

Selectively eliminating and conserving exotic plants to save an endangered butterfly from local extinction

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Keywords

microevolution; host plant evolution; habitat selection; exotic species; *Brachypodium*; habitat quality.

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Received 28 March 2008; accepted 12 August 2008

doi:10.1111/j.1469-1795.2008.00203.x

Abstract

Rare butterfly conservation requires understanding of butterfly interactions with the resource conditions that influence population growth. Exotic plant invasions can reduce butterfly population size and growth by displacing key resources, degrading habitat conditions and directly impacting fitness, but exotic plants may also be incorporated into native butterfly diets, rendering practicing conservation biologists a choice between exotic plant control and butterfly population persistence. *Euphydryas editha taylori* (Nymphalidae), a candidate endangered butterfly species in the Pacific Northwest of North America, switched from an unknown native larval host plant to become entirely dependent on an exotic larval host *Plantago lanceolata* in extant western Oregon populations. Furthermore, the last Oregon butterfly populations are surrounded by two exotic grasses, *Brachypodium sylvaticum* and *Festuca arundinacea*, both of which can dominate remnant native prairies and degrade native grassland structural conditions. When given a choice of habitat conditions, *E. e. taylori* oviposited on larval host plants surrounded by increasing abundance of short-statured native bunchgrasses and adult nectar resources, indicating that females select egg-laying sites based on habitat conditions rather than just host plant presence. Both larval and adult resources substantially diminished with increasing cover of exotic grasses and were nearly absent when *B. sylvaticum* and *F. arundinacea* dominated. Butterfly resource loss with increasing exotic grass cover, the documentation of contemporary subpopulation extinction, current historic site conditions and grass invasion history in the Willamette Valley suggest that mass *E. e. taylori* extinction in western Oregon by the late 1970s was due to *B. sylvaticum* and *F. arundinacea* invasion. To prevent the extinction of *E. e. taylori*, land managers must accept that the anthropogenically mediated host switch to *P. lanceolata* must be conserved and that reintroductions/augmentation with a potential native host plant species is unlikely to be effective because larval development is timed to *P. lanceolata* growth.

Introduction

The New World is disproportionately invaded by exotic plants (Lonsdale, 1999) that are cursed for their ability to outcompete native species, change habitat structure and acutely disrupt native ecosystem functioning (D'Antonio & Vitousek, 1992; Chapin *et al.*, 2000; Myers & Bazely, 2003), costing large expenditures of time and money to control (Pimentel *et al.*, 2000). Unwanted plant invasion coupled with habitat fragmentation, is implicated in the extinction and significant decline in butterfly populations and community diversity around the world (Thomas & Jones, 1993; New *et al.*, 1995; Collinge, Prudic & Oliver, 2003). Mechanisms for the loss of butterflies from unwanted/exotic plant invasion can be grouped into three general categories: the loss of host plant and adult nectar resources through vegetative competitive exclusion (Thomas *et al.*, 1986;

Thomas & Jones, 1993; Weiss, 1999), a change in habitat structure that interferes with beneficial lycaenid larvae–ant interactions (Thomas, 1983; Mouquet *et al.*, 2005), and plants that change resource condition without eliminating the resource. The documented cases where butterfly fitness is negatively impacted by exotic plants occur when host plant apparency is reduced so that larval resources are not detected (Severns, 2007) and when females selectively oviposit on an exotic plant that when ingested by larvae leads to mortality (Graves & Shapiro, 2003; Keeler *et al.*, 2006). Faced with the loss of host plants and structural modification of their habitat, butterfly populations may either go extinct, adapt to their new conditions and flourish or persist at low densities following exotic plant invasion. Due to urbanization and habitat loss, Sacramento Valley, California, butterfly populations have either been locally extirpated or have incorporated exotic larval host plants into their diet,

