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Translocation of imperiled species under changing climates

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Conservation translocation of species varies from restoring historic populations to managing the relocation of imperiled species to new locations. We review the literature in three areas—translocation, managed relocation, and conservation decision making—to inform conservation translocation under changing climates. First, climate change increases the potential for conflict over both the efficacy and the acceptability of conservation translocation. The emerging literature on managed relocation highlights this discourse. Second, conservation translocation works in concert with other strategies. The emerging literature in structured decision making provides a framework for prioritizing conservation actions—considering many possible alternatives that are evaluated based on expected benefit, risk, and social–political feasibility. Finally, the translocation literature has historically been primarily concerned with risks associated with the target species. In contrast, the managed relocation literature raises concerns about the ecological risk to the recipient ecosystem. Engaging in a structured decision process that explicitly focuses on stakeholder engagement, problem definition and specification of goals from the outset will allow creative solutions to be developed and evaluated based on their expected effectiveness.

Keywords: conservation; managed relocation; structured decision making; translocation; risk

Introduction

Habitat loss, invasive species, climate change, and other drivers of ecosystem change are resulting in increasing rates of species imperilment and decreasing success of traditional *in situ* conservation methods.[1] The failing capacity to conserve biodiversity is driving a suite of more radical approaches.[1–12] Zoo and botanic garden managers are rethinking their organizational missions;[13–17] protected area managers, their objectives;[4,7,18–20] and endangered species managers their strategies.[21–25] Within this spectrum, translocation of imperiled species is increasingly used as a conservation strategy.[26–28] However, moving species to conserve them has its own challenges. Translocation is a process that often fails,[29–33] moving species can lead to conflict among human interests in conservation,[34,35] translocation may cause unintended negative consequences to either the target species[36] or the recipient ecosystem, and finally translocation can be costly relative to other actions.[37] Under scenarios of climate change the challenges of translocation are exacerbated. For example, conservation translocations under changed climates may need to occur outside of historical distributions, referred to as managed relocation of species, and this raises additional complexities in an already challenging process.

Our purpose is to review the recent literature on conservation translocations and decision making in conservation to synthesize translocation recommendations and to focus future scientific study. Managed relocation, the conservation translocation of species outside historic distributions in anticipation of changing future climates, generates significant scientific and public concern and requires a formal decision process to evaluate the potential benefits and risks. We are just beginning to experience the ecological impacts of anthropogenic

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climate change, with the severest projected impacts on natural ecosystems yet to come.[38] Thus, there is time to plan—to develop adaptation strategies and protocols to help conserve biodiversity under climate change. With significant uncertainty about how climate will change, as well as how ecosystems will respond to the myriad other drivers of future environmental change, action comes with a large risk of making management mistakes.[39,40] Likewise, failing to act, or to act in a timely manner ultimately risks species extinction.[41] Risk generates conflict and controversy over the appropriate steps on behalf of conservation.

There are numerous cases where the need for conservation translocation is immediate.[27,28,42] These cases provide opportunities to work out protocols and processes to minimize conflict and maximize the opportunity for success. Further, there is growing recognition that dramatic, sometimes unprecedented and controversial, management actions will be required in order to maintain biological diversity through this century and into the next.[7,24,43,44] As a consequence, there is a rapidly growing research interest in understanding the trigger points for engaging in novel management actions.[26]

The conservation translocation literature is robust with examples. As climate change drives new conservation thinking, the emerging literature on managed relocation is adding new insights to this rich literature.[45–47] We integrate emerging literature on (1) imperiled species translocation, (2) managed relocation, and (3) conservation decision making to better understand how managers may plan for climate change adaptations that include translocation of imperiled species. Specifically, we focus on the suite of strategies directed at reducing extinction risk by managing the distribution of imperiled species in natural habitats. In treating this subject, we call specific attention to three issues often overlooked in translocation efforts. First, we focus on biological assessments and planning within a decision support framework to foster careful evaluation of translocation against alternative management options. Second, we draw attention to the requirement of risk assemement, including the risk of negative ecological impacts of translocation on recipient ecosystems. Finally, we highlight the need for translocation plans to formally integrate stakeholder concerns and social acceptability into all phases of the management action. As future translocations may increasingly occur outside historic distributions, it becomes critically important to use a thoughtful and structured process to integrate social and scientific concerns into planning, monitoring, and assessing impacts.

