Assisted Migration
as a Climate Change Adaptation Strategy for Conservation

A Report for Staff of The Nature Conservancy

Assessing post-burn condition of translocated longleaf pine in Maryland ©Matt Kane

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For more information on the Center for Resilient Conservation Science and to access the report and companion screening form, visit: https://crcs.tnc.org.

Executive Summary

The climate is changing, and plants and animals are moving to seek more suitable conditions as their current habitat becomes less hospitable due to warmer temperatures or changing precipitation patterns. Maintaining and in some cases rebuilding landscape connectivity to facilitate this movement is a core strategy in The Nature Conservancy's (TNC) approach to managing for climate resilience (Anderson et al., 2023). But fragmented habitats that restrict species dispersal and a rapidly changing climate that may outpace natural dispersal rates present a compelling argument for land managers to intervene and intentionally translocate species or genetic material to more suitable ranges (Lombard et al., 2021), a process broadly referred to as assisted migration[1]. The goals of TNC's Assisted Migration Project were to document the current range of assisted migration activities within TNC, assess the state of the science, identify key issues of concern, and develop practical guidelines for TNC staff considering the use of assisted migration as a conservation strategy.

We found widespread interest in assisted migration within TNC, with the organization already engaged in a variety of ways, from the development of guidance to relevant on-the-ground activities (see Appendix 2 for a partial list of TNC projects). Current implementation is almost entirely limited to translocations within a species range, a type of assisted migration sometimes referred to as assisted gene flow or assisted population migration. Staff expressed cautious optimism about the usefulness of assisted migration, tempered with concerns about unintended consequences, particularly the creation or spread of invasive species, and an uncertain cost/benefit ratio for the practice. Practitioners called for more information and organizational guidance, for which we hope this document helps to fill the gap.

A literature review revealed that there is not yet a robust body of science documenting the success of assisted migration as a conservation strategy. Documenting success requires evidence of a self-sustaining population that is pre-adapted to the changing climate and does not negatively impact the existing community or ecosystem at the recipient site. Relatively few studies report long-term, empirical data from experimental or conservation implementation studies, as compared to theoretical or modeling studies. Available empirical studies mostly report success in terms of individual survival and growth, not reproduction, and do not assess community-level impacts. Because assisted migration is an active area of research, and because many of the drivers of success will be context-specific, we urge TNC staff to build or tap into local networks of colleagues, partners, and academics engaged in this work on similar systems and taxa.

This report draws from TNC experience, a literature review, and existing guidance documents produced by other organizations and agencies. Additionally, we developed a companion

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[1] As used in this report**, assisted migration** refers to the human-mediated movement of an organism for conservation benefit to the translocated organism and/or the recipient ecosystem, in response to or anticipation of climate change impacts. For brevity's sake and to align with our project scope, we use the term 'assisted migration' broadly, to include movement of an organism within the species range or outside the species range.

Assisted Migration Screening Form intended to guide decision-making by TNC staff in North America considering the implementation of assisted migration. The screening form includes guiding principles, assessment questions, and resources that address the key issues of concern regarding assisted migration:

- Potential Risks, including ecological risks to the source population and/or recipient ecosystem, socioeconomic or cultural impacts to local and indigenous communities, and reputational risk to TNC.
- Feasibility Factors, including the technical difficulty of moving species, potential impediments from policy and regulations, opposition from interested parties, and limited staff and partner capacity to implement the work and monitor the results.

We do not propose new TNC policy or a formal process for review and approval of assisted migration projects. Instead, we advocate for the continued reliance on the judgement and expertise of on-the-ground staff to make determinations of when and how to proceed. We provide the information in this report and the screening form to support decision making by TNC staff and other conservationists considering assisted migration. We encourage staff to continue the conversation on assisted migration, sharing their experiences to provide the building blocks of best practices and lessons learned regarding this emerging climate adaptation strategy.

Acknowledgements

This work would not have been possible without support from TNC’s California Division and invaluable feedback from our internal Advisory Committee. Special thanks to Mark Anderson, Director of Conservation Science for TNC’s Center for Resilient Conservation Science, for guiding this work and offering key insight to this emerging approach in Conservation. This report and the accompanying Screening Form were greatly improved by thoughtful input from Advisory Committee members. Their expertise on conservation work amidst a changing climate and the time they provided to this project was greatly appreciated. Special thanks to those who contributed their time presenting during the Listening Sessions at the start of the project, and those who shared their experiences and perspectives throughout this effort.

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Deborah Landau; Director of Ecological Management, Maryland/DC
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Introduction

Background

The climate is changing. Temperatures are increasing – the planet has warmed 1.1 degrees C already and is on track for 3.2 C of warming by 2100 (Fig. SPM5a in IPCC, 2023). Precipitation is more complicated - the amount, timing, and intensity of precipitation events is changing. Some places are becoming wetter overall, and other places are becoming dryer. Over the last 60 years, sea level has risen markedly, ranging from 2.5 inches in Los Angeles to over 12 inches in Galveston Texas (Spanger-Siegfried et al. 2014)

Species ranges are changing in response to climate change. As their current habitat becomes less hospitable due to warmer temperatures or changing moisture, plants and animals are moving to seek more suitable conditions. Generally, the movement is northward in latitude or higher in elevation, but there are regional variations to this pattern (Chen et al., 2011).

Maintaining and in some cases rebuilding landscape connectivity to facilitate species movement is a core strategy in TNC's approach to managing for climate resilience (Anderson et al., 2023). But some species will not be able to move fast enough on their own to keep pace with climate change. Slow-growing and long-lived taxa such as trees might find natural migration in response to climate change particularly challenging. In addition, many species will encounter anthropogenic barriers that prevent them from reaching locations where future conditions might be more favorable for their survival and reproduction. As a result, some species will face extinction or local extirpation, and ecosystem functions that depend on those species may be lost. Fragmented habitats that restrict species dispersal and a rapidly changing climate that may outpace natural dispersal rates present a compelling argument for land managers to intervene and intentionally translocate species or genetic material to more suitable ranges (Lombard et al., 2021), a process broadly referred to as assisted migration[2].