and now persist in low relative abundance (Shapiro, 2002; Graves & Shapiro, 2003). Singer, Thomas & Parmesan (1993) observed an increasing preference for oviposition by *Euphydryas editha monoensis* on an exotic host plant associated with human disturbance and predicted the future demise of the population, which now appears inevitable (M. Singer, pers. comm.). While exotic plant invasions are becoming increasingly common throughout the world (Sax, Gaines & Brown, 2002; Myers & Bazely, 2003) and some exotic plants may be used by native butterflies, it appears that the exotic plant–butterfly interactions are usually not as beneficial as the native plant–butterfly interactions that were replaced (Singer, Ng & Thomas, 1988; Bowers, Stamp & Collinge, 1992; Singer *et al.*, 1993; Schultz & Dlugosch, 1999).

Euphydryas editha taylori (Nymphalidae), Taylor's checkerspot butterfly, a federal candidate for endangered status, is currently known from only two populations in the Willamette Valley of western Oregon, USA. It owes its continued existence in Oregon to an invasive Eurasian weed (Wolff & Schaal, 1992) *Plantago lanceolata* which the butterfly uses as its sole larval host plant in the last two Oregon populations. Once documented to thrive and 'swarm by the thousands' in meadows of western Oregon before 1970 (Dornfeld, 1980), *E. e. taylori* was thought extinct until a sizeable population was discovered by the junior author in 1999 near Corvallis, OR (Pyle, 2002). Within the last 50–70 years, the invasion of exotic grasses and shrubs, many of which were intentionally introduced as forage or as ornamental species, have degraded the native *Festuca* spp.- and *Danthonia californica*-dominated Willamette Valley bunch grass prairies to an unnaturally tall condition (Clark & Wilson, 2001; Wilson & Clark, 2001). Some of the dominant exotic grasses, including *Arrhenatherum elatius* and *Festuca arundinacea*, are two to three times the height of native bunchgrass species and form an extensive turf layer not characteristic of native Willamette Valley bunchgrass prairies (Wilson & Clark, 2001; Maret & Wilson, 2005). The unnatural height and thatch conditions created by exotic grasses may reduce the abundance of native forbs that serve as adult and larval butterfly resources (Schultz, 2001; Severns, manuscript in revision). Furthermore, the presence of exotic grasses appears to restrict butterfly access to sheltered basking sites which may affect oviposition site selection (Severns, 2007). It is likely that the pervasive exotic grass invasion in the Willamette Valley has impacted many of the endemic plants and animals (Wilson & Clark, 2001; Severns, 2007), a large number of which are either threatened with extinction, endangered or now extinct (Oregon Natural Heritage Information Center, 2007).

The last two known sites in Oregon for *E. e. taylori* are besieged by two encroaching exotic grasses, *Brachypodium sylvaticum* and *F. arundinacea*, that markedly dominate and modify the structural condition of remnant native grasslands. Given the common and often weedy nature of the local larval host plant *P. lanceolata*, we thought it curious that *E. e. taylori* appears to be restricted in Oregon to only two small populations. Historical capture records indicate

E. e. taylori was broadly distributed over the 70 km separating Corvallis, OR south to Eugene, OR as little as 50 years ago (A. D. Warren unpubl. data). Could the invasion of exotic grasses be responsible for the nearly state-wide extinction of the butterfly over the last half century? We investigated the role of exotic grass invasion on the abundance of *E. e. taylori* adult and larval resources, and the effect of grass species composition on oviposition site selection in the last large remaining Oregon population.

Materials and methods

Study species

Euphydryas editha taylori, *sensu lato*, is sparsely distributed throughout western Oregon, Washington and Vancouver Island in British Columbia, Canada. In Oregon, the butterfly is found at two sites just west of Corvallis, our study site, Cardwell Hill and Baezell Monument, c. 4 km west of Cardwell Hill. In Washington State, there is one large and several smaller populations in the Puget Trough (Stinson, 2005; A. Potter, pers. comm.) and potentially one population remaining on Vancouver Island (Guppy & Shepard, 2001). Censuses of the Oregon populations are generally no > 1500 individuals combined, and in most years are below 1000 individuals (D. Ross unpubl. data). The population sizes in Washington are small (< 100 individuals) in all but the largest population, which appears to number upwards of 5000 individuals (Stinson, 2005).