Conservation translocations span a continuum from modest population augmentation to establishing populations in locations with no history of previous occupancy.[23] Terminology to describe these actions, however, is variable.[48] We restrict our usage of this terminology to conservation applications. We use the term *conservation translocation* for any action that involves moving individuals of a species from one location to another for a conservation purpose (e.g., extinction risk abatement, population restoration, establishment in predator-free habitats, reinforcing low populations, increasing genetic variability, improving ecological function).[26] We use the term *managed relocation* to refer to that subset of conservation translocations that are restricted to moving species outside their historic distributions for the purpose of establishing and managing populations in response to changing climate.[48] *Assisted migration* and *assisted colonization* are generally considered synonyms of managed relocation.[47,49–51] We prefer *managed relocation* because it mandates a postrelease management obligation, whereas the more commonly used *assisted colonization* does not.[47]

With the recent explosion of literature on species translocations generally and managed relocation specifically, we attempt to clarify critical research questions to facilitate sound conservation translocation decisions that integrate scientific understanding and social concerns. The managed relocation literature has exploded; over 75% of 195 papers (ISI search, 15 June, 2012 on title words *managed relocation* or *assisted colonization* or *assisted migration*) have been published since 2008. This literature has ranged from empirical descriptions of projects,[52] to rationale for decision support[46] and debate regarding the scientific,[24,53–57] ethical,[11,58–60] and legal[3,61–63] issues associated with managed relocation. In contrast, the conservation translocation literature is robust, with numerous case studies emerging each year.[27,28]

Finally, an array of applied tools, variously called structured decision making, decision analysis, or decision support, have emerged from decision theory and multiattribute utility theory[64,65] and are