Assisted migration as a conservation strategy is controversial, in part because it represents a paradigm shift for conservation - from preserving what is there or restoring what was lost to anticipating what might be needed in the future. Brown et al. (2022) discusses the need to shift from preservation and restoration to anticipating and managing for change. At least two different frameworks have been proposed for how to think about a continuum of management actions for climate change adaptation: Resist-Accept-Direct (RAD) adopted by the National Park Service (Schuurman et al., 2020) and Resistance-Resilience-Transformation (R-R-T) used by the US Forest Service (USDA Forest Service, 2023). The highly subjective decisions and ethical debates about if, when, and how natural systems ought to be managed has led to a lack of consistent policy on assisted migration (Cooke et al., in press) despite the growing calls for developing policy both at the international level (Brodie et al., 2021) and national levels.

[2] As used in this report, **assisted migration** refers to the human-mediated movement of an organism for conservation benefit to the translocated organism and/or the recipient ecosystem, in response to or anticipation of climate change impacts. For brevity's sake and to align with our project scope, we use the term 'assisted migration' broadly, to include movement of an organism within the species range or outside the species range.

There are many unknowns associated with assisted migration, including large uncertainties associated with predicting future conditions and potential natural range shifts. These climate change related uncertainties add a layer of complexity beyond the already challenging work involved in more traditional restoration or reintroduction projects. There are also many potential risks. People have a history of failing to anticipate unintended consequences of moving species, as evidenced by the many species we intentionally introduced that have become invasive. In a recent survey of experts, transmission of diseases was ranked the most important potential risk of assisted migration for native biota at the recipient site (Kracke et al., 2021[3] and Figure 1). Despite the uncertainties and risks, the reality of climate change has caused conservation practitioners – including those at TNC – to begin to plan for and implement assisted migration.

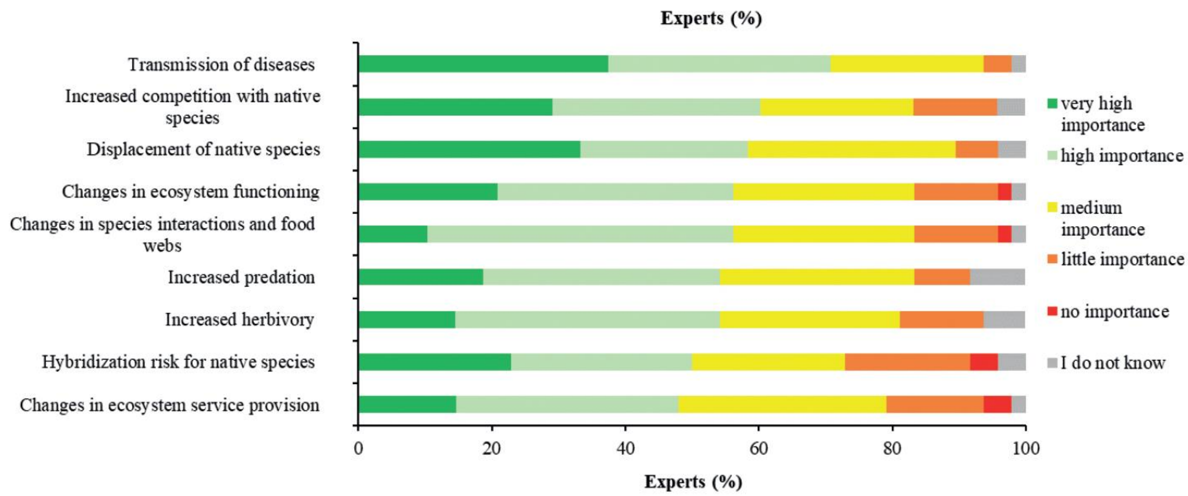

Figure 1 Expert opinion on the importance of potential risks of assisted migration for native biota of the recipient site. Adapted from Kracke et al., 2021.

To date, TNC has not produced consistent guidance about assisted migration, or provided resources to support land managers in deciding when, how, or where to implement this strategy (Lombard et al., 2021). Recognizing this gap, TNC's North America Region (NAR) leadership proposed a project to synthesize information on the science of assisted migration and develop decision-support guidance for TNC staff. The Assisted Migration Project was developed as a one-year research fellowship under TNC's Coda fellowship program, sponsored by the Center for Resilient Conservation Science, with funding from the California Division. The project team consisted of two long-tenured staff, Michelle Canick, Coda Fellow and Project Lead, and Adam Starke, Coda Fellow, with guidance from Dr. Mark Anderson, acting as science sponsor. In addition, the project was guided by an internal advisory committee consisting of TNC staff engaged, or likely to face decisions about engaging, in assisted migration projects (see Acknowledgements section). The goals of the project were to document the range of assisted migration activities within TNC, assess the state of the science, identify key issues of concern, and develop practical guidelines for TNC staff who are considering the use of assisted migration as a conservation strategy. The outcomes of the project do not include an organizational policy for TNC, although this work could be used as the first step towards developing such a policy.

[3] Kracke et al., 2021 use the term 'assisted colonization' and define it as 'intentionally moving and releasing an organism outside its native range'.

Instead, we provide general principles, guiding questions, and assessment resources to empower TNC staff to make good decisions on if, when, and how to engage in assisted migration and other conservation translocations for climate change adaptation.

Terms and Definitions

There is enough ambiguity and inconsistency in the definition of assisted migration, and related terms such as managed relocation and assisted colonization, to inspire at least three academic papers (Ste-Marie et al., 2011, Schwartz et al., 2012, Hällfors et al., 2014), plus an effort by the National Invasive Species Council to 'harmonize terminology' for a developing a risk-assessment framework (Falk, 2023, personal communication). The most common area of disagreement, seen in the scientific literature as well as popular media, is whether the term assisted migration should only be used to refer to the movement of organisms outside of the current or historical species range. Although this is unresolved, **in this report, we use the term 'assisted migration' as an umbrella term, to include movement both within and outside of a species current or historical range.** Assisted movement within a species range is sometimes called assisted gene flow or assisted population migration. Treating these a subset of assisted migration makes sense because they are subject to many of the same considerations and risks. While we are adopting this convention to align with our project scope, we try to distinguish if we are referring to movement within-range or outside-range in cases where the difference is relevant and important. Below we discuss how the term is used by different disciplines.

The International Union for Conservation of Nature (IUCN) has an extensive and systematic nomenclature for conservation translocations, which they define as the "human-mediated movement of living organisms from one area to another for a conservation benefit to the translocated populations or the ecosystems that it occupies" (IUCN/SSC, 2013). Within this nomenclature, the terms "assisted migration" and "managed relocation" are listed as synonyms of "assisted colonization", which is defined as a "conservation translocation outside of the species indigenous range to avoid extinction or extirpation." Other terms are used for translocations within the species indigenous range, or translocation outside the species indigenous range to perform an ecological function (see Figure 2).