In Oregon, adult *E. e. taylori* eclose as early as mid March but the peak flight period is mid April through early May (Warren, 2005). Eggs are laid on the underside of *P. lanceolata* leaves in clusters of 40–200. About 10–14 days after oviposition, the eggs hatch and gregarious pre-diapause larvae consume young leaf tissue within the confines of a webbed nest they maintain through three instars. In mid to late June larvae enter and remain in diapause until early February, when they resume activity and eat expanding *P. lanceolata* leaves until early March, finally pupating within 2 cm of the ground, suspended from a small web. Oregon populations of *E. e. taylori* use *P. lanceolata* as their pre- and post-diapause host plant and several of the Washington State populations also appear to rely on *P. lanceolata*. The native larval host plant for the Oregon populations was never documented and remains a mystery because there are no native *Plantago* spp. in the Willamette Valley (Gilkey & Dennis, 2001). However, some *E. e. taylori* populations in Washington State use a combination of different pre- and post-diapause native host plants in the field including *Castilleja* spp., *Collinsia* spp. and *Plectritis congesta* (J. Pelham pers. comm.; A. Potter pers. comm.). At one Oregon site (Cardwell Hill), *P. congesta* is present, but *E. e. taylori* from this locality do not oviposit on this species in a laboratory setting (M. Singer, pers. comm.), nor is it used as a host plant under field conditions (P. M. Severns, pers. obs.).

The exotic grasses *B. sylvaticum* and *F. arundinacea* have leaves and inflorescences approximately three to six times as tall as the 'native' *Festuca rubra*, which is 1–2 dm in height.

Both *B. sylvaticum* (Chambers, 1966) and *F. arundinacea* (Cowan, 1956) were noticeably abundant in parts of western Oregon by the middle half of the 20th century. It appears that *F. arundinacea* was introduced as a forage crop (Cowan, 1956) and *B. sylvaticum* was planted as an ornamental species (Hitchcock, 1950); both species tend to form near monocultures following establishment. There is some debate as to the native or exotic position of *F. rubra* in western Oregon (Wilson, 1997); however, we consider the stature and growth habitat of *F. rubra* to be comparable to the proposed historical matrix grass species *Festuca roemerii* (Wilson, 1997).

Study site

We selected a 1.4 ha prairie remnant surrounded by 50–100-year-old *Pseudotsuga menziesii* and *Quercus garryana* trees as our study site (Cardwell Hill) to investigate the relationship between exotic grasses, native grasses, nectar, host plant abundance and oviposition patterns. This small and completely enclosed area hosts the densest and largest remaining known population of *E. e. taylori* in the state, has discrete areas dominated by native and exotic grasses, and an area of degraded remnant native prairie that is a mixture of native and exotic grasses. Due to the limited prairie area surrounded by trees that serve as substantial physical barriers to emigration at the study site, female butterflies have a choice of oviposition habitats. Butterflies feed primarily on nectar of *Fragaria virginiana* and infrequently visit *P. congesta*, *Amelanchier alnifolia* and *Calochortus tolmei*. The latter three nectar sources are either uncommon at the study site or do not overlap with the peak butterfly flight time.

Habitat conditions

In mid May of 2005, 2 weeks after the end of the *E. e. taylori* flight period, we searched for second instar larvae in four distinct grass assemblages: an area dominated by *F. arundinacea*, another dominated by *B. sylvaticum*, a remnant of native prairie dominated by *F. rubra* and an area that was degraded by several exotic grass species. The *B. sylvaticum* area was nested within the *F. rubra*-dominated habitat and the degraded and *F. arundinacea* habitats were adjacent to the *F. rubra*-dominated patch. The size of each area was measured to the nearest square meter and we searched for egg masses within the measured habitat. To describe the relationship between vegetation in the native *F. rubra*-dominated, *B. sylvaticum*-dominated, *F. arundinacea*-dominated and the moderately degraded area, we randomly selected 15–20 1 m² quadrats within each habitat. Due to the discrete boundaries of the exotic and native grasses, we could easily associate each oviposition site with a dominant grass species. Within each quadrat, we counted the number of *P. lanceolata* plants, *F. virginiana* flowers, and measured the cover of each grass species, the cover of herbaceous plants, non-graminoid monocots and bare ground. *F. virginiana* blooms primarily in April, while adult butterflies are