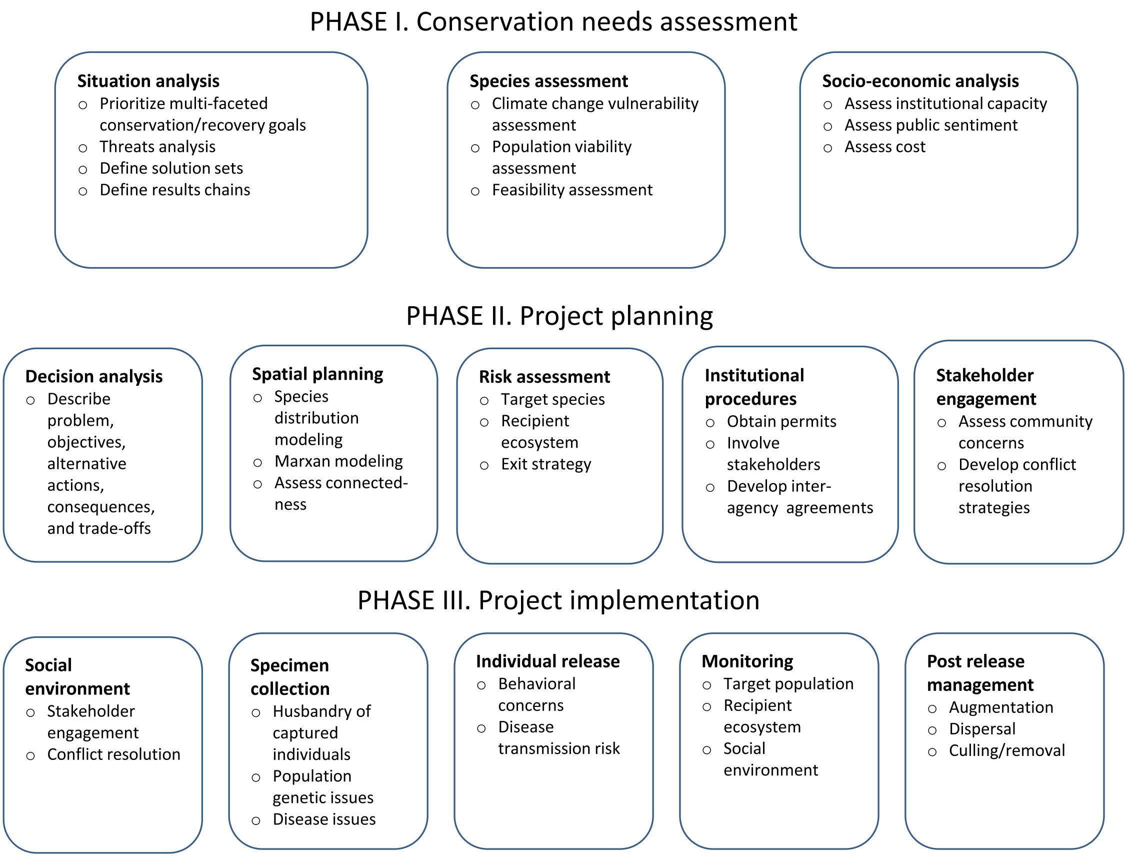

Figure 1. Translocation of imperiled species as a three-phase activity that includes actions associated with a needs assessment (phase I); project planning (phase II); and implementation (phase III). This step chart emphasizes the need for social engagement throughout the process and the value of using emerging conservation decision support tools. Although these phases may proceed sequentially from left to right through each phase, adaptive management suggests planning should return to the situation analysis in order to ensure that translocation remains the favored action despite barriers and challenges that are encountered through the assessment, planning, and implementation processes.

finding applications in conservation.[47,50,65] This literature has attempted to use decision science to foster robust decisions for conservation.[66–68] Following these ideas, we examine the various phases of translocation project development with a focus on the application of conservation tools that can support decisions and resolve problems that need to be addressed at each of three phases of a translocation process (Fig. 1).

Phase I: conservation needs assessment

Actions to foster the common conservation objective of reducing the threat of extinction often focus on increasing the number of populations of threatened species[69] and may include actively establishing new populations. The candidate assessment phase of the translocation process may be relatively simple when the driving goal of a translocation is to reintroduce a species that has been extirpated from a portion of its range, and increasingly complex when goals include ecosystem management objectives. If the conservation objective is to alleviate extinction risk for a target species, then it is not necessarily a simple matter of justifying a translocation project as restoring what once was. There is typically a suite of management alternatives available for achieving the goal of extinction risk abatement (e.g., augmentation of existing populations; habitat management; management of threats such as predation *in situ*; fostering connectivity and dispersal; translocation). Given agreement on conservation goals, structured decision making can be used to assess the most

Table 1. A hypothetical imperiled species translocation planning timeline to develop decision support

Phase I: The needs assessment		
Situation analysis	**Examples of frameworks**	**Examples of tools**
How severe is the extinction risk?	Red Lists; Endangered Species Act	Population Viability Analysis (PVA)[130]
How does abating extinction risk for the taxa compare to other conservation objectives?	The Open Standards for the Practice of Conservation (OS);[73] structured decision making[71,74]	
What are the threats to the target species?	Structured decision making[71,74]	OS threats analysis;[73] consequence table[131]
What are the consequences of alternative management actions on species persistence?	Structured decision making[71,74]	OS results chains[73]
Species assessment		
Are current populations stable and likely to persist?		PVA[130]
Does climate change threaten persistence?	Vulnerability assessment[76]	
Can the species tractably be collected, husbanded, and relocated?	Feasibility assessment[124,131,132]	
Socioeconomic analysis		
Is there institutional capacity to conduct a translocation effort?	Feasibility assessment	
Is the action a cost-effective strategy?	Economic assessment[131]	
Is a translocation likely to be socially acceptable?	Systematic conservation planning;[105,106] structured[71,74] decision making[71,74]	

beneficial and cost-effective strategies to employ; translocation is but one option.

There are conditions that must be met before considering a species as a candidate to alleviate extinction risk through translocation (Table 1). To begin, managers evaluate whether a proposed action on behalf of the species is motivated by a threat to the species persistence, making it a candidate for conservation translocation. An alternative motivation, for example, would be the restoration of ecosystem structure or function by replacing extirpated species.[70] The act of translocation, in each case, may be the same, but the motivation is different, leading to a different set of alternative actions against which translocation is considered.

