Managed Relocation: Integrating the Scientific, Regulatory, and Ethical Challenges

MARK W. SCHWARTZ, JESSICA J. HELLMANN, JASON M. McLACHLAN, DOV F. SAX, JUSTIN O. BOREVITZ, JEAN BRENNAN, ALEX E. CAMACHO, GERARDO CEBALLOS, JAMIE R. CLARK, HOLLY DOREMUS, REGAN EARLY, JULIE R. ETTERSON, DWIGHT FIELDER, JAQUELINE L. GILL, PATRICK GONZALEZ, NANCY GREEN, LEE HANNAH, DALE W. JAMIESON, DEBRA JAVELINE, BEN A. MINTEER, JAY ODENBAUGH, STEPHEN POLASKY, DAVID M. RICHARDSON, TERRY L. ROOT, HUGH D. SAFFORD, OSVALDO SALA, STEPHEN H. SCHNEIDER, ANDREW R. THOMPSON, JOHN W. WILLIAMS, MARK VELLEND, PATI VITT, AND SANDRA ZELLMER

Managed relocation *is defined as the movement of species, populations, or genotypes to places outside the areas of their historical distributions to maintain biological diversity or ecosystem functioning with changing climate. It has been claimed that a major extinction event is under way and that climate change is increasing its severity. Projections indicating that climate change may drive substantial losses of biodiversity have compelled some scientists to suggest that traditional management strategies are insufficient. The managed relocation of species is a controversial management response to climate change. The published literature has emphasized biological concerns over difficult ethical, legal, and policy issues. Furthermore, ongoing managed relocation actions lack scientific and societal engagement. Our interdisciplinary team considered ethics, law, policy, ecology, and natural resources management to identify the key issues of managed relocation relevant for developing sound policies that support decisions for resource management. We recommend that government agencies develop and adopt best practices for managed relocation.*

Keywords: ethics, policy, law, conservation, translocation

As climate change effects accumulate, resource managers, policymakers, and scientists grapple with the challenge of designing effective adaptation strategies to conserve biodiversity and the services provided by species and ecosystems. The changing climate has prompted calls for a paradigm shift in conservation from managing and restoring predisturbance ecosystem conditions to a wider variety of goals that include maintaining biodiversity and conserving ecosystem functioning (Hobbs et al. 2006, Camacho 2010). The magnitude of projected climate change, however, suggests that humans may be forced to choose between the unfortunate alternatives of witnessing extinctions and intentionally manipulating species' distributions in efforts to prevent extinction and maintain biodiversity.

Here, we report on the findings of the Managed Relocation Working Group (MRWG), an independent collection composed of over 30 scientists, scholars, and policymakers that met to discuss dimensions of managed relocation. Managed relocation raises a difficult suite of biological, legal, and ethical issues. Owing to the nature of this committee, most of the examples refer specifically to the United States, but the issues we treat are broadly applicable, including those related to policy. The MRWG represents an interdisciplinary group seeking a comprehensive consideration of managed relocation.

The MRWG members span the spectrum from those who view managed relocation as an acceptable—or even necessary—climate change adaptation strategy to those who consider managed relocation undesirable under any future climate change scenario. The MRWG was focused on identifying the scholarship required to fully consider an interdisciplinary assessment of managed relocation as a climate change adaptation strategy. Recognizing that ad hoc managed relocation efforts are already under way, we assert that developing a functional policy framework for managed

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relocation is a grand challenge for conservation. We seek to identify and evaluate benefits, risks, and critical uncertainties to foster reasoned decision-support and policy frameworks for managed relocation.

Defining *managed relocation*

Managed relocation has been used synonymously in the literature with several terms, including *assisted migration*, *assisted colonization*, and *managed translocation* (Hunter 2007, McLachlan et al. 2007, Hoegh-Guldberg et al. 2008, Olden et al. 2011). We define *managed relocation* as the intentional act of moving species, populations, or genotypes (the *target*) to a location outside a target's known historical distribution for the purpose of maintaining biological diversity or ecosystem functioning as an adaptation strategy for climate change (Richardson et al. 2009). Managed relocation is distinct from other types of conservation-motivated translocations, including biological control of invasions, restoration of populations within a native range, and rewilding, because it entails moving a target outside its historical distribution in response to climate change for the benefit of natural resources management (table 1). As such, *managed relocation* is a specific case of the more general *translocation*, a term that can refer to any species intentionally moved by people for any purpose. Managed relocation may be motivated by a desire to (a) maintain genetic diversity, (b) protect species from extinction, (c) mimic dispersal interrupted by human habitat barriers, (d) maintain ecosystem functionality, or (e) maintain a population used in natural resource extraction. Finally, we follow the Intergovernmental Panel on Climate Change's (IPCC) definition of an *adaptation strategy* as an adjustment in natural or human systems in response to climate change to moderate harm or to exploit new conditions (IPCC 2007a).

We prefer *managed relocation* to alternative terms because it is value neutral and emphasizes all of the steps that one might take in adaptation, including source extractions; establishment; performance and affect monitoring; and, possibly, the control of established populations. Because managed relocation is the intentional introduction and maintenance of populations for a specific conservation-focused outcome, it includes ethical, social, and policy concerns (Camacho et al. 2010, Minteer and Collins 2010, Sandler 2010). Although many technical issues are central to managed relocation, ethical, legal, and social components pose equally challenging questions about the appropriate use of managed relocation.

