, D.M., Koford, R.R., Miller, J.R., 2007. Butterfly responses to prairie restoration through fire and grazing. *Biological Conservation* 140, 78–90.

Evaluates effects of three restoration practices (i.e., grazing, burning, and burning and grazing) on the vegetation characteristics and butterfly communities of remnant prairies. Total butterfly abundance was highest on prairies managed with burning and grazing and lowest on those only burned. Butterfly species diversity was highest on sites that were only burned; butterfly species richness did not differ among practices. In the best predictive regression model, total butterfly abundance was negatively associated with the percent cover of bare ground and positively associated with the percent cover of forbs. Each restoration technique supported a different suite of butterfly species; communities were equally species rich yet compositionally different. Responses of individual species were highly variable. Concludes that because of the variation in responses to

different restoration practices, no single practice that will benefit all species or even all species within habitat-specialist or habitat-generalist habitat guilds. Keywords: disturbance; fire; grassland butterflies; insect response; management; prairie; restoration; time.

- [256] Vogel, J.A., Koford, R.R., Debinski, D.M., 2010. Direct and indirect responses of tallgrass prairie butterflies to prescribed burning. *Journal of Insect Conservation* 14, 663–677.

Investigates direct mortality and indirect effects (i.e., changes in composition and structure of vegetation; increases in the cover of bare ground) of time since prescribed burning on grassland butterfly abundance and species richness and how these metrics and the composition of remnant prairie vegetation change in relation to time since fire. Finds that recovery times for butterfly populations are potentially longer than those previously reported. Keywords: disturbance; fire; grassland butterflies; insect response; management; prairie; restoration; time.

- [257] Wagner, D.L., Van Driesche, R.G., 2010. Threats posed to rare or endangered insects by invasions of nonnative species. *Annual Review of Entomology* 55, 547–568.

Review; principal data sources were Federal Register ESA-listing proposals. Assesses relative frequency of threats (16 endangerment categories) for insects of conservation importance (57 ESA-listed species + 116 rare eastern North America butterflies). Determines more insects overall are at risk from invasive species than any other threat; notes impacts can cascade through communities, destabilize trophic interconnections, alter ecosystem properties (e.g., hydrology, fire susceptibility, light availability, nutrient cycles, soil chemistry), change other biotic and abiotic parameters. Compares the two groups (i.e., ESA-listed insects vs. eastern butterflies); threats are very different aside from invasive species and development. The top-ranked six primary threats for all USFWS federally endangered and threatened insects are the primary threats listed for Taylor's checkerspot (USFWS, 2012a) (i.e., "habitat loss through conversion and degradation of habitat, particularly from agricultural and urban development, successional changes to grassland habitat, military training, and the spread of invasive plants"); threat combinations and some category names are the only difference. Keywords: ESA; butterfly conservation; invasive species.

- [258] Wahlberg, N., Klemetti, T., Selonen, V., Hanski, I., 2002. Metapopulation structure and movements in five species of checkerspot butterflies. *Oecologia* 130, 33–43.

*Studies rates and patterns of migration of females and males in five closely-related ecologically similar checkerspots, two *Euphydryas* spp., three *Melitaea* spp., using biological and statistical models. Notes data sets they collected were challenging material for comparative study; no two were similar. Connectivity and average patch sizes varied between each fragmented landscape. Concludes habitat patch area has a substantial effect on movement; large patches more likely than small ones to receive immigrants; butterflies were more likely to leave small rather than large patches. Keywords: butterfly distribution; *Euphydryas* spp.; fragmentation; grassland butterflies; habitat patch; metapopulation; model.*

- [259] Walker, K.J., Stevens, P.A., Stevens, D.P., Mountford, J.O., Manchester, S.J., Pywell, R.F., 2004. The restoration and re-creation of species-rich lowland grassland on land formerly managed for intensive agriculture in the UK. *Biological Conservation* 119, 1–18.