in flight, but we counted senesced flowers after the flowering period to avoid disturbing butterflies and assumed that the number of strawberries and unfertilized flowers were available during the *E. e. taylori* flight. Cover of grasses, herbaceous plants and bare ground was estimated to the nearest per cent from 1 to 10% cover, and in 5% increments thereafter. We applied the same sampling methods to estimate the habitat at the oviposition site, centering the 1 m² quadrat over the center of the larval mass. Because first and second instar *E. editha* larvae rarely move far, if at all, from the original oviposition site (Singer, 1971), we considered this method for locating quadrats representative of selected oviposition habitat and it also minimized the chances of physical harm to the larvae. One person estimated cover throughout the course of the experiment to avoid bias introduced through multiple observers. Templates of known cover were used to calibrate the cover estimates.

Analyses

We used Poisson regressions in the statistics program NCSS (2000) with untransformed total exotic grass cover and the number of *P. lanceolata* plants and *F. virginiana* flowers in each quadrat, to investigate the site-wide effects of exotic grass cover on the density of butterfly resources. To describe the habitat gradients associated with oviposition site selection, we used vegetation data gathered from oviposition sites and analyzed the vegetation patterns with Non-Metric Multidimensional Scaling (NMDS) ordination (Kruskal, 1964; Mather, 1976). Cover estimates of grasses, herbaceous and non-graminoid monocots, bare ground, and the number of *P. lanceolata* plants and *F. virginiana* flowers were all combined into a main matrix and we used Sørensen distances in the NMDS ordination. All cover data for multivariate analysis were arcsine square root (cover) transformed, as recommended by Sokal & Rohlf (1981), and the number of *Plantago* plants and *F. virginiana* flower number were $\ln(x+1)$ transformed to improve the data distribution and conserve relative proportions in the NMDS analysis. We used PC-ORD Version 4.25 (McCune & Mefford, 1999) to perform the NMDS ordination on the slow and thorough program setting.

Results

There was a notable difference in the amount of larval and adult resources between the *F. rubra*-dominated, degraded, *F. arundinacea*-dominated and *B. sylvaticum*-dominated habitats (Table 1). When compared with the *F. rubra*-dominated habitat, all other habitats had a lower abundance of either the larval or adult resources, or both in our vegetation quadrats (Table 1). The moderately degraded habitat was intermediate in the number of *P. lanceolata* plants per quadrat between the *F. rubra* dominated habitat and the habitats dominated by exotic grasses, but the number of host plants per quadrat appeared to decline quickly with a high cover of exotic grasses. The number of

Table 1 Summary of four different habitats available for oviposition and egg mass density in each habitat