The creation of new populations is one of several potential management options for alleviating extinction risk. Undertaking a structured decision making process[71] or situation analysis[72] that explicitly states the goals for conserving the potential candidate species, threats to achieving these goals, and strategies to alleviate threats, can foster clear decisions on whether a species is a viable candidate for translocation (Table 1). The Open Standards for the Practice of Conservation (OS)[73] outlines one such protocol for constructing a situation analysis that explicitly details working hypotheses for direct and indirect threats to achieving conservation goals and alternative strategies for alleviating those threats. Like OS, structured decision making[71,74] also fosters the development of clear planning and the delineation of assumptions to choose among alternative actions to achieve a conservation objective. Structured decision making strongly emphasizes getting the context (the scope and bounds of the problems) right, including engagement with key stakeholders, and it facilitates agreement on the objectives, the definition of alternative management actions, and the evaluation of expected consequences of these alternative actions. The next step of structured decision making is to assess the key trade-offs among these consequences and then finally to determine how to implement the decision to promote learning over time and opportunities to revise management based on this learning.[71]

Assessing condition may range from a simple reference to endangered species recovery criteria for a minimum number of populations to achieve delisting of an endangered species[69] to formal population viability assessment.[75] Creating additional populations through translocation may then be high or low priority relative to other options for achieving the stated conservation goals. For example, creating more populations of species that are at risk due to exploitation might simply expand illegal exploitation and not work toward reducing extinction risk. A complete condition assessment will examine whether the addition of populations is a high-priority objective and whether the target species requires translocation in order to establish new populations.

As a consequence of climate change, assessing the security of a species includes projecting how changing environmental conditions may affect current conservation measures and the long-term stability of the target species. Climate change vulnerability assessment[76] can inform an estimate of the degree to which new populations are viewed as critical components of a conservation strategy.[77] In addition, not all species that are in need of additional population creation are feasibly translocated (Table 1). The biology of the species may preclude translocation as a viable alternative, suggesting that a preliminary feasibility assessment is warranted early on in the planning process.

If the target species appears to be a viable candidate for translocation because of biological need, then socioeconomic issues must also be considered (Fig. 1). For a species to be considered a candidate for translocation, managers must be certain that there is adequate motivation for action. This motivation can come in at least three forms (Table 1). First, there must be institutional support with which to conduct the translocation. This requires that institutional structure allows the translocation, including permitting and cross-agency cooperation.[78] A recurrent issue in translocation is that it often involves interagency collaboration, which is fraught with pitfalls.[79]

A second socioeconomic concern is that there must be adequate financial support to conduct the translocation (Table 1). Balancing the needs of a presumptive conservation target against other potential protection efforts can be a difficult task. In order to meet these criteria, managers must treat translocation as an investment decision.[9,80–82] Based on what is known, would translocation be a wise investment of limited resources, or do alternative priorities take precedence?

Finally, there must be adequate public support to accept the translocation as a legitimate conservation action (Table 1). Targets for translocation are often large vertebrates that can engender strong positive and negative feelings among stakeholders.[34,35,57,83] Beyond negative attitudes toward species translocations based on safety, there are legitimate public concerns regarding conservation translocations on the basis of divergent understandings of conservation goals. This problem comes to the fore with managed relocation, where the priority to protect an endangered species may come into conflict with a conservation goal of minimizing adverse ecological impacts of rapid climate change. Management efforts to slow ecological responses to climate change, allowing biota to respond on their own time frames, would run in direct opposition to facilitating change through managed relocation. Attention must be given to public attitudes toward the translocation within the recipient ecosystem. This challenge is acute where managed relocation of species into novel environments is primarily regarded by sectors of stakeholders as undesirable.[57]

Consider a mammal, threatened by introduced predators (e.g., cats and foxes) and climate change. The use of a consequence table can help to identify the trade-offs of a decision given the consequences and feasibility of each alternative action, and to form the basis of a structured decision-making process (Table 2). The table should include the consequences of taking no action. Feasibility includes the social and political feasibility of executing an action as well as the scientific and technical feasibility. While the positive consequences assume that an action is undertaken under the best possible conditions,

Table 2. **Consequence table showing predicted outcomes based on alternative strategies for a problem of conserving an endangered mammal threatened by introduced predators (cats and foxes) and climate change**[a]