Review of key constraints on restoration of grasslands from agricultural land (e.g., responses of aggressive species to N-deposition; lost specialist flora and fauna associated with semi-natural grasslands) and of various techniques used to restore and re-create grasslands (e.g., extensive cutting and grazing management, sowing with diverse seed mixtures). Argues that although restored landscapes are likely to contribute to biodiversity, restoration success will ultimately depend on reinstating communities and ecological functions of reference ecosystems; while it is technically feasible to re-create a few plant assemblages, less is known about re-assembly of fungal, microbial and faunal communities or the importance of trophic interactions during grassland succession. Concludes more research is required on functional attributes of semi-natural grasslands, as well as methods required to restore local ecotypes, balance site-specific nutrients, phase introduction of desirable but poor-performing species, and assess performance of different genotypes during restoration. Keywords: biodiversity; grasslands; plant community; restoration.

- [260] WallisDeVries, M.F., Baxter, W., Van Vliet, A.J.H., 2011. Beyond climate envelopes: effects of weather on regional population trends in butterflies. *Oecologia* 167, 559–71.

Agrees that effects of climate change on biodiversity are increasingly evident by shifts in ranges across taxa, but underlying mechanisms that affect individual species are poorly understood. Argues that climate envelope models overestimate the positive effects of climate change in northwestern Europe; their power to predict future ranges has been seriously questioned in recent studies. Analyzes correlations between butterfly abundance and weather during their life cycles; 15 successive years of data. Significant weather effects were obtained for 39 of 40 species, most frequently associated with temperature. Data from warm dry 2003 indicate negative effects of climatic extremes generally underestimated for habitat specialists in drought-susceptible habitats, whereas generalists remain unaffected (could apply to PNW). Supports other findings about importance of including population trends in predicting range shifts in response to climate change. Keywords: biodiversity; butterfly population; climate change; model; weather.

- [261] Warren, M.S., 1993. A review of butterfly conservation in central southern Britain: II. Site management and habitat selection of key species. *Biological Conservation* 64, 37–49.

Examines management for conservation, habitat selection and use of agricultural land in fragmented habitats by key butterfly species in southern Britain. Describes short-term gains, but habitats on sites not managed either for agriculture or conservation are steadily deteriorating with serious implications for butterflies, distinct plant and animal communities they support. On managed sites, little preference was found between sheep and cattle grazing for most species. Keywords: butterfly conservation; fragmentation; grazing; habitat.

- [262] Warren, S.D., Holbrook, S.W., Dale, D.A., Whelan, N.L., Elyn, M., Grimm, W., Jentsch, A., 2007. Biodiversity and the heterogeneous disturbance regime on military training lands. *Restoration Ecology* 15, 606–612.

*Argues that large numbers of threatened and endangered species and unusually high biodiversity occur on active and former military training areas; many species flourish due to disturbance, not despite it, although military training is not the ideal disturbance vector. Reviews nature and extent of disturbances and landscape heterogeneity (e.g., mosaics of habitat include a continuum of disturbance and succession; large areas virtually untouched, favoring disturbance-averse species; heavily disturbed areas favoring disturbance-dependent species). Provides illustrations from various taxa as support (e.g., grasses that need disturbance for seedling establishment; birds that take advantage of mudflat islands created by amphibious vehicles; and pronghorn antelope that prefer high-explosive target areas, presumably in response to increased productivity of forbs and grasses). Endangered butterflies are used as examples: northern Europe's most important site for *Euphydryas aurinia* is Salisbury Plain Training Area, because its requisite host plant is an early successional species that thrives with periodic burning on the firing range; Karner blue butterfly depends on one host, and both lupine and butterfly are positively correlated with a suite of training activities, including vehicle traffic, bivouacking, and fires caused by munitions. Taylor's checkerspot on the AIA at JBLM would be a third example. Keywords: biodiversity; disturbance; *Euphydryas* spp.; fire; grassland butterflies; insect response; military.*

- [263] Warren, S.D., Scifres, C.J., Teel, P.D., 1987. Response of grassland arthropods to burning: a review. *Agriculture, Ecosystems & Environment* 19, 105–130.