The advantage of the IUCN nomenclature is that it is comprehensive, well defined, and well documented. However, it does not distinguish conservation translocations carried out as a climate adaptation strategy from those done in response to other stressors such as habitat destruction. The term 'conservation translocation' in Google Scholar returns papers on traditional species rescue projects and misses papers relevant to climate-related assisted migration or assisted gene flow. The IUCN nomenclature appears to be more common outside the US and it is often used in reference to animal translocation projects.

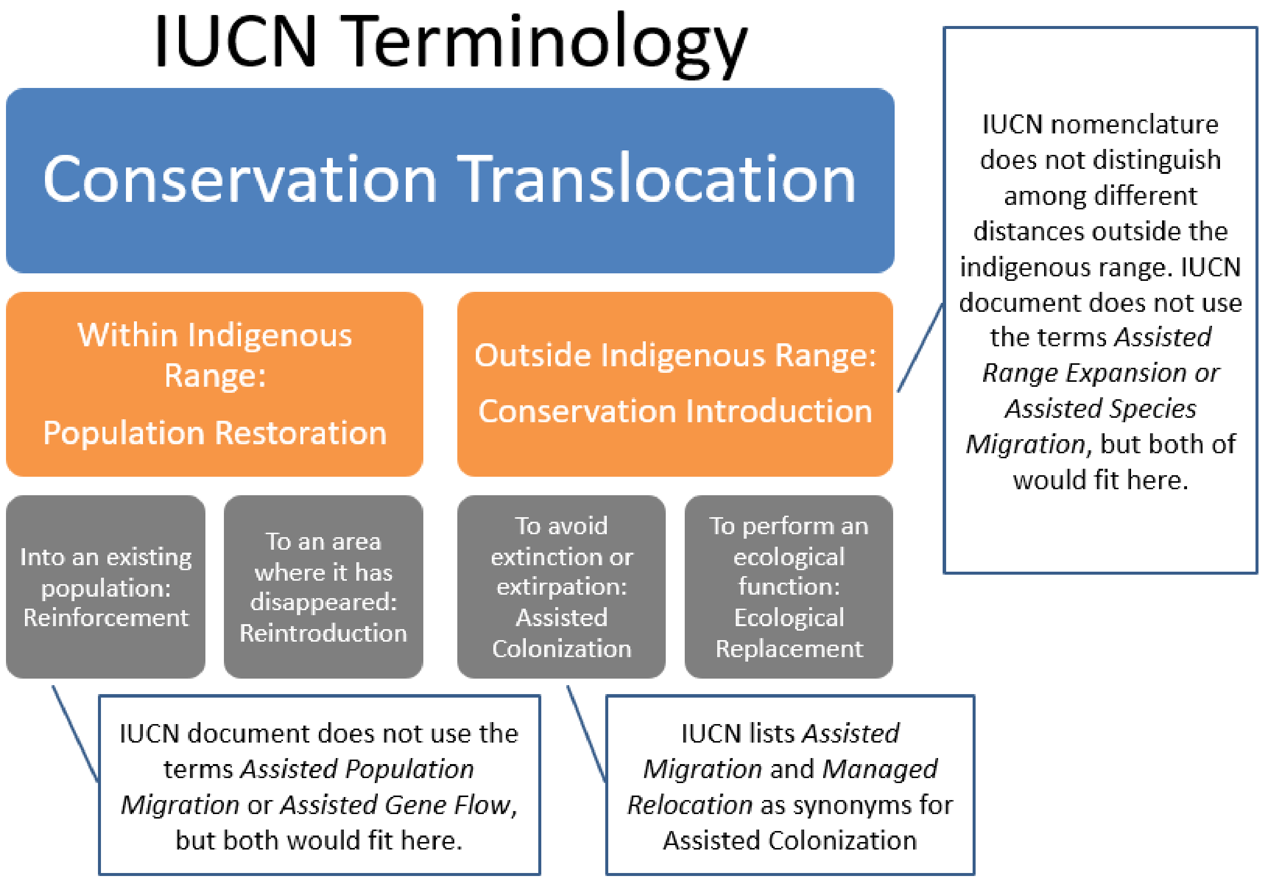

Figure 2 IUCN terminology for conservation translocations. Adapted from IUCN/SSC, 2013.

In the context of forestry, Ste-Marie et al., 2011 proposed terminology that broadly defined assisted migration as 'the human-assisted movement of species in response to climate change' and distinguished among movement a) within the species range, called assisted population migration b) just outside the species range, called assisted range expansion, and c) far outside the species range, called assisted long-distance migration. This terminology is used within the US Forest Service, except that they have adopted the term 'assisted species migration' instead of 'assisted long-distance migration' (see Figure 3 and Handler et al., 2018). The distinction between moving a species just outside their range or far outside their range is not reflected in the IUCN terminology, and it is a useful distinction because long-distance translocation is assumed to carry more risk of unintended consequences such as creating new invasive species (Mueller and Hellmann, 2008) or spreading forest pests and pathogens (Winder et al 2011), and it is thought to be less likely to be successful (Skikne et al., 2020, Keith et al., 2023, Grady et al., 2015). One difficulty is that although assisted species migration is specified as being 'beyond areas accessible via natural dispersal' (Ste-Marie et al., 2011) or beyond the 'natural migration boundary' (Handler et al., 2018), the distance that distinguishes between range expansion and species migration is still a bit ambiguous and may be interpreted in different ways.