Ecological history as a benchmark

Twenty thousand years ago, during the last glacial maximum, the mean global surface temperature of the Earth was 4–7 degrees Celsius cooler than it is today (IPCC 2007b), and much of the high northern latitudes were covered in a mile-tall ice sheet. In response to these profound changes in climate, species responded individually. Some species shifted their distributions great distances, others expanded their ranges by expansion, whereas still others remained in place. Species that were unable to shift their geographic distributions appear to have been particularly prone to climate-caused extinction. Many freshwater fish in the southwestern

Table 1. Several terms that describe the movement of species from one location to another for a directed purpose.

Term	Definition	Example	Source
Managed relocation	The intentional act of moving species, populations, or genotypes to a location outside a known historical distribution for the purpose of maintaining biological diversity or ecosystem functions as an adaptation strategy for climate change	Introducing a butterfly species to a region that is predicted to be and to remain suitable habitat under the conditions that the species' former locations are likely to become unsuitable with climate change	Richardson et al. 2009
Assisted migration	Introducing a species into a new location by bringing propagules or individuals and releasing them	Introducing *Torreya taxifolia* to North Carolina from its native distribution in Florida	McLachlan et al. 2007
Assisted colonization	Assisted migration with the introduction managed to ensure successful establishment	See *assisted migration*	Hunter 2007
Introduction, accidental	Accidental movement of a species, due to human activity, from an area in which it is native to a region outside that range	The accidental introduction of zebra mussels to water bodies by boats	Richardson and Pyšek 2006
Introduction, intentional	Intentional movement of a species, due to human activity, from an area in which it is native to a region outside that range	The intentional introduction of nonnative birds to the Hawaiian islands	Richardson and Pyšek 2006
Reintroduction (or *reenforcement*)	An attempt to establish an extirpated species within its historical native range or to rebuild native populations within that range	The reintroduction of wolves in the Rocky Mountain West	Seddon 2010
Rewilding	Introduction of an analog species to replace an extinct species in order to maintain ecosystem functioning or to prevent extinction	Introducing elephants to North America as an analog of extinct mammoths or to reduce the extinction risk to elephants	Donlan et al. 2006
Translocation	Any movement of a species from one location to another	Moving a sport fish into previously fishless lakes, reintroducing wolves to Yellowstone National Park	Seddon 2010

United States, for example, were lost as the surface area of glacial-period lakes decreased dramatically during the past 20,000 years (Smith 1981). Similarly, tree diversity in Europe plummeted during the repeated glacial periods of the Pleistocene, because range shifts were blocked by the absence of land at lower latitudes, where Europe meets the Mediterranean Sea (Svenning 2003). In contrast, trees in North America and Southeast Asia, lacking obvious north–south dispersal barriers, largely survived the Pleistocene (Svenning 2003).

In general, the fossil records of trees and mammals show wide variation in the ways in which species' distributions have changed since the last ice age. In central Mexico, for example, two small mammal species, the cinereus shrew (*Sorex cinereus*) and the Mexican spiny pocket mouse (*Liomys irroratus*), occurred together during the full glacial maximum (Lomolino et al. 2010). Today, the spiny pocket mouse still inhabits central Mexico, but the shrew's range has moved more than 1000 miles north, to Canada and the northern United States (Lomolino et al. 2010). Despite improvements in our ability to identify traits associated with a species' ability to colonize new ecosystems (*invasiveness*; Richardson and Pyšek 2006) and to clarify the relationship between species distribution and environmental factors (Guisan and Zimmermann 2000), we have a poor understanding of why different species show such divergent responses to past climate changes. Although some past range shifts can be accurately reconstructed by species distribution models (SDMs), many cannot, which suggests that our future ecological projections are also highly uncertain (Dobrowski et al. 2011). Unexplainable histories suggest uncertain futures and, therefore, extinction risk assessments (an essential component of conservation management) carry high inherent uncertainty.

Meeting the future threat

Concerns about species extinction, population extirpation, the loss of genetic diversity, and the maintenance of particular ecosystem services are the dominant motivations for considering managed relocation. Field measurements show that twentieth-century climate change has already shifted the geographic ranges of plants, animals, and biomes around the world (IPCC 2007a, Gonzalez et al. 2010). Projected biological responses to projected future climate raise concern for escalating extinction rates (Walther 2010). The inherent capacity for species movement, even if dispersal corridors are available, may be slow relative to the pace of future climate change (Jackson and Sax 2010). Compounding the threat of climate change, humans have diminished natural populations and fragmented landscapes in ways that decreases dispersal rates and may block some range shifts (Jackson and Sax 2010, Thomas 2011). The human population continues to grow, exacerbating habitat loss and reducing the area of suitable habitat for many species (Sala et al. 2005, Thomas 2011). Even highly mobile species may have difficulty responding to the irregular pace and interdecadal variation that is expected in climate change (Jackson et al. 2009, Early and Sax 2011). In addition, the genetic structure of species can inhibit range change. Some species may have uniform climatic tolerances over their range, but others are composed of locally adapted forms that would each need to track changing conditions (Zakharov and Hellmann 2008).

Conservation ecologists are beginning to call for adapting management strategies for climate change (e.g., increasing the connectivity, resistance, and resilience of natural protected areas; e.g., Heller and Zavaleta 2009). Others have suggested more radical approaches, such as embracing novel anthropogenic ecosystems as a management goal (Hobbs et al. 2006, Thomas 2011). The proponents of managed relocation contend that conventional conservation strategies will not provide sufficient protection from future environmental change (Vitt et al. 2010, Thomas 2011).