Review focuses on response of arthropod species to prescribed burning from the perspective of manipulating (i.e., eradicating) populations. Develops model that correlates arthropod responses with sequential stages of burning impacts (i.e., pre-burn fuel development, combustion, shock, and ecosystem recovery). Directly incorporates habitat alterations — e.g., with vegetation and soil litter gone, soil temperature, insolation, and wind increase, soil moisture and humidity decrease, soil chemistry is modified — exposure, desiccation, and predation can lead to mortality. Claims larvae in diapause in the soil are not likely to be affected by slight temperature increases generated by passing fire, or will seek refuge within dense clumps of bunchgrass, in soil cracks, under rocks. Argues that grassland burning stimulates an array of reactions depending upon interactive factors, and that most accounts do not relate population changes to fire behavior; instead, comparisons are made between those on burned areas and on unburned areas, with inferences as to fire effects. How to kill them, how and where they survive is relevant for how not to kill insects. Keywords: fire; grasslands; habitat quality; insect response.

- [264] Washburn, A.L., 1988. Mima Mounds: an evaluation of proposed origins with special reference to the Puget Lowlands. Washington State Department of Natural Resources Division of Geology and Earth Resources Report of Investigations 29, pp. iv + 1–53.

Surveys multiple hypotheses; critically reviews most plausible explanations for the origin of the Mima mounds that occur across a large swath of the south Puget Sound lowlands, including on Mima Prairie. Compares similar landforms in other regions of North America; presents maps,

photographs, cross-section diagrams; investigates soils, grain-size distribution on and between mounds, mound orientation. Knowledge of geology, soils, microtopography and historical conditions are relevant for restoration of vegetation and habitat. Keywords: prairie; topography.

- [265] Washington Department of Fish and Wildlife, 2005. Washington's comprehensive wildlife conservation strategy. Final draft submitted to the U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, Olympia, WA, pp. vi + 1–619 + appendices 1–18.

Wildlife Action Plans are developed by each U.S. state and territory: 1) to conserve species before they become too rare; 2) before conservation actions become more costly; and 3) to qualify for federal funding. Relevant to TCB; providing insight to WDFW policies: Volume 1, Chapter I: introduction and background; Chapter VII: monitoring and adaptive management; Volume 2: approach and methods; Appendices 1–3, 9, 10: CWCS Species of Greatest Conservation Need; SGCN Status and Trend Checklist; SGCN Conservation Problems and Actions Checklist. Keywords: butterfly conservation; conservation; habitat; management; monitoring.

- [266] Washington Department of Fish and Wildlife, 2006. South Puget Sound wildlife area management plan. Washington Department of Fish and Wildlife, Olympia, WA, 67 pp.

Describes management plans for parcels owned or managed by WDFW as Wildlife Areas. Habitat for Taylor's checkerspot at: 1) Scatter Creek, largest areas of high-quality native prairie habitat off Joint Base Lewis-McChord; 2006 actions included enhancement, invasive species control for Scotch broom and tall oatgrass, and evaluation for potential butterfly reintroduction; and 2) West Rocky Prairie, mentioned here but no 2006 plans or activities. Keywords: habitat conservation; invasive species; prairie; restoration.

- [267] Washington Department of Fish and Wildlife, 2012. Threatened and endangered wildlife in Washington: 2011 annual report. Washington Department of Fish and Wildlife, Olympia, WA, 180 pp.

*Describes Taylor's checkerspot pp. 75–77; includes general species overview; updates on current conservation actions in Clallam County; genetics research; notes that captive-rearing and reintroduction combined with intensive habitat management have met with preliminary success on Puget Sound prairies. Keywords: butterfly conservation; *Euphydryas editha taylori*.*

- [268] Washington Department of Natural Resources, 1997. Final habitat conservation plan. Final draft submitted to the U.S. Fish and Wildlife Service, Washington Department of Natural Resources, Olympia, WA, 546 pp.

Initially prepared as a multi-species HCP for WDNR state trust forest lands within the range of the ESA-listed northern spotted owl, the HCP also covers DNR Natural Area Preserves that are historical habitat for Taylor's checkerspot, including Bald Hills NAP, Rocky Prairie NAP, and Mima Mounds NAP. With the proposed listing of the butterfly, areas managed by WDNR

are proposed for exclusion from designation of critical habitat (USFWS 2012a). Keywords: balds; ESA; habitat conservation; HCP; prairie.

- [269] Weiss, S.B., 1999. Cars, cows, and checkerspot butterflies: nitrogen deposition and management of nutrient-poor grasslands for a threatened species. *Conservation Biology* 13.