	<i>Festuca rubra</i> dominated <i>n</i> =20 quadrats	Degraded habitat <i>n</i> =20 quadrats	<i>Festuca arundinacea</i> dominated <i>n</i> =20 quadrats	<i>Bachypodium sylvaticum</i> dominated <i>n</i> =15 quadrats
Area surveyed	682 m ²	500 m ²	200 m ²	110 m ²
# of egg masses	31	12	1	–
Egg mass density	0.046/m ²	0.024/m ²	0.005/m ²	–
# <i>Plantago</i> ^a plants	19.4 (2.3)	9.2 (1.8)	4.8 (0.9)	1.3 (0.8)
# <i>Fragaria</i> flowers	9.4 (2.0)	0.7 (0.3)	1.6 (0.5)	0.3 (0.2)
% <i>F. rubra</i>	52.9 (3.8)	3.8 (1.1)	0.4 (0.3)	8.2 (2.5)
% <i>F. arundinacea</i> ^a	0.9 (0.8)	9.1 (2.2)	47.9 (6.6)	–
% <i>B. sylvaticum</i> ^a	2.70 (1.2)	0.3 (0.3)	4.0 (1.6)	69.7 (5.7)
% <i>Elymus glaucus</i>	3.3 (0.7)	0.8 (0.6)	1.4 (1.0)	6.4 (1.9)
% <i>Cynosurus echinatus</i> ^a	1.0 (1.0)	13.8 (5.2)	27.5 (7.8)	0.7 (0.7)
% <i>Danthonia californica</i>	0.5 (0.5)	0.3 (0.3)	0.5 (0.5)	1.7 (1.2)
% <i>Bromus</i> spp. (exotic/native mix)	11.6 (2.0)	46.7 (6.9)	–	–
% Herbaceous plants and non-grass monocots	23.3 (3.3)	23.1 (5.5)	10.8 (2.1)	13.7 (3.0)
% Bare ground	1.4 (0.8)	2.7 (1.2)	1.4 (0.6)	–

The mean number of *Plantago lanceolata* plants per quadrat, number of *Fragaria virginiana* flowers per quadrat and vegetation cover per quadrat are followed by ± 1 SE in parentheses.

^aExotic species.

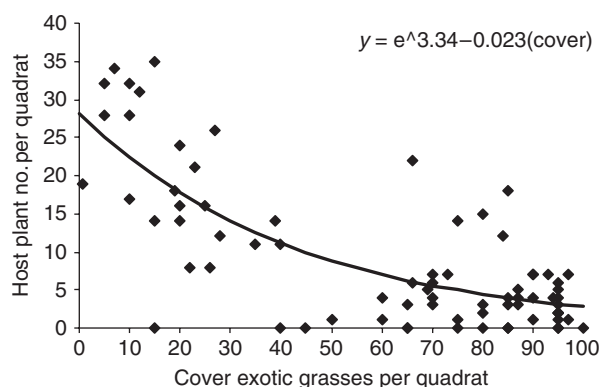


Figure 1 Poisson regression of larval host plant abundance and the cover of exotic grasses in vegetation quadrats [d.f. = 73, log likelihood (model) = -298.9, $G=357.5$, $P<0.000001$, variation explained by model = 51.7%].

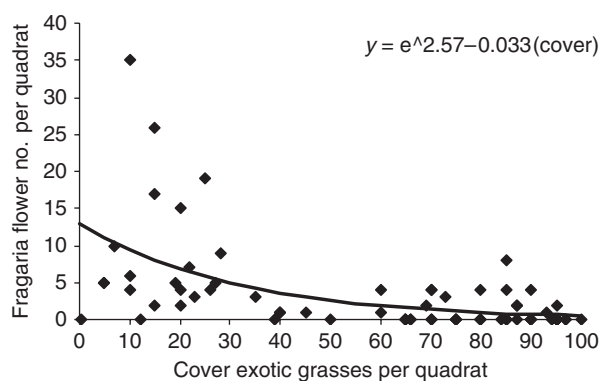


Figure 2 Poisson regression of adult nectar resources and the cover of exotic grasses in vegetation quadrats [d.f. = 73, log likelihood (model) = -217.5, $G=312.9$, $P<0.000001$, variation explained by model = 42.4%].

F. virginiana flowers per quadrat available for butterfly feeding was conspicuously low in all but the *F. rubra*-dominated habitat (Table 1). Our regression analyses examining the overall effect of exotic grass cover on butterfly resources demonstrated that the abundance of adult and larval *E. e. taylori* resources decreased rapidly with increasing cover of exotic grasses. Both the number of *P. lanceolata* plants per quadrat (Fig. 1) and the abundance of *F. virginiana* flowers per quadrat (Fig. 2) diminish substantially with increasing cover of exotic grasses.