Managed relocation is already being applied. Climate-motivated translocations have been implemented with an endangered tree, *Torreya taxifolia*, in the southeastern United States (Barlow 2011; *www.torreyaguardians.org*) and with two butterfly species in the United Kingdom (Willis et al. 2009). Additional undocumented cases may be more frequent than is realized. For example, giant sequoia (*Sequoiadendron giganteum*) has been widely planted outside its historical range, although the motivation for such plantings remains unclear. Pressure to undertake managed relocation is likely to increase as the consequences of climate change become more apparent.

Natural resource extraction (e.g., forestry, fisheries) industries have also begun to recognize the potential need to employ managed relocation to maintain harvestable stock. For example, in translocations of commercially harvested lobsters in Australia, a future climate model has been used to identify novel translocation locations (Green et al. 2010). The forestry industry is also experimenting with managed relocation (McKenney et al. 2009). Similarly, horticultural planting outside native historical distributions contributes to passive range expansions (Van der Veken et al. 2008, Woodall et al. 2010), and botanic gardens are beginning to explore their capacity to actively foster range expansions under climate change (e.g., Vitt et al. 2010).

Balancing risk, benefit, and uncertainty

Scientists disagree about the wisdom of engaging in managed relocation as an adaptation strategy (e.g., Hunter 2007, Ricciardi and Simberloff 2009, Thomas 2011). A central argument for the opponents of managed relocation is that past species translocations—both intentional and accidental—have resulted in unintended and occasionally severe negative ecological consequences (Ricciardi and Simberloff 2009). In contrast, the proponents of managed relocation argue that extinction can be a severe negative ecological consequence and that managed relocation can be used to reduce its likelihood (e.g., McDonald-Madden et al. 2011). Balancing extinction risk against the potential negative impacts of managed relocation (including other species' extinctions) requires choosing between comparably unfortunate risks. Within this debate, the benefits of managed relocation are not limited to extinction prevention; they may also affect how keystone or foundation species maintain specific ecological functions (Hoegh-Guldberg et al. 2008, Kreyling et al. 2011). Therefore, an assessment of the values and the risks of managed relocation should include the ecological impacts on both the target species and the *recipient ecosystem* (the ecosystem to which the relocated species is being moved), as well as economic and social values influenced by management actions.

Benefit and risk comparisons are challenging because ecological data provide inexact evidence on the degree of anthropogenic threats to biological diversity. Risk and uncertainty, in the best of situations, are difficult concepts for framing scientific information for societal engagement in decisions. Overlaying management actions that establish species outside historical distributions, which is a departure from time-honored standard practices of conservation management, adds to the challenge of managing natural resources in a manner consistent with public interest. Translocations beyond historical distributions have been conducted in response to threats posed by invading species (e.g., establishing Guam rail on the island of Rota or kakapo on small islands off of New Zealand, where predators are absent), but these are actions in response to a clearly attributable threat in a confined spatial environment (e.g., islands). Given inexact projections of risk, stakeholders may reasonably disagree on what constitutes adequate evidence to support particular management actions. Similarly, stakeholders may disagree about the value of different outcomes (e.g., extinction abatement or continued harvest productivity). Nevertheless, the ecological threat of climate change is not likely to be completely addressed by management actions that rely on traditional strategies (e.g., Thomas et al. 2011). Although managed relocation may include actions that are commensurate with the magnitude of possible future climate change, ad hoc decisions on when and where to deploy managed relocation are unlikely to satisfy societal goals effectively.

Biologically centered decision-support frameworks for managed relocation have emerged (e.g., Hoegh-Guldberg et al. 2008, Dawson et al. 2011, McDonald-Madden et al. 2011, Thomas et al. 2011). However, implementation should also include societal interests in the process of making decisions (Richardson et al. 2009). A transparent, structured decisionmaking process can facilitate societal acceptance of decisions when scientific uncertainty is high, policies are permissive with respect to individual action, and society holds conflicting values. In the natural sciences, conservation biologists, invasion biologists, and restoration ecologists are all beginning to recognize the necessity of broadening their perspectives in order to improve decisions and the social acceptability of decisions regarding natural resources management.

Our view is that the starting point for developing a decision framework for managed relocation should be an examination of the goals of conservation, values underlying those goals, and the possibility for conflict among both goals and underlying values. The next step is to examine the legal and institutional framework within which managed relocation decisions are made. Third, we must develop and agree on scientific standards of evidence to support managed relocation decisions. Finally, we must create tools for resolving goal or value conflicts. Toward this end, the MRWG identified a series of ethical, policy, ecological, and integrated questions that should be answered to support a socially and scientifically acceptable decision framework (box 1).

Ethical foundations for evaluating managed relocation

New ethical divisions have erupted among conservationists regarding managed relocation. These emerging arguments pivot on different axes from those of many traditional environmental ethics debates. Such debates often pit societal commitments to protect nature against individual freedom (e.g., the freedom to exploit nature). Furthermore, environmental ethical arguments often distinguish intrinsic from instrumental values of species and ecosystems for the purposes of protecting nature (Norton 1988, Rolston 1994). Support for and opposition to managed relocation can invoke both sides of these dichotomies (e.g., managed relocation can be defended by an appeal to the intrinsic and instrumental value of a climate-challenged species, just as it can be critiqued by an appeal to the intrinsic and instrumental value of an ecosystem that will be affected by translocation). Furthermore, the choice of conservation targets (e.g., populations, species, habitats, or ecological processes) is a complex process shaped by values and other cultural commitments (Sarkar 2005). Managed relocation, at least as it has been discussed thus far, appears to privilege a species-centered approach to conservation rather than ecosystem- or habitat-centered approaches.