Demonstrates threats to Bay checkerspot butterfly and overall effects on local biodiversity of the interaction between three components of human-induced global change: land-use alterations, invasive species, and N-deposition from air pollution. Describes the process: urbanization led to fragmentation and loss of specialized habitat in nutrient-poor CA serpentine-soil grasslands, and a further land-use change, removal of cattle grazing, allowed invasive non-native grasses fertilized by smog-induced N-deposition to dominate habitat. Recommends interdisciplinary research and suggests moderate grazing as a management response; results can be diverse native ecosystems where grazers eat the grass, cycle and redistribute nutrients, disturb the soil surface, and provide sites for native species to germinate. Keywords: Euphydryas editha bayensis; N-deposition; biodiversity; grazing; invasive species; management.

- [270] Weiss, S.B., Murphy, D.D., Ehrlich, P.R., Metzler, C.F., 1993. Adult emergence phenology in checkerspot butterflies: the effects of macroclimate, topoclimate, and population history. *Oecologia* 96, 261–270.

Models adult emergence patterns of Bay checkerspots to simulate post-diapause development in topographically-heterogeneous habitat using slope-specific daily insolation values as the rate-controlling variable to account for cloud cover and solar exposure. Emergence curves are predicted as a function of varying topographic conditions, weather patterns, larval distributions, and mortality. Notes adult emergence times determine adult reproductive success in Bay checkerspots; phenological predictions provide insight on population dynamics and can be incorporated into management. Keywords: butterfly population; Euphydryas editha bayensis; insolation; larvae; microclimate; topography.

- [271] Weiss, S.B., Murphy, D.D., White, R.R., 1988. Sun, slope, and butterflies: topographic determinants of habitat quality for *Euphydryas editha*. *Ecology* 69, 1486–1496.

Demonstrates the effect of slope and aspect in determining the temperature and hence habitat choice of invertebrates in grassland habitats. Combines observational and experimental studies of the phenologies of butterfly life stages and host plants in a habitat that supports a dense, large population with theoretical modeling of solar exposure characteristics to initiate a quantitative assessment of the roles that microclimates on different slope exposures play in determining the phase relationship between the adult flight period of Bay checkerspot and the senescence of its host plants. Keywords: Euphydryas editha bayensis; habitat quality; insolation; topography.

- [272] Weiss, S.B., Weiss, A.D., 1998. Landscape-level phenology of a threatened butterfly: a GIS-based modeling approach. *Ecosystems* 1, 299–309.

*Presents a spatially explicit GIS-based phenological model that predicts population-wide adult butterfly emergence using various input types: field data on larval distribution and abundance; a larval growth model; daily weather; and a topographic habitat model. GIS improvements on the original phenological model include continuous slope and aspect ranges and hillshading to account for delayed emergence in deep canyons. Keywords: butterfly phenology; climate; *Euphydryas editha bayensis*; GIS; insolation; larvae; microclimate; topography; weather.*

- [273] Weiss, S.B., White, R.R., Murphy, D.D., Ehrlich, P.R., 1987. Growth and dispersal of larvae of the checkerspot butterfly *Euphydryas editha*. *Oikos* 50, 161–166.

*Argues that habitat heterogeneity rather than habitat area may be the crucial determinant of habitat quality for Bay checkerspot. Investigates how growth and movement of sixth (last) instar larvae vary with ground-level insolation, which is determined by slope exposure and date, and how these factors determine timing of pupation and adult flight. Infers from this how topographic heterogeneity of a habitat can determine population persistence. Results consistent with observations during an extended drought that dense populations in large topographically homogeneous areas declined severely or were extirpated but less dense populations in small heterogeneous areas persisted. Keywords: *Euphydryas editha bayensis*; habitat heterogeneity; habitat quality; insolation; larvae; microclimate; topography.*

- [274] Williams, D.W., Jackson, L.L., Smith, D.D., 2007. Effects of frequent mowing on survival and persistence of forbs seeded into a species-poor grassland. *Restoration Ecology* 15, 24–33.

Evaluates forb seedling establishment in a 25-year-old prairie planting dominated by undesirable native grasses (midwest prairie; warm-season C4 grasses). Recently burned plots were broadcast-seeded in winter with 23 native forb species at a rate of 350 viable seeds/m². Treatment plots mowed weekly; control plots unmowed. Forbs in mowed plots had significantly greater root and shoot mass than those in controls in the first and second growing seasons but were not significantly more abundant; by the fourth season, forbs were twice as abundant in the mowed treatments. Suggests that mowing reduced competition for light from large established grasses, allowing forb seedlings the opportunity to reach sufficient size to establish, survive, and flower in the second and subsequent years. Keywords: forbs; grasslands; invasive species; mowing; prairie; restoration; seed.