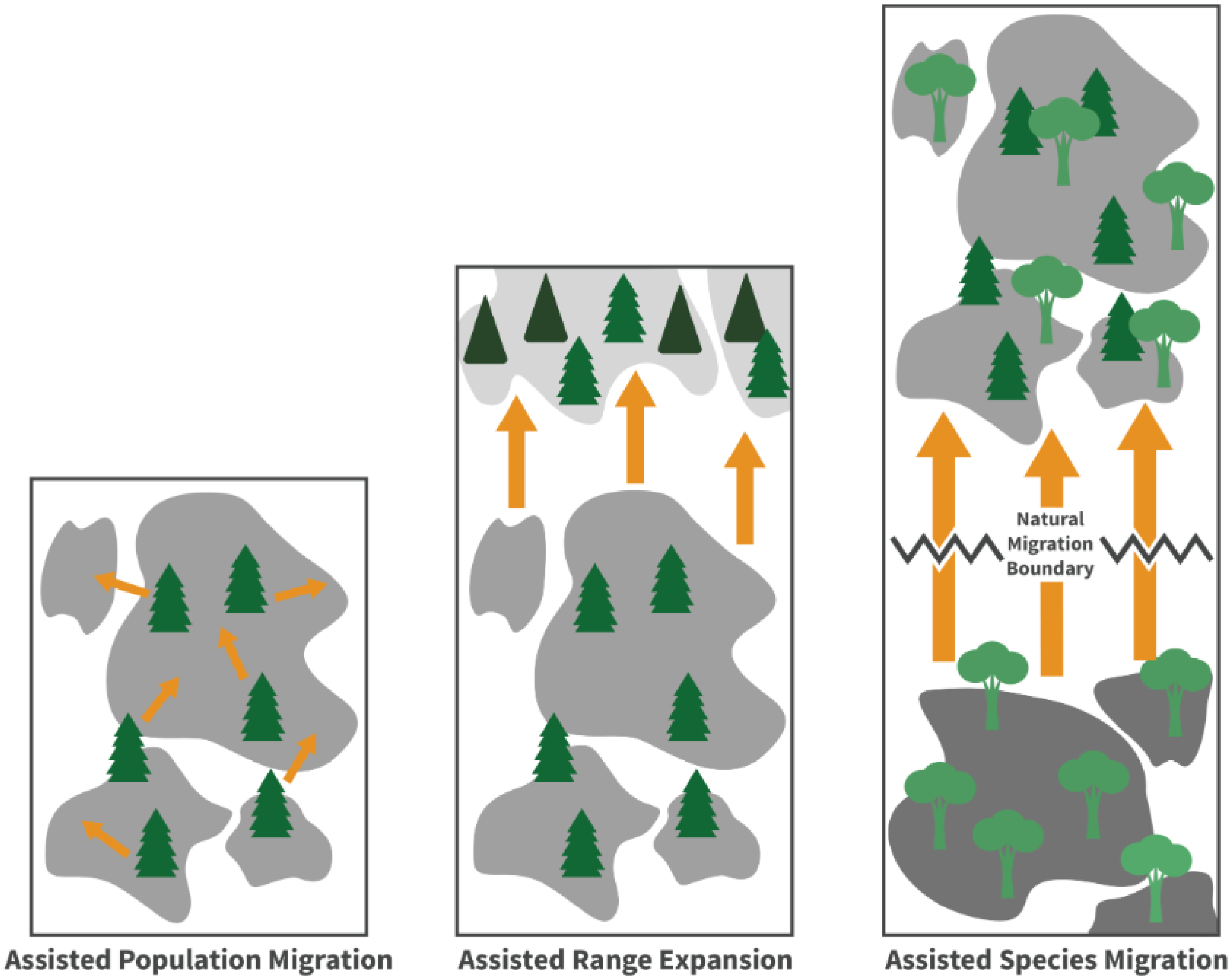

Figure 3 Forms of assisted migration ([Handler et al., 2018])

There is also ambiguity and inconsistency in reference to species ranges. Some authors who use the forestry assisted migration nomenclature refer to movement outside a species' current range (Williams and Dumroese, 2013) and others refer to movement outside its historical range (Handler et al., 2018). The IUCN nomenclature refers to a species indigenous range, defined as the distribution of a species prior to major human disturbance, and still other authors use the term native range (e.g., Kracke et al., 2021) or natural range. Range maps may not always be accurate for a species current range, and determining the historical range is even trickier – one complication is deciding how far back in time to go, and another difficulty is finding supporting data. Not only does this ambiguity impede a shared understanding among practitioners, but it can also have policy implications, such as when regulations require the use of 'native' species'[4] or prohibit the use of 'non-native' species, to control the introduction and spread of invasive species. See the Policies and Regulations section for a more detailed discussion of this topic.

A main take-away from our exploration of the terminology and definition conundrum is not to assume that your definition of 'assisted migration' is the same as another person's definition.

[4] A similar debate has continued around the definition of native vs non-native species.

When working with partners, it is particularly important to reduce linguistic uncertainty. The U.S. Forest Service (USFS) generally uses the term 'assisted migration' as an umbrella term including movement within and outside a species range, as shown in Figure 3. The National Park Service (NPS) and US Fish and Wildlife Service (USFWS), on the other hand, appear to prefer the term 'managed relocation' and restrict its meaning to movement outside a species range. The different terms and definitions used by these federal agencies may reflect the taxa they commonly work with - trees in the USFS, animals in the USFWS and NPS. While it makes sense to use whatever term a partner is comfortable with, it is essential to establish a common understanding of *what* is being moved (species, population, or genotype[5]), *where* it is being moved (inside or outside its range, and how far), and *why* it is being moved (for the conservation benefit of the target species and/or the recipient ecosystem) - regardless of the term used.

Project Scope and Methods

This project was intended to address the need for guidance on the use of assisted migration as a climate change adaptation strategy by TNC. Given the range of translocation activities that TNC has done and is considering doing in the future, we used a broad definition of assisted migration to define the scope for this project.

Working with our steering committee, we defined Assisted Migration as:

> *The intentional movement of species, populations, or genotypes by people for a conservation outcome in response to or anticipation of climate change.*

The scope for our guidance then includes the intentional movement of species either within or outside their known historical range, to improve the climate resiliency of the translocated species and/or of the recipient ecosystem. To align with our project scope, we use 'assisted migration' as an umbrella term, to include translocation within or outside a species range. As described in Terms and Definitions, assisted migration within the species range is sometimes referred to as assisted gene flow or assisted population migration. Other conservation strategies used for climate change adaptation, such as removing barriers or otherwise modifying the habitat to facilitate the natural movement of species, fall outside our scope. While we are primarily focused on translocation as a climate change strategy, our deliverables are informed by and useful for traditional species-rescue translocations undertaken in response to non-climate stressors such as habitat destruction. Translocations done primarily for economic or recreational purposes fall outside of our scope, although there may be secondary economic or recreational benefits to certain conservation translocations.