Objective	Maximize number of viable subpopulations (B)	Minimize (C) cost(C)	Maximize feasibility (F)	Cost-effectiveness $B^{*}F/C$
Performance measure	Probability of persistence	$M	Probability	
Do nothing	0.01	0.01	1.0	
Kill feral predators	0.7	0.5	0.3	0.41
Build predator-free exclosure	0.75	0.5	0.7	0.91
Translocate	0.5–0.95	0.6–2.5	0.1–0.6	0.02–0.95

[a]Consequences tables form the basis of more detailed decision analysis by specifying clearly the objectives, their performance measure, the alternative actions, and the consequences of these actions on the performance measure. Here, the cost-effectiveness of the alternative actions is calculated as the benefit (B) (difference between the probability of persistence of the species with the action and without the action *do nothing*) multiplied by the feasibility (F) (social–political and technical feasibility of taking the action as intended), divided by the cost (C) (economic cost of undertaking the action). In this case, because of the uncertainty regarding the estimates for the action *translocate*, the action *build predator-free exclosure* is likely to be the most cost-effective. For more information on cost-effective analysis, see Ref. 66.

feasibility captures the likelihood that the action will not achieve the intended consequences because of other constraints. For example, managing feral cats may have a high ecological benefit, but the feasibility of doing so is likely to be low because of the social resistance to cat management as well as the possible technical challenge of complete extirpation. If the objective is to prioritize which action to take, one can use a simple cost-effectiveness analysis (a form of structured decision making, see details in Ref. 66). Alternatively, if we want to know which actions to take over time considering the dynamics and uncertainty in the system and our understanding of the system as a result of monitoring, we can use more complex tools of decision analysis, including various optimization techniques.[84,85]

In our hypothetical example (Table 2), we include a range of values for benefits (b), costs (c), and feasibility (f) for the action *translocate* based on uncertainty. Uncertainty in cost includes the potential that the translocation results in adverse ecological impacts, and species removal may be needed. Uncertainty in feasibility includes both the potential for the translocation to succeed as intended and the potential for high social resistance to translocation. By including this uncertainty, the action to translocate may be the most or the least cost-effective action, depending on whether we assume the best or worst case scenario.

Often the best action to take cannot be determined. Where there is an opportunity to learn about the efficacy of actions through time, techniques such as expected value of perfect information (EVPI) can be employed. EVPI allows the analyst to estimate what action is likely to provide the greatest increase in information gain (reduction in uncertainty) for each research dollar invested.[86] Optimization tools are also useful for evaluating actions when explicitly considering uncertainty.[46,84,85,87] Combined with active adaptive management, optimization tools can also be used to evaluate which actions provide the greatest benefit over time.[88]

Phase II: project planning

Elevating a species to become a candidate for translocation entails decisions supporting the aforementioned biological need, expected benefit, and cost, along with the technical, institutional, and social feasibility of alternative management actions. Having begun this assessment, careful and specific project planning[89] is required (Fig. 1). Just as in a needs assessment, project planning for translocation includes a suite of both biological and social concerns (Table 3). Numerous sources provide guidance for the biological concerns that must be addressed when planning translocations.[26,90] Despite these recommendations, it appears that the

Table 3. A hypothetical imperiled species translocation planning timeline to develop decision support

Phase II: Project planning	
Decision analysis	**Sources, tools, frameworks**
Describe problem, objectives, engage stakeholders, define alternative actions, consequences, and trade-offs	Structured decision making[71,94]
Spatial planning	
Assessing potential translocation sites	Species distribution modeling; patch occupancy models[133,134]
Finding an efficient spatial solution	Spatial PVA's combined with Marxan or zonation dispersal modeling[135]
Assessing connectedness among population and proposed sites	
Risk assessment	
Target species risk	Populations genetics, behavioral ecology, disease risk[91,92]
Recipient ecosystem risk	Modeling ecosystem impacts; develop a termination strategy
Institutional procedures	
Permissions	Obtain necessary permits; assess cross-institutional needs
Cooperation	Develop a project team;[105,106] develop a stakeholder network