The managed relocation debate brings a relatively neglected ethical question to center stage: How do we prioritize conservation duties in the face of unavoidable conflict? Some have argued that our long-running commitment to protecting species from anthropogenic threats warrants considering managed relocation as a conservation strategy (Camacho 2010, Camacho et al. 2010, Minteer and Collins 2010). However, this same argument for protecting species from anthropogenic threats has also been deployed in opposition to managed relocation (Ricciardi and Simberloff 2009). Moreover, some have claimed that traditional ethical arguments for protecting species do not justify managed relocation, since much of the value that is at risk derives from a species' connection to its historical habitat, and this will be lost when the species is translocated (Sandler 2010). However, it could be argued that there are aesthetic, cultural, and moral values at stake that are not eroded by managed relocation and that these values trump historical considerations. Finally, the ethical debate over managed relocation can be viewed as highlighting the tensions in conservation

Box 1. A proposed set of key questions identified by the Managed Relocation Working Group that are central to creating a cohesive, broad-based general framework for decisionmaking relative to proposed managed relocation actions.

Ethical questions
What are the goals of conservation, and why do we value those goals?
Which conservation goals take ethical precedence over others and why?
What is the ethical responsibility of humans to protect biodiversity (genotypic, population, species, ecosystem)?
Is there an ethical responsibility to refrain from activities that may cause irreversible impacts, even if restraint increases the risk of negative outcomes?
How does society make decisions in consideration of divergent ethical perspectives?

Legal and policy questions
Do existing laws and policies enable appropriate managed relocation actions?
Do existing laws and policies inhibit inappropriate managed relocation actions?
Do the existing implementation policies of environmental laws provide the guidance for resource managers to fulfill their obligations for climate change adaptation?
What is the process for managers, stakeholders, and scientists to work collaboratively to make managed relocation decisions?
Who pays for managed relocation, including the studies needed to support an action, monitoring, and the outcomes of the management action?

Ecological questions
To what extent do local adaptation, altered biotic interactions, no-analog climate space, and the persistence of suitable microhabitats within largely unsuitable landscapes mitigate the extinction risk (and managed relocation need) of species listed as *vulnerable*?
What evidence suggests that species are absent from climatically suitable locations because of dispersal limitations that could be addressed by managed relocation?
What are the limits of less dramatic alternatives to managed relocation, such as increasing habitat connectivity?
How well can we predict when management must address interacting suites of species rather than single species?
How well can we predict when relocated species will negatively affect host system species or ecosystem functioning (e.g., nutrient flux through food webs, or movement of individuals)?
How well can we predict the likelihood of a species' successful long-term establishment in light of a changing climate?

Integrated questions
What are the priority taxa, ecosystem functions, and human benefits for which we would consider invoking managed relocation?
What evidence of threat (extinction risk, loss of function, loss of benefit to people) triggers the decision process?
What is adequate evidence that alternatives to managed relocation are unavailable and that the probability that managed relocation will succeed is adequate
What constitutes an acceptable risk of harm and what are adequate assurances for the protection of recipient ecosystems?
Who is empowered to conduct managed relocation, and what is their responsibility in the event that the consequences are not those predicted?

between *positive duties* (e.g., saving species from extinction, enhancing ecological resilience) and *negative duties* (e.g., refraining from activities that undermine ecological integrity or that lead to decline of other species) (Minteer and Collins 2012).

The rate and magnitude of environmental change challenges the very possibility of defending species and ecosystems in their historical habitats. The alternative appears to be making principled and scientifically informed distinctions between acceptable and unacceptable interventions in rapidly changing ecological systems (Camacho 2010, Minteer 2011). Developing this latter approach would require devising an ethical framework for active, adaptive interventions on behalf of nature (Minteer and Collins 2010). Some of the skepticism surrounding managed relocation as a conservation strategy stems from what may be seen as an overly aggressive and interventionist approach to conserving species under conditions of rapid environmental change (Jamieson 2008). The challenge is therefore to distinguish, within particular decision contexts, ethically acceptable conservation actions from unacceptable ones along a continuum of interventions (from those that are commonly accepted to those that are not).

It is difficult to discern at this stage in the discussion whether the spirited debate over managed relocation emerges from ethical disagreements or from the currently weak capacity of ecological science to predict the outcomes of species introductions. In order to help clarify or resolve these questions, some environmental ethicists have called for an increased engagement of scientists in the discussion of ethical issues (Norton and Noonan 2007, Odenbaugh 2008).

It is also not entirely clear how the ethical debate over managed relocation fits within the normative framework established by conservation laws and policies (Camacho 2010). The US Endangered Species Act (ESA), for example, effectively codifies the ethical position—justified by an appeal to a range of societal values—that humans should undertake a strong effort to prevent species loss. Ecological projections suggest that managed relocation may become necessary to fulfill this promise. The ESA adopts an interventionist mode: Both *ex situ* population establishment and experimental translocation populations can be sanctioned under ESA management guidelines. The ESA, as it is interpreted by the courts, places a strong positive obligation on the US government to prevent extinctions and thus may suggest that managed relocation in the case of listed species is justified. However, the ESA also prohibits the unauthorized taking of endangered species of fish or wildlife and imposes some restrictions on degrading critical habitat for these species. This mandate indicates that people also have broader negative responsibilities not to harm natural systems. Negative ethical duties not to cause damage are problematic for managed relocation because it may be impossible to ensure that no harm results to recipient ecosystems.

