Supporting Information

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SI Text

Materials and Methods

Case 1: Translocating the Bay Checkerspot Butterfly,* Euphydryas editha *bayensis. This specialist butterfly lives in grasslands on serpentine soils in the San Francisco Bay area of California. It is federally listed as threatened, and habitat loss from human development and invasive grasses that outcompete its native food plants have diminished and isolated its populations. The butterfly and its host plants were probably once widespread (1), and recent studies suggest that remaining patches are susceptible to extinction (2). To persist under climate change, *E. editha* bayensis needs larger habitats with greater connectivity, a difficult prospect in an urban area. To enable species persistence, the butterfly could be relocated to areas free of urbanization that are likely to have suitable climatic conditions in the future.

The Bay checkerspot, however, is just 1 subspecies of a widely distributed species that occurs throughout western North America. All populations of *E. editha* feed on plants in the families Plantaginaceae or Orobanchaceae, but individual populations specialize on different species (3). A common feature of *E. editha* populations is a sensitive phenological relationship between larval development and host plant senescence, a relationship strongly affected by climate (4, 5). The Bay checkerspot feeds on *Plantago erecta*, *Castilleja exserta*, and *C. densiflora*. These plants have broad distributions in California, but might be introduced or increased where butterfly populations were translocated. In areas off serpentine soil where competition with nonnative is most intensive, large-scale restoration and habitat creation may be necessary to facilitate host plant populations. In this case, we envision an introduction to northern California. Translocations beyond California may require the introduction of nonnative host plants unless the Bay checkerspot could be shown to consume native hosts.

Evaluation of Case 1 by Stakeholder A, "Advocate for Bay Checkerspot Preservation." *Feasibility Score is 3 (± 2)*: It is uncertain whether this species can be moved successfully. Attempts at within-range introduction have had mixed results, but a successful captive breeding program does exist for *E. editha taylorii*, another threatened subspecies (http://www.oregonzoo.org/Conservation/silverspot.htm). The Bay checkerspot's host plant requirements may necessitate considerable habitat modification and enhancements, but if the introduction occurs in California, those host plants species are native and serpentine grasslands are fairly common in northern California. These considerations lead to a high feasibility score with large variance. *Acceptability Score is 4.5 (± 0.5)*: As a federally-listed species, there is a mandate for conservation of this species. It also is a flagship of the native California grassland, providing historic and aesthetic motivations for preservation. This desire for protection leads to a high acceptability score with small variance. *Focal Impact is 3 (± 2)*: Although recent data suggest that populations may be vulnerable to extinction (1), this outcome is not certain for all populations, and conservation of existing populations may be possible by encouraging the abundance of long-lasting hosts, [e.g., *Castilleja* spp (6)] or by restoring or creating serpentine grassland habitats. Thus, the focal impact score is moderate with a large variance. *Collateral Impact is 4 (± 1)*: The butterfly seems unlikely to competitively displace native species in the host region as it rarely defoliates host plants in the Bay Area [but see (7)]. Further, the butterfly may help to provide additional pollination services to native plants where it is introduced (8). These assumptions lead to a high score (low collateral damage) with some variance.

Evaluation of Case 1 by Stakeholder B, "Conservationist in Introduction Region." *Feasibility Score is 3 (± 2)*: Same as above. *Acceptability Score is 1 (± 0.5)*: The checkerspot is unlikely to provide ecosystem functions that are not currently represented in the introduced region. Further, facilitating host plants of the Bay checkerspot could disturb native *E. editha* or other butterflies that feed on competing plant species. Thus, the acceptability score low with low variance. *Focal Impact is 1 (± 1)*: This species may not go extinct in its natural range. Further, even if the butterfly species were lost, it is unclear (given its low abundance already) whether it would have any significant impacts on the functioning of its own native system. As a subspecies, little phylogenetic distinctiveness would be lost. Conservationists outside the Bay Area acknowledge that this species is an important member of its community in a cultural, social, and legal sense, but they value these qualities less than Bay Area residents. Thus, focal impact is given a low score with moderate variance. *Collateral Impact is 2 (± 1.5)*: This species is unlikely to have large effects in its introduced range, but it might disrupt the functioning of the existing native system, potentially putting native species at risk. The habitat creation or facilitation needed for introduction may replace or compete with other valued species. Some of these species may be the host plants of conservation targets in the recipient region (e.g., Oregon, Myrtle's, and Behren's silverspot butterflies). Introduced *E. editha* bayensis also could compete with, replace, or hybridize with native *E. editha*. This could reduce the diversity of local fauna or pollute the local gene pool. Thus, the score for 1-collateral damage is low, but the possibility of little damage leads to a high variance.