The goals of this project were to document the range of assisted migration activities within TNC, assess the state of the science, identify key issues of concern, and develop practical guidelines for TNC staff. We started with a series of listening sessions and internal discussions to learn about assisted migration activities being considered, planned, and implemented within TNC,

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[5] The distinction between a population and a genotype, for this context, is made by the level of understanding of the organism's biology. A population is a group of organisms that co-exist and interbreed within a given area. A genotype is a measured genetic identity of an organism. Depending on a project's goals, there may be specific genotypes within a given population that are targeted for focused restoration or conservation.

and to assess staff opinions about the use of assisted migration. Next, we reviewed relevant papers from peer-reviewed publications and the grey literature, to familiarize ourselves with existing guidance documents and evidence of success for assisted migration. Finally, we used the information derived from TNC staff experience, the literature, and existing guidance to develop this report and a companion Assisted Migration Screening Form. Throughout the project, the work of the project team benefited greatly from input provided by our internal advisory committee (see Acknowledgements).

Listening Sessions and Internal Discussions

Staff Opinions and Concerns

We held three internal listening sessions at the start of the project to provide space for TNC staff to share their thoughts, concerns, and experiences with assisted migration. The listening sessions were purposefully not recorded, so that staff were able to express their thoughts and concerns freely. Two hundred staff attended at least one of the listening sessions. Each session included an introductory presentation by the project team, staff speakers describing assisted migration projects or related work in which they have been involved at TNC, participant polls, and facilitated discussion. Subsequently, the project team presented at TNC's internal Managing for Resilience workshop and had follow-up conversations with individual staff and teams working on or considering assisted migration.

Overall, there was enthusiasm and support for learning more about assisted migration, with cautious optimism that it may be a useful, and perhaps necessary, tool for our work (Figure 4). There was a clear recognition that TNC must engage in the topic for a few reasons. TNC is already involved in planning and implementing assisted migration (almost entirely within-range translocations), but the activity is not coordinated across states or necessarily aligned with TNC's 2030 goals. There is a need for more data and science to support the development of TNC's internal approach and potentially improve existing strategies used by partners and other practitioners. TNC was recognized as being uniquely positioned due to our land holdings, which could serve as a natural land base for potential assisted migrations projects.

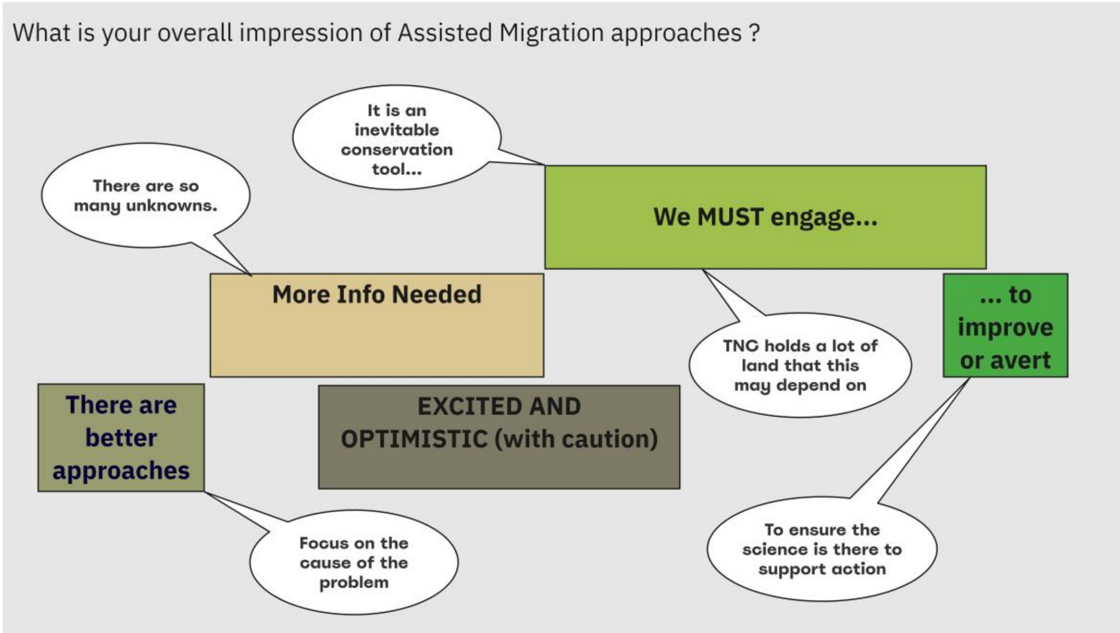

***Figure** 4 What is your overall impression of Assisted Migration? Summary depiction of the relative number and range of responses heard during the listening sessions held with TNC staff.*

When considering whether to engage in assisted migration, particularly if it might involve moving species outside their known historical range, TNC staff expressed concerns that fell into two general categories: unintended consequences and uncertain cost/benefit (Figure 5). Potential unintended consequences focused on the recipient systems, primarily through risks of inadvertent invasions, introducing pests or pathogens, or creating system imbalances. Worries were raised about acting too quickly before the necessary scientific support and tactics for safe implementation were developed or before alternative conservation approaches were assessed. Cost/Benefit concerns recognized that assisted migration could become an expensive distraction, diverting time and money from more well-established conservation management actions with better known outcomes, and that assisted migration could push the focus of our work towards single species and away from ecosystem-focused conservation that may be more critical TNC's long-term goals. Moving species may also have legal implications as a landowner. All these potential issues carry a reputational risk for the organization.