- [275] Wilson, M.V., Clark, D.L., 2001. Controlling invasive *Arrhenatherum elatius* and promoting native prairie grasses through mowing. *Applied Vegetation Science* 4, 129–138.

*Evaluates effects of different mowing regimes on non-native and invasive perennial grass *Arrhenatherum elatius*, native perennial prairie grasses *Danthonia californica* and *Festuca roemerii*, and groups of other native and non-native grasses and forbs as elements of prairie conservation and restoration efforts. Demonstrates an increase in native plant abundance using invasive plant control: four years of the most effective treatment, mowing at 15 cm in late spring, converted an *Arrhenatherum*-dominated site to a prairie dominated by native grasses.*

Differences emerged after two or three years, reinforcing need for long-term studies. Keywords: fescue; grasslands; invasive species; mowing; prairie; restoration; tall oatgrass.

- [276] Wold, E.N., Jancaitis, J.E., Taylor, T.H., Steeck, D.M., 2011. Restoration of agricultural fields to diverse wet prairie plant communities in the Willamette Valley, Oregon. *Northwest Science* 85, 269–287.

Describes a strategy developed for restoring highly degraded intensively managed agricultural sites to native wet prairie that integrates relevant scientific research and lessons learned from previous restoration experience, with a particular focus on sequencing disturbance, colonization, and competitive actions to achieve desired outcomes. Reports monitoring results from projects where this implementation strategy was used; by the second season after seeding, all had more than 40 native species, native cover exceeded 90%; after five years, % cover of native annuals decreased and % cover of native perennials increased, consistent with predictions from succession. Strategy can assist landowners and managers to restore diverse prairie communities from highly disturbed agricultural sites. Keywords: biodiversity; plant community; prairie; restoration; seed.

- [277] Woodcock, B.A., Bullock, J.M., Mortimer, S.R., Brereton, T.M., Redhead, J.W., Thomas, J.A., Pywell, R.F., 2012. Identifying time lags in the restoration of grassland butterfly communities: A multi-site assessment. *Biological Conservation* 155, 50–58.

Review of grassland restoration in Europe. Investigates success at UK enhancement sites, where degraded grasslands are restored by scrub removal followed by renewal of cutting/grazing, and “arable reversion” sites, where grassland is established by seeding bare ground. Individual butterfly traits and ecological characteristics important in determining colonization times; these were fastest for species with widespread host plants or where host plants established well during restoration. Low mobility butterfly species took longer to colonize. Argues that restoration success takes time to achieve and there is a lack of information on long-term effects of management but restoration will contribute to the recovery of butterfly populations. Consistent increases over time in restoration success were seen for sites starting from bare ground, with rapid rates of increase seen over the first 10 years; for grasslands enhancement there were no consistent increases in restoration success over time. Keywords: butterfly conservation; grasslands; habitat; restoration.

- [278] Zonneveld, C., Longcore, T., Mulder, C., 2003. Optimal schemes to detect the presence of insect species. *Conservation Biology* 17, 476–487.

Argues that detection probability estimates are crucial for insect conservation in many situations, including decisions about appropriate management efforts when a species has not been recorded present in historically suitable habitat (e.g., at detection probability 0.99, it is likely extirpated, and reintroduction efforts might proceed; at 0.75 probability, there is less certainty, and the choice may instead be specific enhancement efforts); in a regulatory context (e.g., protection for habitat is usually extended under ESA when a listed species is present; unoccupied habitat is not often protected); or to make more confident assessments of a species’ range or range shift. Presents a model to maximize species detection and reduce uncertainty about absence; describes abundance of a single, discrete generation of adult insects, attributes year-to-year variation in flight period

to peak emergence variation, and calculates probability of detecting the species based on number of survey days that minimize chances of missing a species when it is actually present. Scheme for Quino checkerspot butterfly an example. Keywords: butterfly conservation; butterfly population; ESA; habitat conservation; monitoring.