There are thorny ethical questions surrounding any shift to an adaptationist understanding of conservation ethics and policy that would sanction managed relocation. The conservation message for decades has stressed the importance of saving species within historical ranges. Managed relocation may create perverse opportunities for relaxing societal commitments to habitat protection (Camacho 2010). Perhaps an even more troubling question is whether the acceptance of adaptive and anticipatory strategies, such as managed relocation, will function as a moral hazard by undercutting society's resolve to pursue aggressive climate change mitigation policies. There is a danger that even a measured adoption of managed relocation will encourage ethically irresponsible behavior. Policies sanctioning managed relocation could therefore provide leverage to those who wish to dismantle legal and policy tools designed to protect species and their habitats. Policymakers will have to take great care in communicating the need for relocation proposals to a public with divided interests so that policy revisions do not confuse and weaken human ethical responsibilities toward conservation.

Managed relocation raises significant and complex questions that contrast positive environmental duties to protect species from extinction and ecosystems from disruption with negative duties not to increase the extinction risk of the target species in its existing habitat and not to threaten the integrity of the recipient location. Understanding when and why one duty supersedes another is a key challenge for the ethical evaluation of managed relocation as a conservation strategy. Balancing the role of conventional conservation strategies and values (e.g., conserving species within protected areas) with more anticipatory and interventionist approaches (e.g., moving species to reside in appropriate protected areas outside historical ranges) is difficult. This is especially relevant to the extent that any new model departs from the generally accepted understandings of *wilderness*, *nativeness*, and idealized "pristine" systems free from human control and management (Camacho 2010, Marris 2011). The decisions that we make are likely to hinge on ideas about the kind of world that we intend to steward for future generations.

Legal and policy issues

Regulations are vehicles for achieving social outcomes. The use or misuse of managed relocation will be dictated in part by regulatory structures, resource-management policies, and stakeholder involvement (Camacho et al. 2010, Shirey and Lamberti 2010, Barlow 2011) and in part by other incentives. The effectiveness of regulations depends on how easily they can be enforced and on the weight of the economic or social incentives pushing against them.

Ideally, the legal framework for managed relocation would foster careful review of proposals for managed relocation, would provide a basis for distinguishing ethically and ecologically sound actions from those that are not, would discourage or prohibit inappropriate efforts, and would perhaps support those deemed appropriate. There are several challenges to transitioning from the current regulatory situation to that ideal. The legal and policy frameworks for these challenges vary by country. We focus on specific policy issues in the United States, but the principles are generalized to the challenges that most countries face in applying twentieth-century environmental legislation to climate change issues.

First, the current regulatory environment for managed relocation is highly fragmented and variable. The laws and policies governing the relocation of species vary widely by jurisdiction, taxon, and proposed action. Multiple regulators will often have jurisdiction over different components of managed relocation decisions (Camacho 2010). In the United States, for example, authority to regulate the movement of most flora and fauna falls under state jurisdiction (Fischman 2005). Federal authorities have overlapping control over the relocation of species listed as *endangered* or *threatened* under the ESA or covered under the Migratory Bird Treaty Act and of relocations to or from federally owned lands. At both the federal and the state level, numerous different agencies, some with conflicting missions and goals, may have jurisdiction over decisions pertaining to managed relocation. Local and tribal authorities may also be involved. Finally, there may be conflicting stakeholder interests in both the donor and recipient locations (Richardson et al. 2009). An ideal framework would require coordination, or at least communication, among all these entities and a way to resolve conflicts among them.

Second, it may be difficult to effectively regulate nongovernmental managed relocation initiatives. Across most of the United States, the anthropogenic movement of most species—other than those that have been formally identified as *endangered* or *threatened* under the ESA or as *noxious* under the Lacey Act (the 1900 federal law establishing criminal penalties for illegal trade in plants and wildlife)—is effectively unregulated. Some states have more comprehensive regulations but are unable to effectively enforce them. In California, for example, a permit is required to release into the wild any animal that is not native or that “may be genetically detrimental to agriculture or to native wildlife” (California Code of Regulations Title 14, § 671.6) or to put any live fish, aquatic animal, or aquatic plant in the waters of the state (California Fish and Game Code § 6400). Nonetheless, illegal introductions, such as that of the northern pike into Lake Davis (Goedde 1998), have caused ecological and economic havoc.

Therefore, it may be as important to discourage ad hoc managed relocation by enthusiastic individuals or groups as it is to provide guidelines for well-planned actions. So far, there has been little discussion of how best to limit unsanctioned private actions. This is a curious gap, given that one of the most visible cases of managed relocation is being conducted by a citizen action group (*www.torreyaguardians.org*) that has moved a federally listed *endangered* plant species across state lines and 600 kilometers north of the historical distribution of the species, without any regulatory oversight (figure 1). This is not to imply a governance failure. Plants are afforded limited protection under the ESA, no oversight was required by the agencies, and this private group sought no public consultation. Although legislating or regulating restraint sounds simple, it is difficult to do so effectively. Private translocation, as the Lake Davis example mentioned above demonstrates, can be extremely difficult to detect and prevent. However, individuals and groups like the Torreya Guardians, who are motivated by conservation goals, may be dissuadable by education efforts. An ideal policy framework for managed relocation would not rely on a simple prohibition of private actions but, instead, would include outreach efforts designed to inform well-meaning conservation advocates of the harm that inappropriate translocation can cause.

Third, current conservation law, generally, does not include stipulations about responses to changing climate, and this can result in conservation policies that may present barriers to appropriate managed relocation (Camacho 2010). For example, under existing regulations for designating experimental populations (50 CFR 17.81(a)), if the US Fish and Wildlife Service (USFWS) were to determine that the primary habitat of a federally listed *endangered* or *threatened* species had been unsuitably and irreversibly altered or destroyed by climate change, it could decide (through a process that requires public review and comment) to create an experimental population outside the probable historical distribution. However, because experimental populations are subject to less protection under the ESA, the USFWS might then be placed in the awkward position of more stringently regulating landowners in the donor ecosystem than those in the recipient ecosystem. Similar complications could be generated, depending on how state designations of *nonnative species* are construed and, in particular, how *nonnative* is interpreted in light of climate change and shifting potential geographical distributions.