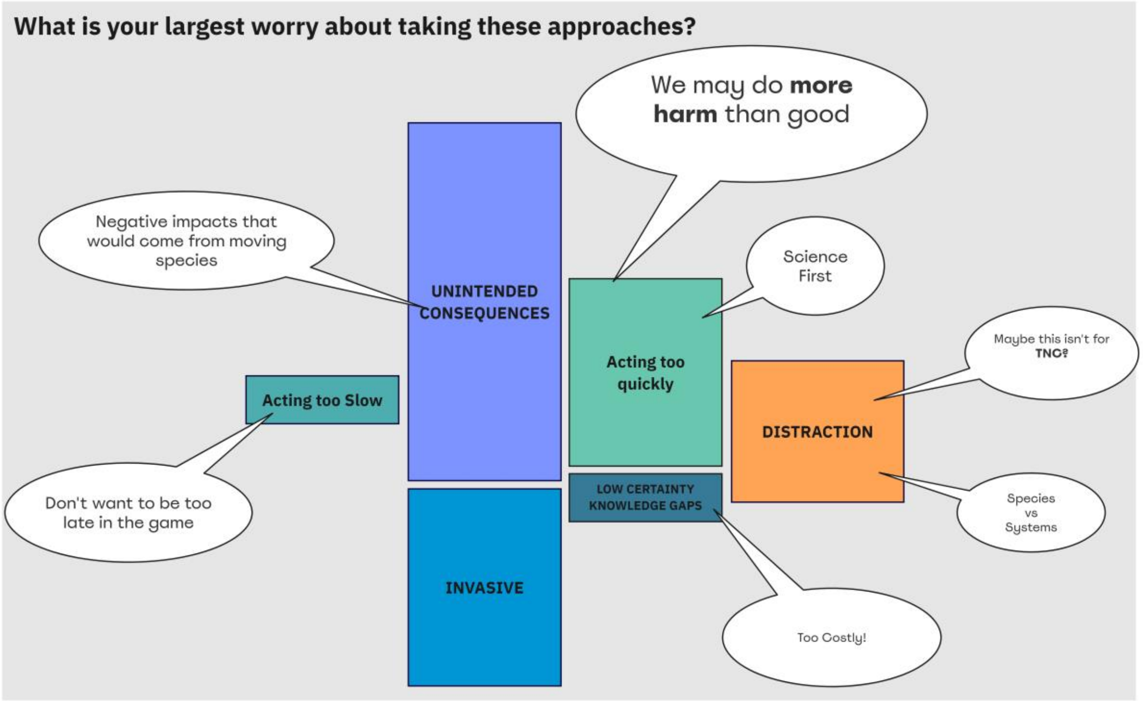

***Figure** 5 Graphical depiction of the proportional responses surrounding the worries about Assisted Migration. Attitudes towards the approach vary with concerns for unintended consequences the leading issue.*

Flagged resource needs ranged from seeking a basic understanding of the current science, to implementation guidance and best-practices manuals, to clearly defined TNC policy and/or SOP development. Perhaps this reflects the range of readiness to engage that was evident across staff. Funding to implement research of the topic and guidance for its use were also flagged as a need (Figure 6).

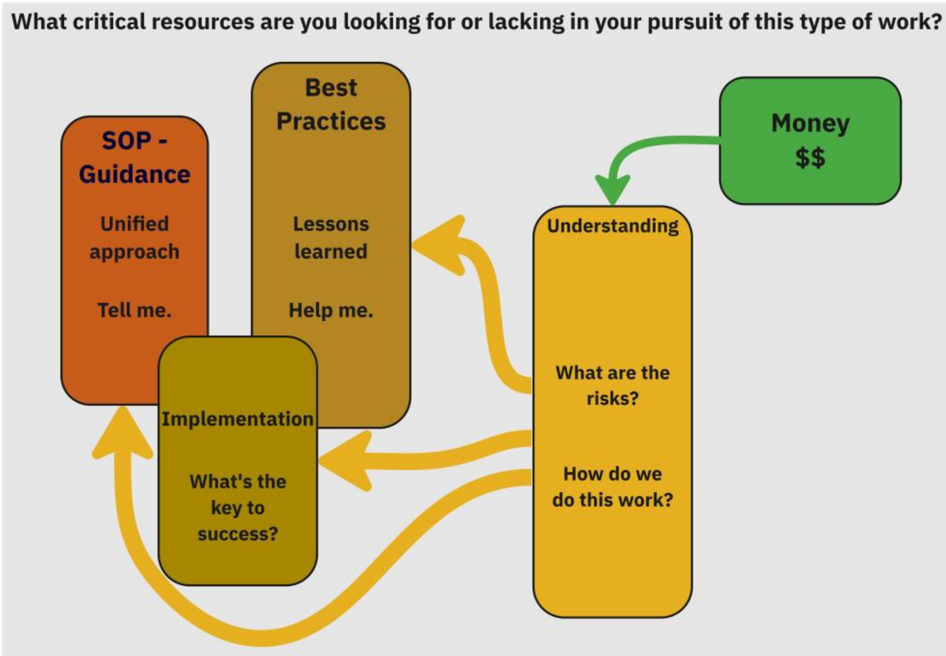

Figure 6 Graphical depiction of the critical resources identified by TNC staff. Arrows demonstrate the connections between the two primary types of resources that were identified; built knowledge about the subject and guidance on if, when and how to implement.

We discovered that other agencies and organizations have conducted similar internal assessments. The U.S. Fish and Wildlife Service (USFWS) surveyed staff opinions about conservation introductions[6] to inform development of an internal decision-support framework (Cole et al., 2022). Their results were remarkedly similar to ours - USFWS staff expressed cautious interest in conservation introductions, perceived such translocations as potentially necessary in some situations but also more risky than traditional methods, and called for clear guidance on when and how to implement the strategy. Kracke et al., (2021) found similar attitudes about assisted colonization[7] from a survey of scientific publication authors.

TNC Projects

Polling of staff showed that nearly half of the respondents were either engaged in or considering projects related to assisted migration (Figure 7). Follow up conversations revealed that current implementation is almost entirely limited to within-range translocations (assisted gene flow or assisted population migration). Although TNC has engaged with projects involving birds and amphibians, most of our work (planned and implemented on-the-ground projects as well as development of guidance documents) has focused on trees in forested ecosystems. There are also a few examples of work with herbaceous plants in prairies.

[6] Cole et al., 2022 uses IUCN nomenclature, in which conservation introduction is the intentional movement and release of an organism outside its indigenous range, to avoid extinction (assisted colonization) or perform an ecological function (ecological replacement). (IUCN/SSC, 2013 and Figure 1).
[7] As used in Kracke et al 2021, assisted colonization refers to intentionally moving and releasing an organism outside its native range.

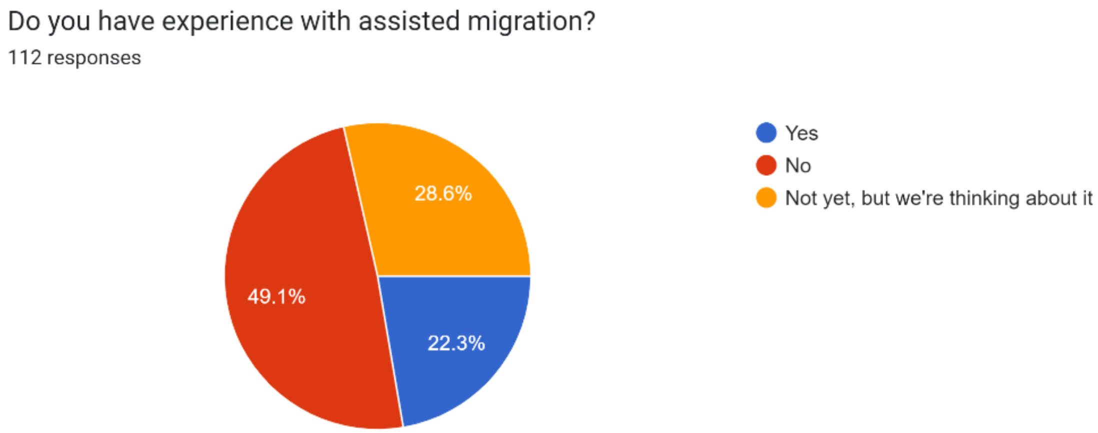

Figure 7 Range of experience with assisted migration as reported by TNC staff attending listening sessions and managing for resilience workshop. Note that most of this experience was later determined to be related to moving populations or genotypes within the species range (assisted gene flow) rather than moving species outside their known historical range (assisted species migration).