Butterflies laid egg masses at more than twice the density in the *F. rubra*-dominated area as they did in any of the other habitats within the study site (Table 1). While we recorded 12 different oviposition sites in the degraded habitat, which was comprised of both native and exotic

grasses, only one egg mass was laid in a habitat dominated by an exotic grass (Table 1). The egg mass laid in the *F. arundinacea*-dominated habitat had over 60% bare ground and contained only one large *P. lanceolata* plant, markedly contrasting with the average habitat in the *F. arundinacea*-dominated habitat (Table 1).

The NMDS ordination resulted in a two-dimensional solution with a final stress of 6.8 ($P=0.02$ from 300 Monte Carlo simulations) and a final instability of 0.00001 from 112 iterations. The final stress value of 6.8 is interpreted as a reliable and stable ordination according to Clarke (1993). The ordination revealed that the bulk of eggs were laid in areas that were increasingly dominated by *F. rubra* and had greater numbers of both *P. lanceolata* and *F. virginiana* flowers (Fig. 3). The horizontal axis, which corresponded to

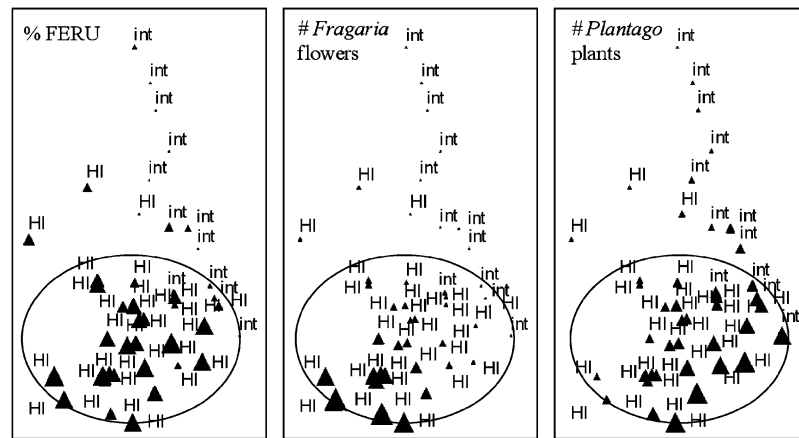


Figure 3 NMS ordination of the primary environmental gradients related with oviposition site selection by *Euphydryas editha taylori*. The circle delimits the habitat in the ordination space where most eggs were laid with increasing triangle size representing the increase in cover of *Festuca rubra* (% FERU), the abundance of *Fragaria virginiana* flowers and number of *Plantago lanceolata* plants. Labels 'int' = degraded and 'HI' = *F. rubra* dominated reference the grass communities where eggs were laid.

F. rubra cover and butterfly resources, explained 85.3% of the variation in the NMDS ordination. The vertical axis, which was related to the presence of *F. arundinacea*, explained 8.5% of the ordination variation. Together these two axes explained 93.8% of the vegetation composition data from butterfly oviposition sites in the ordination.

Discussion

Exotic grass invasion and butterfly extinction

The loss of butterfly resources with exotic plant invasion seems surprisingly under-documented (Weiss, 1999), given that it is a logical consequence of invasion by exotic plants that competitively reduce the abundance and diversity of native plants (Schooler, McEvoy & Coombs, 2006), many of which are likely to be host plants for a suite of insects. We found a decrease in larval host plant abundance (Fig. 1) and adult resources (Fig. 2) with increasing cover of exotic grasses, indicating that the Oregon *E. e. taylori* populations are at risk of extinction due to exotic plant invasion. We also have evidence that exotic grass invasion lead to the historical extinction of *E. e. taylori* populations.