Ultimately, an effective regulatory framework must address these challenges. Longstanding goals and legal standards that emphasize preserving protected lands on the basis of the historical range of natural variability or that emphasize minimizing human intervention may make promoting ecosystem function very difficult under climate change (Camacho 2010). Agencies and even legislatures may need to modify existing policies or laws in order to justify the appropriate uses and to identify any misuses of managed relocation. Unfortunately, it may be difficult to modify environmental laws while maintaining the goals of the original law (Camacho 2010).

Any policy framework authorizing managed relocation should minimize uncertainty regarding the risks and benefits of its use and to articulate, evaluate, and promote public deliberation about the values that managed relocation may affect (Camacho 2010). One possible solution is to foster interjurisdictional and interagency collaboration in defining best management practices for managed relocation. Key nongovernmental organizations should be included in that process. Progress toward this goal is imminent. For example, in the United States, the draft National Fish, Wildlife, and

***Torreya taxifolia* quick facts.**

- Dioecious conifer that suffered a disease epidemic that wiped out the adult population in the 1960s.
- Federally listed as *endangered* under the Endangered Species Act.
- There are fewer than 1000 individuals in the wild, all juveniles, and the population is experiencing a slow but steady decline.
- Captive populations of over 150 genotypes exist in more than three botanic gardens in the southeastern United States.
- Several *ex situ* trees produce seed.
- Torreya Guardians released 31 plants from legally obtained material in North Carolina in July of 2008.

Figure 1. The case of **Torreya taxifolia***, a federally listed* **endangered** *tree whose populations continue to decline in the wild. With several mature, seed-producing trees in the wild, the species is not at imminent risk of extinction. Despite this, the Torreya Guardians (***www.torreyaguardians.org***) felt that the species “belongs” in the Appalachian Mountains and introduced 31 trees there in 2008 (Barlow 2011). Photograph: Mark W. Schwartz.*

Plants Climate Adaptation Strategy, a collaborative effort among federal, state, and tribal partners, outlines numerous strategic climate change adaptation responses, including possible consideration of managed relocation. This report calls for the development of criteria and guidelines for action (*www.wildlifeadaptationstrategy.gov*). In addition, the adaptation chapter of the Ecosystems, Biodiversity, and Ecosystems Services technical input report for the 2013 National Climate Assessment also includes managed relocation as a possible strategy (Bruce A. Stein, National Wildlife Federation, personal communication, 2 March 2012). These documents represent the provisional first steps toward agency consideration of the full ramifications of managed relocation and the need for interagency coordination.

A cautious approach toward managed relocation might initially restrict its use to a narrow set of situations. An example would be cases in which (a) substantial data suggest that the extinction risk of a species without relocation is high, (b) relocation is feasible, (c) the target population could be easily contained, (d) the introduction is unlikely to cause substantial harm to the proposed site, and (e) the proposed site will likely be compatible with the introduced population for a substantial period (Camacho 2010). Whatever standards are adopted, they should include periodic review and revision as new research and controlled applications yield additional information about their efficacy in achieving management goals for natural systems.

Ecological questions

The ecological literature is growing rapidly with respect to the managed relocation of individual species with the goals of preserving genetic diversity (Sgrò et al. 2011), reducing extinction risk (McDonald-Madden et al. 2011, Thomas 2011), maintaining ecosystem functioning (Kreyling et al. 2011), and sustaining wild populations for resource extraction (Green et al. 2010, Wang et al. 2010). Moving species to maintain ecosystem functions and services is inadequately understood, both scientifically and socially. The importance of a shared coevolutionary history in maintaining ecosystem roles, although it is debated in the ecological literature, is simply not known. On one hand, research in ecology suggests that separating coevolved taxa might compromise important ecological functions. On the other hand, proper *ecological fitting* (*sensu* Janzen 1985) may allow species with no coevolutionary history to function adequately in newly assembled communities. Recent reviews and meta-analyses suggest that some invaded communities may perform certain ecosystem functions at a higher level than historical, native communities (Liao et al. 2008, Ehrenfeld 2010, Vilà et al. 2011), but the number of functions examined has been limited. So, although the results so far suggest that relocating species may help maintain ecosystem processes, additional work is needed.

Some populations, species, or groups of species are likely to be better candidates for managed relocation than others because they pose less risk of causing unintended damage where they are relocated, because they are able to tolerate extraction from their source populations, and because they have a high probability of a successful establishment. The characteristics of good candidates or choices include life-history attributes rarely associated with invasiveness. For example, compared with ruderal species, slow growing, shade-tolerant, long-lived trees are probably more likely to require managed relocation, and they are also often less likely to become widespread invaders. In general, introduced plants are less likely to cause rapid extinctions than are introduced animals, because predation is the principal interaction that leads to rapid extinction (Sax and Gaines 2008). Relocations within continents that do not transgress major biogeographical boundaries (e.g., mountain ranges) could reduce the risk of unforeseen negative consequences (Mueller and Hellmann 2008). We can use existing ecological knowledge to make preliminary assessments of the risk of species imposing undue impacts on their recipient ecosystems. However, we also know that ecological prediction is often poor. If managed relocation actions become common in the future, some fraction will unavoidably result in unintended management consequences (Mueller and Hellmann 2008).