majority of translocations are conducted without an obvious integrated biological assessment.[91] Among proposed planning requirements, three overarching goals related to harm repeatedly emerge. The proposed action must strive to harm neither (1) the extant population; (2) the individuals being translocated; nor (3) the recipient ecosystem. This assessment of harm includes issues associated with disease transmission within the target species and between the target and other species.[92,93] These concerns also include genetic issues for both the existing and new populations.[26] With respect to harming recipient ecosystems, translocations to areas where the target has been extirpated generally involve the assumption that the recipient ecosystem can absorb the species without negative impact. This assumption comes into question for managed relocation where species are being introduced to new ecosystems. Naturally, decisions often must consider offsetting harm, and therein lies the challenge of making decisions regarding managed relocation.

Through the application of a structured decision making process,[71,94] managers can plan by evaluating the options given by the objectives of the translocation program and the consequences of alternative management strategies. This careful evaluation of alternative strategies is essential for making a robust case for a translocation effort.

After being satisfied that individuals of the target species can be feasibly moved with minimal risk to the target species, recipient locations must be identified (Table 3). A solid working hypothesis for the habitat requirements of the target species is needed. In the case of climate change, this must include an assessment of the capacity of the species to persist within its historic distribution. Species distribution modeling or habitat occupancy modeling can be used to project this suitable habitat.[95,96] Combined with information on species dynamics, species distribution models can provide information on population viability.[97]

With respect to concerns for adverse impacts to either target species or recipient ecosystems, risk assessment frameworks may be appropriate for understanding the potential negative impacts of translocation efforts (Table 3). Most efforts to summarize translocation risk focus on the risk to the target species.[26] Elements to consider include the conservation status of the site, tenure security, and minimization of opportunities for hybridization and invasiveness.[78] Several types of sites are recommended for exclusion: sites of high species endemism, IUCN category 1 reference reserves, and fully functional threatened ecological communities.[78] Humans have a long history of intentional and unintentional alteration of species distributions.[98] Hubris with respect to tinkering with the distributions of species costs millions of dollars in management costs each year[99] and drives untold ecological damage.[98] Even though there have been few examples of translocated threatened species creating adverse ecological impacts, many ecologists remain concerned.[47,53,55,57,100,101] As climate change adaptation strategies suggest more dramatic translocations, the risk of adverse impacts from our conservation efforts increases, demanding that more attention is paid to risk assessment.

Risk assessment of adverse impacts to recipient ecosystems should include an appraisal of termination costs—is it feasible and what might it cost to control or eradicate the target translocated species should it prove to have negative impacts on the recipient ecosystem? If there are no good eradication methods possible (e.g., many insect taxa), then more effort is warranted to provide assurances that the risk of adverse impacts is minimal. The consequence is that we may, in the end, choose to forego translocation efforts on behalf of species, despite compelling evidence of a possible extinction, simply because the consequences of adverse impacts are too great. There may be many cases where these risks suggest increased emphasis on less risky (lower cost) but potentially less successful (lower benefit) and more socially acceptable (more feasible) strategies like augmentation of existing populations (Table 3).

Institutional procedures may create barriers to conservation action involving translocations (Table 3). There may need to be changes to existing environmental legislation to facilitate managed relocation.[78] Permits for collection, husbandry, transportation, handling, and release may all be required for targets of translocation. Interagency or even international agreements may be required. Changes to national laws or international guidelines may also be needed.[48] For example, under recent IUCN guidelines, populations introduced outside the natural range of the taxon are not assessed globally as contributing to the conservation status of a species.[102] Under this rule, managed relocation may not make a positive contribution to IUCN Red List conservation status[103] or to the Millennium Assessment Goals.[102]

A critical function of a manager is consideration of the ethical and social acceptability of a translocation action among stakeholders (Fig. 1). Many notable translocation cases have generated public controversy (e.g., bears and wolves[34,35,83]). With future climate change, more conservation translocations may be managed relocations, which carry their own potential for controversy.[53,54,57,104] Systematic conservation planning,[105,106] the Open Standards Framework for the Practice of Conservation,[73] and structured decision making[71] each provide a framework for engaging stakeholders with different views.