We visited seven historic localities for *E. e. taylori* near Eugene ($n = 2$) and Corvallis ($n = 5$), OR and observed that these sites were dominated by *B. sylvaticum* (Oak Creek near Corvallis), *F. arundinacea* (Corvallis/Eugene) and *A. elatius* (Corvallis/Eugene). In the four sites dominated by *B. sylvaticum*, there were no larval or adult resources, while in three sites that were a mixture of *A. elatius* and *F. arundinacea* butterfly resources were scarce if present. Oregon populations of *E. e. taylori* significantly dwindled in the 1970s and 1980s (A. D. Warren unpubl. data), within 30 years of the noted Willamette Valley invasion by *B. sylvaticum* and *F. arundinacea*. The corresponding time span between the documented occurrence of exotic grasses

and the apparent extinction of Oregon *E. e. taylori* is consistent with lag phase for colonizing plant population growth (Myers & Bazely, 2003). Loss of adult and larval butterfly resources with exotic grass cover and the condition of historically occupied butterfly populations suggest that the timing differences between exotic grass invasion and butterfly demise is not likely to be a historical coincidence.

Unfortunately, we have also witnessed contemporary *B. sylvaticum* invasion and *E. e. taylori* population extinction. A small subpopulation ($c. 0.5$ ha) adjacent to our study site contained hundreds of butterflies in 1999 and was dominated by *F. rubra*. In 2001, *B. sylvaticum* invaded the prairie from the neighboring forest understory and by 2003 all butterfly resources were gone and only a few *F. rubra* plants remained. Butterflies have been observed in the extinct subpopulation after 2003 but because larval and adult resources are absent this site will never support *E. e. taylori* until the exotic grasses are managed. Our observations of vegetation change in historic butterfly sites, the negative impact of exotic grasses on butterfly resources and the unfortunate situation that last remaining Oregon butterfly populations are besieged by exotic grasses, leads us to conclude that if exotic grass invasion is not controlled Oregon *E. e. taylori* will become extinct.

Habitat conditions and oviposition site preference

Dennis, Shreeve & Van Dyck (2002) proposed that quantification of functional butterfly resources and their surrounding conditions reveal how butterflies assess habitat quality, which is essential knowledge for effective butterfly conservation. They argued that the distribution of essential resources across the landscape is as important to population persistence as the condition in which the resources reside. In the case of Oregon *E. e. taylori*, the host plant flourishes in the degraded upland prairie habitat in this study (Table 1) and is

commonly associated with disturbed areas in the Willamette Valley such as road verges and urban habitats (Gilkey & Dennis, 2001). However, the NMDS ordination of oviposition habitat (Fig. 3) indicated that oviposition habitat conditions, cover of native grasses and nectar resources, appear to have a large influence on site selection. Females selected host plants with a greater local abundance of native grasses and nectar flowers. Moreover, the restricted distribution of *E. e. taylori* to a small portion of the 1.4 ha study site despite the broad distribution of the host plant in disturbed conditions, also suggests that the butterflies require specific habitat conditions for reproduction. Our data suggest that adult nectar resources are the first to be lost when exotic grasses begin to degrade but not dominate butterfly habitat (Table 1). Because *E. e. taylori* appears to assess habitat quality by a combination of host plant and adult nectar resources (Fig. 3), which coincide only in the *F. rubra*-dominated habitat (Table 1), habitats having only a high relative abundance of *P. lanceolata* are unlikely to be used by egg-laying females. Selecting suitable sites for butterfly reintroduction or restoring conditions suitable for *E. e. taylori* must target grass stature/composition, host plant and adult resource abundance if the greatest chances of success are to be realized.