SDMs may provide guidance on species that are unable to tolerate changing climatic conditions and on the identification of potentially suitable future habitats. Interest is growing in the use of models of projected future species distributions to support managed relocation (e.g., Carvalho et al. 2010), but it is difficult to place high levels of confidence in the accuracy of such models (Sinclair et al. 2010). Range shifts arise from a complex suite of drivers, including direct physiological responses to climate, responses to nonclimatic environmental conditions (e.g., disturbance), indirect effects of changing species associations, and environmental conditions with no analog in the training data set. Factors such as changing disturbance regime, species interactions, phenotypic plasticity, and adaptation are difficult to include in projecting future distributions. Furthermore, the dispersal capacity of a species projected to need to shift its distribution is a separate component of vulnerability and is, likewise, often poorly predicted (Thuiller et al. 2008).

Empirical cases documenting constraints on the capacity of SDMs to accurately forecast management need are accruing. Research that compares species' native and naturalized distributions has shown that SDMs often have a questionable ability to predict habitable climates. For example, in an examination of 26 plant species introduced to Australia, 20 of them were found to occur in areas not predicted to be suitable on the basis of native climate tolerances (Gallagher et al. 2010). Dobrowski and colleagues (2011) built climatic niche models from a historical data set and assessed their model's accuracy by comparing modern-day distribution data with the historical model's predictions. They found that the typical internal cross-validation metrics used in SDM studies consistently overestimated model projection accuracy. Although the average temporal transferability of SDMs was fair to good, about 20% of the species models showed a poor to very poor fit when projected out 75 years. The suites of species that were poorly or well modeled were not random subsets, and certain ecological traits (e.g., dispersal capacity, fire adaptation, commonness) were associated with each group. Furthermore, Dobrowski and colleagues (2011) found that the variability in the niche models' performance was driven principally by differences between species traits rather than to model algorithms or the time period of the model's calibration. Additional work is needed to better characterize these types of errors and to determine which sorts of species in which sorts of circumstances are likely to be well predicted by SDMs.

Recommendations

Stakeholders, resource managers, and scientists are developing varied climate adaptation strategies, including managed relocation. Decisions are currently being made in an atmosphere of multiple competing ethical frameworks, ambiguous policies, and scientific uncertainty. Clear policy frameworks to facilitate decisionmaking are critical when scientific uncertainty around specific cases of biotic responses to climate change remain large and competing ethical frames persist. However, definitive answers may be elusive, because biological systems are complex and so scientific uncertainty will remain high. Therefore, the MRWG did not seek definitive answers. Rather, the group sought to clarify the dimensions of an integrated approach to the appropriate use—with sufficient constraint—of managed relocation actions. These issues span science, law, policy, and ethics. Regardless of these challenges, some people, organizations, and governmental agencies want to protect threatened biodiversity using managed relocation. The difficult ethical, legal, or scientific issues will lead to conflict. Treating these issues in isolation, likewise, is unlikely to improve our capacity to create robust strategies regarding managed relocation. Researchers need to work with the agencies charged with upholding species protections, resource-management agencies, and stakeholders in order to address the multifaceted problems that climate change poses. Only with this integrated information can policymakers provide clear guidance for managed relocation.

Although many research questions remain unanswered, the literature on managed relocation is growing rapidly and provides empirical examples that can lead to overarching guiding principles. However, a better understanding of the limits of accurately predicting risk is a grand challenge for conservation. This challenge is acute with respect to managed relocation, because we simply do not yet have the capacity to predict the need for action or the capacity to predict the impacts of our actions. In addition, a healthy and spirited debate is developing in the scientific literature regarding what are, in effect, social issues. In parallel, an increasing number of papers address the sociopolitics, law, and ethics of managed relocation. This ongoing work is important, but it is neither fully developed nor adequately deployed by natural resource managers.

A structured decisionmaking process for managed relocation must integrate ethical, legal, and scientific considerations in a way that is both deliberative and publicly transparent. Resource managers need standards, protocols, and guidelines for evaluating whether, when, how, and for whose benefit managed relocation might be implemented. Conservation increasingly appears to come into conflict with other human needs (e.g., food, security, health, well-being). This conflict drives the need for a clear ethical foundation for conservation action (Odenbaugh 2008). Society strongly supports robust environmental stewardship, but people diverge in their opinions when conservation actions result in costs to people and in cases where differing conservation priorities conflict with one another. Clearly articulated ethical principles may be the strongest position from which to develop policies regarding managed relocation.

Closely linked to the scientific and ethical considerations is whether and under what conditions managed relocation is a cost-effective strategy. Decision theory applied to conservation is an appealing framework for the clarification of the scientific issue (e.g., McDonald-Madden et al. 2011), and it can include both budgetary and ethical criteria (e.g., Sarkar et al. 2006).

Clearly articulated international, national, and regional policies of conservation and biological resource management under climate change, built on an ethical foundation, will help to integrate stakeholder interests and to reduce conflict. Most of the world's conservation treaties, laws, policies, and guidance documents that might inform managed relocation decisions predate explicit consideration of climate change. The potential for climate change to directly and indirectly drive massive species extinctions brings this policy mismatch into sharp focus.