Many of the TNC projects could be described as climate-smart or climate-informed ecological restoration, or adaptive forest management, in which a restoration project seeks to restore habitat using seed sources that are from regions or populations predicted (or assumed) to be better adapted to future climate conditions (Figure 8). Several such projects were described as occurring on disturbed lands such as former agricultural fields, clear-cuts, or mined lands. A circumstance that came up a few times was 'unintentional' assisted migration or assisted gene flow, in which the lack of local seed sources resulted in the use of seeds from another part of the species' range. TNC is also engaged in some traditional species rescue efforts related to amphibians and birds, including outside-range translocation of island birds. While climate-change was not the primary motivation for these species rescue translocations, climate projections at the release sites are being considered. A partial list of TNC projects related to assisted migration and other conservation translocations is provided in Appendix 2, and a case study of red spruce restoration is highlighted below.

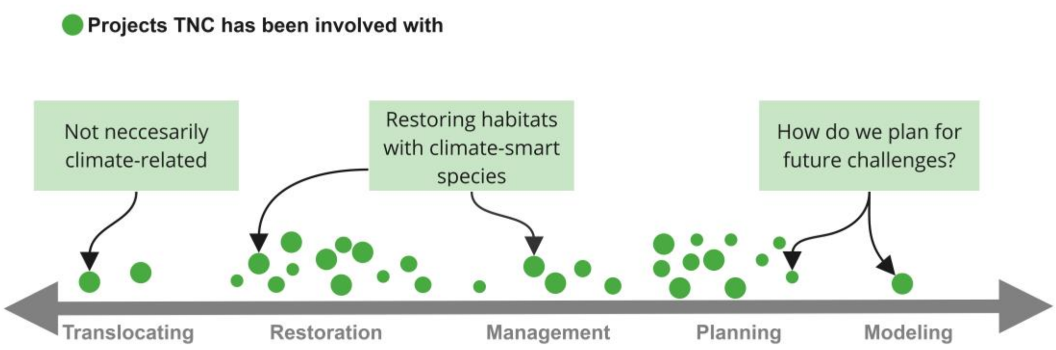

Figure 8 Spectrum of project types that TNC staff are engaged in. Most of the work currently falls within the restoration space and could be classified as either resilience-building or transformational actions as defined within the Resist-Resilience-Transformation (R-R-T) typology proposed by Peterson St-Laurent et al. (2021) and discussed throughout the Managing for Climate Resilience on TNC-managed Lands in the eastern U.S. (Lombard et al., 2021).

TNC Case Study: Red Spruce Restoration across the Appalachians

Red spruce seedlings. © Kathryn Barlow / TNC

TNC staff from several state chapters have collaborated on a multi-partner effort aimed at climate-smart restoration of red spruce in the Appalachians. Academic partners used common garden experiments and statistical models developed through genomic analysis to identify climate-adapted seed sources. A forestry partner collected seeds from six locations in the Central Appalachians, which were grown out and then planted as seedlings at restoration sites in MD, WV, and VA. In 2021, TNC completed 338 acres of red spruce forest restoration in three key corridors connecting existing stands of red spruce in the Central Appalachians. Because this project consists of moving seed sources within the species' range, it is an example of assisted gene flow or assisted population migration. Lessons learned include the challenge of nursery production for genetic diversity (tree nurseries producing at scale are not accustomed to maintaining sources of genetic material) and the importance of clear communication (some partners were initially concerned that the project involved genetically modified organisms). Along with partners from the Central Appalachian Spruce Restoration Initiative (CASRI), TNC continues red spruce restoration and monitoring in the Central Apps, with a long-term vision of connecting to the disjunct populations in the Northern Apps.

Literature Review

This section provides an overview of the scientific discussions, debates, and policy actions that relate to the use of assisted migration, with a particular focus on its use in conservation (versus silviculture) and how this tool fits into the work of The Nature Conservancy. The bulk of this review was conducted through the review of published literature and guided by interviews with fellow staff and external partners. Specific resources were also shared by participants of the listening sessions and the Managing for Resilience workshops. The primary focus of the literature review was to gather existing guidance on appropriately using assisted migration and to learn how effective assisted migration has been in practice. In addition, we also found some important works relating to the ethical and moral implications of the approach and how policies and regulations may be shaped by these discussions.

All literature was gathered in a Zotero library, thematically organized through tagging, and those pieces that were particularly helpful or important were reviewed and emphasized in bold and discussed briefly below. Some news and popular media stories were also gathered and included in the Zotero library. These may have value to practitioners in understanding how media characterizes assisted migration or the public's perception and response to the approach. It should be noted that this effort was not a systematic review of all literature but a selective review of a wide variety of resources that may be helpful to conservation practitioners.

Overview

The body of literature on assisted migration is rapidly growing and covers a wide range of topics and systems from the ecosystem level down to the genome, which make a succinct summary of the entire topic challenging. Issues that receive substantial attention range from why assisted migration may be a critical tool in conservation (Hoegh-Guldberg et al., 2008, others), why it should or should not be pursued (Novak at al., 2021, Strayer 2022, Ricciardi and Simberloff, 2009), how the approach should be used among or alongside other conservation tools (Prober et al., 2019, others) and what ecological, economic, social, and cultural considerations need to be accounted for in planning for an assisted migration. The subject of nomenclature and maintaining a common vocabulary among practitioners was also a recurring topic (see Terms and Definition section). To keep up-to-date on the literature, we recommend bookmarking this Google Scholar search query based on Twardek et al., 2023.