Reconciling microevolution, exotic plant invasion and conservation

Preservation of *E. e. taylori* in Oregon will necessarily challenge traditional restoration and conservation practices, and we will have to morally weigh and reconcile the survival of a taxon on the brink of extinction against our concept of restoring 'native habitat'. *Euphydryas editha taylori* in Oregon is dependant on one larval host plant *P. lanceolata* which is considered to be an exotic but naturalized species in North America (Wolff & Schaal, 1992). If *P. lanceolata* is indeed an exotic species in western Oregon (and there is no native cryptic taxon), then the butterfly must have switched from a native larval host species to *P. lanceolata*. A potential alternative native host plant for *E. e. taylori* is *Castilleja levisecta*, an endangered species used by *E. e. taylori* in some Washington populations (J. Pelham pers. comm.) and historically collected in the Willamette Valley. This potential host species is currently extirpated from Oregon but could be reintroduced (Lawrence, 2005). Ostensibly, the reintroduction of *C. levisecta* in Oregon may provide a usable native alternative to *P. lanceolata*, but there are several compelling reasons why this reintroduction should not proceed for *E. e. taylori* conservation. First, we do not know if Oregon populations of *E. e. taylori* can complete larval development on *C. levisecta* or other *Castilleja* species. Second, there is some ambiguity as to which *Castilleja* species are used as pre- and post-diapause larval host plants in Washington (A. Potter pers. comm.). Third, the emergence of post-diapause *E. e. taylori* larvae in Oregon occurs by mid February, but the aboveground leaves of *C. levisecta* do not emerge until mid March (B. A. Lawrence pers. comm.). This discordant timing between larval activity and

plant development would doom reintroduction attempts based entirely on *C. levisecta*. Singer *et al.* (1988, 1993) demonstrated that other subspecies of *E. editha* have marked heritability in larval host plant preference and the introduction of novel hosts in some cases can be maladaptive. Furthermore, host plant switches are likely to involve a reduction in the effective population sizes. An attempt to force *E. e. taylori* onto a potential native host plant is likely to create a population bottleneck, a demographic feature most conservation plans try to avoid. Thus, it seems unwise to introduce a new or potential larval host plant into *E. e. taylori* populations dependent on *P. lanceolata* if population persistence is the goal. We are advocating the maintenance of an anthropogenically derived non-native condition because the introduction of native host plants could lead to an ecological trap (*sensu* Schlaepfer, Runge & Sherman, 2002; Battin, 2004).

Evolutionary biologists reviewing microevolution (Thompson, 1998; Carroll *et al.*, 2007; Hendry, Nosil & Rieseberg, 2007; Kinnison & Hairston Jr, 2007), rapid evolutionary changes that can be measured over ecological time scales, have argued that ecologists should incorporate microevolution into their experiments because selection can affect population growth rates. If evolution can occur over ecological time then selective forces will also affect plant and animal conservation and restoration. Ashley *et al.* (2003) called for land managers to practice 'evolutionarily enlightened management' when implementing conservation plans because evolution can play a part in population persistence over the life of restoration projects. In the case of *E. e. taylori*, we appear to have the unfortunate duty of perhaps providing the first example of how contemporary rates of evolution resulted in a larval host switch to an invasive, exotic plant, which may be necessary for the survival of the endangered taxon. Singer *et al.* (1993) had warned that humans are modifying habitats to an unnatural disturbance condition that butterflies may find attractive and colonize but to ensure population persistence we may have to maintain the anthropogenic habitat condition. This scenario that Singer *et al.* (1993) proposed appears to have occurred in *E. e. taylori* and may foreshadow the future of other butterflies in North America. Shapiro (2002) has suggested that the maintenance of exotic larval host plants may be the only way the butterfly community in urbanized habitats of the Sacramento Valley will remain intact, because native larval host plant abundance appears too low to support butterfly populations. While some restoration 'purists' may be opposed to the propagation or maintenance of an exotic species, an understanding of how evolution interacts with ecology, conservation and restoration may be the only way to save organisms like *E. e. taylori* from extinction. Regardless of whether or not the resources required for *E. e. taylori* are native, they are what this butterfly requires for survival. Land managers must choose between actively increasing/maintaining the abundance of a non-native component to the plant community and managing habitat conditions or the extinction of a butterfly.

Acknowledgments

We extend our sincerest thanks to Dana Ross and Nate Miller for their help with collecting vegetation data. John Pelham, Ann Potter, Mike Singer and Beth Lawrence kindly provided life-history information about *E. e. taylori* and larval host plants. Josef Settele, Trent Garner and an anonymous reviewer provided thoughtful comments that improved this paper.

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