Case 2: Translocating* Torreya taxifolia *to the Southern Appalachians. *Torreya taxifolia* (Cephalotaxaceae) is a dioecious coniferous tree that is endemic to the bluffs that extend 5–10 km eastward from the Apalachicola River for approximately 35 km in northern Florida, extending less than a kilometer into Georgia (9–11). During the late 1950s and early 1960s, all adult trees throughout its range were killed as a consequence of a pathogen outbreak (12). The current population is likely not >1,500 individuals (13), likely seeds and seedlings that were viable at the time of the decline (11). During the past 40 years, there has been a single tree that has been observed to have matured into a seed bearing adult. It produced 2 seeds. This individual is now dead, and the seeds produced are presumed dead as well. The agent of the decline is unknown but is thought to be a fungal pathogen (14–15). The current rate of decline is slow. Estimates of growth and mortality data suggest that it will be at least a century before the population goes extinct in the wild (3). Cuttings from ≈150 trees are currently grown in botanic gardens.

More recently, 2 efforts have begun for the conservation of this species. *Torreya taxifolia* has been planted in North Carolina in an attempt to establish populations in that region (http://www.torreyaguardians.org/). This effort was done as an indirect response to climate change. The species is in declining in its native range with no sign of recovery. Proponents felt that this species 'belongs' in the region where they relocated it. They also feel that this intervention is the best chance for the species to survive, given its condition in its native range.

***Evaluation of Case 2 by Stakeholder A, "Advocate for a Broad Distribution of* Torreya taxifolia."** *Feasibility score is 4 (± 1)*: Seeds are moderately easy to germinate; plant material in the form of cuttings are

legally available through several botanical gardens in possession of numerous genotypes of known origin. Cuttings, however, take many years to reestablish apical dominance, so the process is slow. With a small number of mature female trees at Biltmore Gardens (Asheville, NC), the most available seed represents a very narrow subset of the genetic variability of the species. Although this is a federally listed species, it is possible to plant legally obtained plant material on private lands without seeking state or federal approval or permits. *Acceptability score is 4.5 (± 0.5)*: The species is generally sparse and does not tend to form monospecific stands. The likelihood of this species becoming weedy is low. *Focal Impact score is 4.5 (± 0.5)*: There is no supportive evidence that we can conserve the species in its recent historical range. *Torreya taxifolia* represents 1 of 2 North American species in the genus and 1 of 5 North American Representatives in its family; 1 of 7 species in its genus and 16 species in its family worldwide (17). Loss of this species significantly erodes biodiversity. *Collateral impact score is 4.5 (± 0.5)*: This species is slow growing, produces few seed and is of relatively small stature as a mature tree. Being dioecious and producing relatively few seeds, this species would be relatively easy to control. Related taxa tend to be found either in localized patches or as subdominants in mixed forests. It appears unlikely to dominate and displace other Appalachian forest species [none of the 10 species in the family are known to be invasive when planted outside their range (18)].

Evaluation of Case 2 by Stakeholder B, "Advocate for Local Conservation of* Torreya taxifolia." *Feasibility score is 2 (± 1)*: *Torreya taxifolia* is a federally listed species. Thus, even though it may be legally possible to translocate the species, actions should be conducted under the auspices of the relevant federal agencies. Cooperation with federal agencies appears unlikely. The limited number of parental genotypes available for seed would force reintroduction to drive the species through a genetic bottleneck. *Acceptability score is 1.5 (± 0.5)*: The introduction of this species will erode the ecological integrity of a very diverse forest community type that is, itself, threatened by climate change. There is currently strong public support for conservation of local forests based on the argument that this region protects essential and irreplaceable biodiversity; adding a nonnative species will erode this support by arguing, effectively, that the local biodiversity might also be conserved somewhere else through managed relocations. *Focal Impact score is 2 (± 1)*: While recognizing that the species is an important representative of a small lineage, the species is currently being grown in botanical gardens. It would be a simple step to plant the species as yard trees to help preserve this lineage. The persistence of this species does not depend on finding new wild habitats. Further, there is not sufficient evidence to suggest that restoration of the species within its current range is not feasible. Adequate local restoration must be tried and shown to fail before this species should be moved. Climate change may pose an issue for this species, but we know that introduced pathogens were the proximate cause of the decline. We need to wait until we have documented proof that a local solution is not possible. *Collateral impact score is 1 (± 1)*: Introducing this species to southern Appalachian mixed forests is unacceptable because it may disrupt critical ecosystem attributes of local forests and displace species. Conifers produce more acidic litter than hardwoods, an introduction of this sort, if successful, is likely to alter local soil chemistry and trigger other less predictable ecosystem changes. We simply cannot predict the impact of this introduction.