Despite our emphasis on US policies, agencies, and problems, the issues of managed relocation extend beyond national borders and involve nations with contrasting regulations, law-enforcing capacities, and economic needs. For wealthier countries, a policy void may lie in constraining unsanctioned actions. In contrast, less wealthy countries may lack both enabling and constraining policies, as well as the resources to enforce regulations even when they exist. Given that managed relocation exceeds the frontiers of any single nation, we suggest that the scientific, economic, and ethical issues should also be tackled at the international level. Existing institutions, such as the Convention on Biological Diversity, the Ramsar Convention on Wetlands, the Man and Biosphere Programme, and the United Nations Convention to Combat Desertification, may play key roles in assisting different nations to collaborate on this issue. International collaborations that currently work to reduce illegal biotic trade, such as the Association of Southeast Asian Nations' Wildlife Enforcement Network (ASEAN-WEN), could expand their scope to include consideration of cross-border managed relocation of highly threatened species. Cooperation among countries could start at capacity building and move to the more difficult issues of coordinated actions.

Within the United States, the MRWG recommends that government agencies and nongovernmental conservation organizations develop detailed policies on managed relocation. At the federal level, this effort could be led by groups structured like the Climate Change Adaptation Task Force (cochaired by the White House Council on Environmental Quality, the Office of Science and Technology Policy, and the National Oceanic and Atmospheric Administration) or the National Fish, Wildlife, and Plants Climate Adaptation Strategy (cochaired by the USFWS, the National Oceanic and Atmospheric Administration, and the New York Division of Fish, Wildlife, and Marine Resources; *www.wildlifeadaptationstrategy.gov*). State government fish and wildlife and resource-management agencies will also need to be fully engaged in this effort, because—other than actions involving endangered species—most regulation of the movement of plants and animals in the United States is under state jurisdiction.

Ideally, these efforts would entail broad public consultation, specialist consultation, agency actions, and possibly even legislative action to determine the public policy on managed relocation. Specialist consultation should be interdisciplinary to effectively address the complex ethical, policy, and scientific issues in which stakeholders will express an interest. In addition, resource-management agencies should examine whether adequate constraints exist to limit the capacity of stakeholders to take managed relocation into their own hands and to decide unilaterally to relocate species in the name of conservation. Guidelines should encourage due restraint and discourage unsanctioned actions that have irreversible consequences. These guidelines should also provide resource managers with a way to take appropriate action on problems that have no solutions under the existing management best practices. However, these guidelines must require adequate monitoring and reporting of sanctioned actions for both the target and the recipient ecosystem.

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Mark W. Schwartz (mwschwartz@ucdavis.edu) is affiliated with the Department of Environmental Science and Policy at the University of California, Davis. Jessica J. Hellmann and Jason M. McLachlan are affiliated with the Department of Biological Sciences at the University of Notre Dame, in Notre Dame, Indiana. Dov F. Sax is affiliated with the Department of Ecology and Evolutionary Biology at Brown University, in Providence, Rhode Island. Justin O. Borevitz is affiliated with the Research School of Biology at Australian National University, in Canberra. Jean Brennan is affiliated with the Conservation Management Institute at the Virginia Polytechnical Institute and State University, in Blacksburg. Alex E. Camacho is affiliated with the School of Law and with the Center for Land, Environment, and Natural Resources at the University of California, Irvine. Gerardo Ceballos is affiliated with the Instituto de Ecología at the Universidad Nacional Autonoma de Mexico, in Mexico City. Jamie R. Clark is affiliated with Defenders of Wildlife, in Washington, DC. Holly Doremus is affiliated with the School of Law at the University of California, Berkeley. Regan Early is the Rui Nabeiro Biodiversity Chair at the Centro de Investigação em Biodiversidade e Recursos Genéticos, at the University of Évora, Portugal. Julie R. Etterson is affiliated with the Department of Biology at the University of Minnesota Duluth. Dwight Fielder is affiliated with the US Bureau of Land Management, Washington, DC. Jaqueline L. Gill and John W. Williams are affiliated with the Department of Geography and with the Nelson Center for Climatic Research, at the University of Wisconsin–Madison. Patrick Gonzalez is affiliated with the US National Park Service's Natural Resource Stewardship and Science Directorate, in Washington, DC. Nancy Green is *affiliated with the US Fish and Wildlife Service, in Arlington, Virginia. Lee Hannah is affiliated with Conservation International's Center for Applied Biodiversity Science, in Santa Barbara, California. Dale W. Jamieson is affiliated with the Environmental Studies Program, New York University, in New York City. Debra Javeline is affiliated with the Department of Political Science, at the University of Notre Dame, in Notre Dame, Indiana. Ben A. Minteer and Osvaldo Sala are affiliated with the School of Life Sciences and with the School of Sustainability at Arizona State University, in Tempe. Jay Odenbaugh is affiliated with the Department of Philosophy at Lewis and Clark College, in Portland, Oregon. Stephen Polasky is affiliated with the Department of Applied Economics at the University of Minnesota, in St. Paul. David M. Richardson is affiliated with the Centre for Invasion Biology, in the Department of Botany and Zoology at Stellenbosch University, in Stellenbosch, South Africa. Terry L. Root is affiliated with the Woods Institute for the Environment, at Stanford University, in Stanford, California. Hugh D. Safford is affiliated with the Department of Environmental Science and Policy at the University of California, Davis, and with the Pacific Southwest Region of the US Forest Service, in Valejo, California. Stephen H. Schneider (now deceased) was affiliated with the Department of Biology at Stanford University, in Stanford, California. Andrew R. Thompson is affiliated with the Southwest Fisheries Science Center of the National Oceanic and Atmospheric Administration, in La Jolla, California. Mark Vellend is affiliated with the Department of Biology at the Université de Sherbrooke, in Sherbrooke, Québec, Canada. Pati Vitt is affiliated with the Chicago Botanical Garden, in Illinois. Sandra Zellmer is affiliated with the College of Law at the University of Nebraska, in Lincoln.*