With social discord over a proposed translocation, the identity of the manager or decision maker is important. For example, if the decision maker is a government agency, then engaging private stakeholders is often a requirement, but private stakeholders may have a limited role in the decision process.[3,48] In contrast, private individuals may be viewed as advocates for a specialized point of view that may not be universally supported. The Torreya Guardians, as an example, translocated an endangered tree species onto private lands over 500 km outside the species' known historic distribution.[107] This was a private action that appears legal despite the target species, *Torreya taxifolia*, being regulated under the U. S. Endangered Species Act.[48] Given that this is a conservation translocation into a new biogeographical location (managed relocation) with no apparent plan to evaluate potential adverse ecosystem impacts or exert population control of the species if there is spread, one could also argue that there is an ethical obligation to public interest.[11,59,62]

Ethicists have described differences in ethical frameworks for conservation related to the combined responsibilities for positive and negative duties to nature:[11,48] a drive to do good, but also to not do harm. Managed relocation has the potential to do both good and harm with respect to socially defined biodiversity values. Stakeholders can become entrenched in their own worldview and it is quite likely that coalitions will form to advocate on behalf of benefits to the target species as well as risks to the recipient ecosystems.[108,109] Resolutions, where they are made, focus on building trust through careful negotiation and collaborative decision making.[110–112] Each of the conservation frameworks discussed here (structured decision making, the Open Standards, systematic conservation planning) provides a potential for building trust. Collaborative decisions and trust building, however, are costly as measured by both time and money, and this too has to be included into the evaluation of alternative actions (Table 3).

Adding managed relocation to the suite of potential threatened species translocation options broadens the consideration of triggers for management action. The focus of management concern for translocations of threatened species has historically been how translocation affects the target species.[113] Choosing between alternative actions, however, results in trade-offs among competing objectives and the impacts that they might have on the ecosystems into which they are introduced. These trade-offs become acute when we acknowledge that conservation objectives include human values that may or may not support assisted movement of species outside their historic distributions as a conservation action.[55]

For the translocation of threatened species within historic distribution boundaries, the concerns for recipient locations, both with regard to adverse ecological impacts on other species or ecosystem functions, is generally regarded as minor. In contrast, ethical concerns over human intervention in nature and a social concern for an idealization of the natural[3,35,53,60,104] often dominate the consideration of conservation translocations outside historical distributions.[114,115] It is challenging to find examples of threatened species that were translocated outside their former ranges and became invasive. History suggests that species that are deliberately introduced into environments adjacent to their historical distributions are less likely to become management problems (except for the case of native Ohio river rusty crayfish, *Orconectes rusticus,* which became invasive throughout the United States[116]). Nonetheless, translocation of a species to habitats outside its historic distribution is a major divergence from traditional conservation tools and highlights differences in motivation among conservationists.[58] Thus, despite calls for a more relaxed view of what constitutes a natural system,[2,7,24] scientists diverge in their views of the efficacy of managed relocation as an endangered species management action.[53] Hence, consideration of translocation as a management strategy requires attention to human values in order to manage conflict and reach a management decision.

Phase III: project implementation

Once target locations are identified, appropriate operational strategies for translocation become a leading concern (Fig. 1). These strategies can include collecting individuals, husbandry of individuals in captivity, consideration of dependent and coevolved species and disease, monitoring, and defining the criteria for determining success.[26,78,92] A common concern in conservation is that we manage actions only when conditions are beyond repair, making failure much more likely.[41] Knowing when to act is critical. Emerging tools that draw upon decision science for natural resource management can help guide timely decisions.[73,74,117,118] With respect to translocation, these tools are particularly useful when there is uncertainty about the trajectory of a species.[81] In these situations, optimization tools can estimate when managers should engage in efforts to conserve populations.[46] Estimating the timing of intervention requires consideration of the potential delays that result from socioeconomic issues, including budget cycles, permitting, and social resistance. Adding nonbiological issues, like conflict resolution, is likely to increase the urgency for action by increasing the time it takes to act. This also implies that the first actions in a translocation project may be focused on reducing conflict among stakeholders[34,35,79] (Fig. 1).