Case 3: Translocating Trees for Commercial Forestry. A mixture of regulations and guidelines varying by province encourages the plantation of locally adapted seedlings on production forest land in Canada (19). Until recently, restrictions on seed transfer have emphasized local climatic adaptation of tree stock in a static setting (e.g., fixed boundary seed zones), but there is increasing discussion about amending seed transfer guidelines to accommodate climate change (18–21). The primary impulse for considering the transfer of genotypes or species into novel areas predicted to be suitable by climate models is economic, but conservation and carbon sequestration are also relevant considerations (20, 22). Any prospective benefits of relaxing seed transfer restrictions to accommodate climate change must be understood in the context of ongoing debates about the impact of Canadian forestry on biodiversity (23, 25).

Evaluation of Case 3 by Stakeholder A, "An advocate for Production Forestry." *Feasibility score is 4 (± 1)*: There is a well-established seed transfer policy and infrastructure framework that could be modified to allow the implementation of climate-based seed transfer (22). Reports that examine such changes indicate that the major feasibility challenge is uncertainty about the degree and direction of future climate change and the nature of local adaptation in trees, that is, whether MR would improve forest production (19, 22, 26) rather than infrastructural or economic constraints. *Acceptability Score is 5 (± 0.5)*: Reports from groups studying this issue argue that increasing maladaptation of tree species to their environment under climate change risks reducing forest productivity and forest health including the resilience of forests to pests and disease (20, 22). Furthermore, climate-based seed transfer may not be perceived as categorically different from current practices (19). *Focal Impact is 5 (± 0.5)*: If the focal unit under consideration is the forest ecosystem, foresters seem to agree that transferring species and genotypes better adapted to future climates will improve productivity and resilience (20, 22). *Collateral Impact is 4 (± 0.5)*: There is little discussion of potential negative impacts of climate-based seed transfer on nearby nonproduction forests in published reports and the benefits envisioned for forest health in focal sites might be expected to provide some regional ecosystem stability (22).

Evaluation of Case 3 by Stakeholder B, "Natural Heritage Conservationist." In contrast to the recent increase in reports by forest managers specifically addressing this MR scenario, we could find no published analysis of climate-driven seed transfer from environmental conservation groups. We note that revisions to provincial management plans will allow input from nongovernmental environmental advocates and that these advocates may agree with production foresters on the need and desirability of MR. However, past conflicts on Canadian forest policy suggest that differing perceptions about the role of production forests (27) might result in differences of opinion about the desirability of this policy shift. *Feasibility Score is 3 (± 1)*: Consistent with the views of production foresters (above), environmental advocates likely do not see the main obstacles to feasibility as infrastructural. However, some forest conservation groups in Canada have been skeptical about the role that production forests will play in mitigating the impacts of climate change. In particular, environmental groups have argued that management for timber extraction leads to inefficient carbon storage in forests (24). Under such reasoning, productivity gains associated with MR might ultimately contribute little to carbon sequestration. These groups have also argued that production forests have a low capacity to facilitate the adjustment of biodiversity to warmer climates relative to extensive natural forests (24). *Acceptability Score is 3 (± 2)*: Like production foresters, environmental advocates are searching for ways to ameliorate projected increases in forest stressors and migration lags under climate change (25). Revised seed transfer policies on production land might be considered coherent with those shared goals. However, the prospect of widespread transfer of nonindigenous genotypes might raise concern in the conservation community about the consequences of manipulating local genetic structure. *Focal Impact is 4 (± 1)*: Because environmental advocates see similar threats from climate change to ecosystem stability as production foresters (24, 25), they may perceive the potential ecosystem impacts on focal

forests similarly. Some environmental advocates, however, are less confident that intensive management is effective at addressing such problems, and they may discount impact accordingly. *Collateral Impact is 2 (± 1)*: Some groups might fear negative impacts on natural forests from species and genotypes escaping from production lands. This action might also risk a loss of sense of place and an alienation of local people from their environment.

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