We limit our treatment of the biological decisions here because there are a variety of sources that detail implementation strategies and issues associated with actual species translocations. [26,78,90,119] In addition, case studies provide a wealth of information on plans, accomplishments, and lessons learned from translocations.[27,28] Common concerns revolve around the extraction of individuals from extant populations, the care and handling of these individuals, and the functional details of their release.[120] These case studies reinforce the idea that planning is critical to success,[121] but also that many conservation decisions are time sensitive.[41]

Conclusions

The practice of conservation is becoming more structured with respect to planning, action, and evaluation.[26,71,73,105,106] Translocation actions follow this trend, with direct attention to monitoring[122–124] and adaptive management[45,125] becoming commonplace. Among the challenging aspects of translocation is engaging an adaptive management program[45] that proactively plans for adaptation to impending environmental changes and is responsive to stakeholder concerns. It is critical that proposed translocations continually revisit, as dictated by adaptive management, the initial premise of a target species as a candidate for translocation, including alternative strategies for achieving the stated objectives as new information modifies our understanding of the costs, benefits, and feasibility of conservation actions.

Conservation agencies and organizations are working to develop climate change adaptation plans[105,126] alongside conservation scientists who are actively working to be relevant to management decisions.[127,128] Structured decision making forces the practitioner to clearly define the context of the problem, to state explicit objectives, and to determine how translocation fits within the context of the overarching conservation goals. This planning structure, in turn, can lead to clear and testable alternative management options and to creative solutions for what are vexing conservation problems. As the impacts of climate change increase, there will be an increased attention to translocations outside the historic range boundaries of species and these managed relocation events will require very clear planning and justification. Managed relocation, by virtue of placing species in novel environments, increases the risk to recipient ecosystems,[100] requiring an expansion of targets of translocation action, monitoring, evaluation, and what constitutes management success.[78]

Similarly, as conservation occurs in an increasingly crowded and resource-limited world, social discord over the wisdom of translocation and managed relocation as conservation strategies becomes more acute. The translocation literature is strongly dominated by research focusing on the biological challenges and outcomes of translocation.[26] The literature on decision support tools for conservation focuses on making decisions under uncertainty,[46] and provides synergy with the managed relocation literature, where conflicts over objectives and uncertainty over outcomes are paramount.[48] Conservation managers working on translocation projects can guide future decisions by reporting more frequently on the process of controversial translocation projects, irrespective of the biological outcome. Managed relocation of endangered species may help conservation decision science develop better formal structures for collaborative decision making on issues that divide the conservation community.

Critical concerns over managed relocation include recipient ecosystem impacts as well as sharply contested social environments where conservationists disagree over the wisdom of proposed actions. Conflict is likely to increase the response time for action, which suggests that social concerns must be addressed early in the translocation planning process to provide sufficient time for action once decisions are made. Further, structuring the decision process so that there is a logical path that specifies presumptive cause and effect relationships among factors that are driving a conservation need may provide a foundation from which conflicts can be discussed and resolved. Although we need more research into the biological need for translocation, and refinements of methods to identify potential habitat value under climate change in order to locate recipient habitats, there is also a need for research in the social sciences to integrate conflict reduction strategies[108,110,111] into structured conservation decisions.

McDonald-Madden *et al.*[46] assess optimal timing for managed relocation of a declining species and include a section called "moving the debate from whether to when." The argument these authors make is that decision analysis can point to an appropriate time for engaging in managed relocation. What this research did not consider, however, is that risk to recipient ecosystems may be viewed by stakeholders as sufficiently large so as to never accept managed relocation as a valid conservation strategy, even if it means extinction of a species. When social acceptability of managed relocation is low for an endangered species, the problem becomes (1) how to resolve conflict in order to develop an effective conservation strategy; (2) whether there are management strategies, *in* or *ex situ*, that can prolong a species' persistence through the resolution of social discord; (3) whether there are acceptable alternative conservation actions, including other translocation sites that, though biologically suboptimal, are sociologically more acceptable. The multifaceted nature of translocation within the context of these features strongly suggests a systematic and structured approach to project planning and implementation.

Addendum

Between the time this was written and went to press, the IUCN issued new updated guidelines for conservation translocations.[129] These guidelines parallel many of the recommendations made herein but do not follow a structured decision-making process, as advocated by this paper.

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Conflicts of interest

The authors declare no conflicts of interest.

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