Existing Guidance

Guidance expressly sought after by TNC staff fell into two areas: 1) deciding if or when to utilize assisted migration in their work; and 2) how to implement assisted migration, should the decision be made to pursue the approach. On the surface, this decision process appears to be linear and easily informed by ecological principles and sound conservation planning but the two questions are intertwined and addressing them fully will create some overlap.

Within the decision of ***if*** or ***when*** assisted migration is appropriate at least two separate inquiries need to be pursued. The first is an ecologically defensible case that assisted migration ought to be pursued. Is a species' imminent and pending extinction cause enough? Can we construct a compelling case from the evidence? (see Moral and Ethical Implications). The second, more pragmatic consideration, is the feasibility of the approach, which is inextricably linked to ***how*** the work will be implemented. The guidance documentation reviewed for this project tended to focus much more on the practical side of these questions, specifically ***how*** to plan and execute assisted migration, and touched on the question of whether the project should move forward mostly through risk and feasibility assessments.

Guidance on ***when*** to utilize assisted migration was common in editorials and review articles that led towards the ethical debate around species value and the role that humans should or should not play (see Moral and Ethical Implications) rather than on any ecological, biological or conservation principle or practice. While some authors attempt to frame this debate in a similar context to other bio- or environmental ethical debates (Aubin et al., 2011, Maier and Simberloff, 2016) there remains no consensus on the topic nor a firm framework for which practitioners can follow for making these decisions[8]. **Hoegh-Guldberg et al. (2008)** offer a high-level decision framework that guides practitioners through a variety of more traditional conservation approaches before suggesting assisted migration as an option to explore. **Annex 3 of the IUCN Guidelines (2013)** provides further decision guidance to help one assess the risk of inaction and alternatives that ought to be considered before deciding to proceed. Indeed, across much of the literature, assisted migration is presented as a last option that should only be pursued after identifying and addressing risks and uncertainties. And is most often considered when the species is at high risk of extinction.

Several guidance documents present a rigorous approach to identifying risks and uncertainties helpful in deciding ***when*** to pursue assisted migration. **NPS's Ecological Risk Assessment Tool** (Karasov-Olson, et al., 2021a), in particular, provides a process for identifying the range of ecological risks and uncertainties associated with a project (Figure 9). Similarly, **Rout et al. (2013)** provide a probabilistic decision tool to help estimate the likelihood of success to help decide if a project should be implemented and can be used to compare against alternatives. Project managers will find value in either of these approaches to assessing a project particularly when concerned with risks and unknowns. The NPS Ecological Risk Assessment Tool has been used successfully by several TNC practitioners. Due to the rigor involved with this process, this tool may be better suited for assessing the project after other conservation approaches have been considered and the decision has been made to seriously consider assisted migration.

Risks of no managed relocation	• Risk to the target • Risk to the recipient ecosystem
Risks to the target of managed relocation	• Risk to the relocated individuals • Risk that the target source population cannot withstand diminished numbers • Risk that removing the target will negatively impact a key function in the source ecosystem • Risk of causing undesired evolution in the target
Risks to non-targets in the recipient ecosystem	• Risk of target transmitting novel disease or associated pest • Risk of competitive interaction negatively affecting abundance or distribution of non-targets • Risk of consumptive effects reducing the abundance or distribution of non-targets • Risk of driving undesired evolution in non-targets
Risks to higher order attributes of the recipient ecosystem	• Risk of indirect and negative impacts on ecosystem structure • Risk of changing ecosystem function
Risks associated with biological invasion	• Risk of invasion within the intended recipient ecosystem • Risk of invasion beyond the recipient ecosystem • Risk of irreversibility of the managed relocation action
Risks associated with socio-economic values	• Risk to a culturally or economically important species • Risk to a valued ecosystem service

Figure 9 Risks included in the NPS Ecological Risk Assessment Tool (Karasov-Olson, et al., 2021a)

[8] The protection from extinction of imperiled species is an example of an issue that began with a debate that led to an accepted and largely adopted social position and subsequent policy changes as in the Endangered Species Act.

Guidance on ***how*** to properly plan and implement assisted migration projects range from specific agency-focused action steps or policy (e.g. VT Natural Resources Lands Team (Patch et al., 2017) and the UK's Reintroductions and other Conservation Translocations Code and Guidance (UK Department for Environment, Food and Rural Affairs, 2021) to high-level decision support tools (IUCN/SSC, 2013), and system/taxon-specific guidelines (McKone and Hernández, 2021**,** Shannon at al., 2023, other USDA guidelines). These guidelines will have differing degrees of value in planning projects depending on the focal system and species. The **IUCN Guidelines for Reintroductions and Other Conservation Translocations** is perhaps the most thorough and encompassing set of guidelines. Although it was created for more traditional conservation translocations, many (perhaps all) of the principles could apply to assisted migration as a climate change adaptation strategy.

Species distribution models and climate predictions can help inform which species or populations may need assisted migration, or where to deploy assisted migration, and we encourage their use during project planning efforts (IUCN/SSC, 2013). These models were not explicitly evaluated in this review due to their species- and geographic-specific focus but their utility has been raised by many authors (Gann et al., 2019, Mozelewski and Scheller, 2020, Schwartz et al., 2012, to name just a few). Similar models are being incorporated into spatial decision tools such as the USDA Seed lot tools which assist practitioners through critical decision steps for matching a site to the ideal seed source needed to maintain a productive forest through future climates. A seed-sourcing bottleneck has been identified as an impediment to implementation (Clark et al., 2023). Conservation projects may be able to leverage these types of support tools but should do so cautiously depending on the goal of the project and the intent of the tool being used.

As sophisticated statistics and genetic tools have become increasingly available new methods have emerged that can assist conservationists in making implementation decisions. Genomic offset, also referred to as genetic offset or genomic vulnerability, is an approach under active development (Rellstab et al., 2021) that in its simplest form seeks to model the relationship between a population's genetic structure and its environment. Understanding this relationship sheds light on the current or future potential maladaptation of a population to its environment and can help identify which individuals (or populations) may have the greatest adaptive capacity under forecasted change. These newer methods are often paired with the more traditional experimental common garden[9] design used in trial translocations prior to full project implementation and are particularly encouraged for those working with plants and trees.

Guidance documents specifically focused on assisted migration are limited in number but there are several key resources that lay a foundation for practitioners involved in project planning. As mentioned above, the IUCN Guidelines are the most expansive set of guidelines but applying them typically requires additional investigation to determine the best course of action for safe and successful implementation. More detailed guidance is difficult to produce because assisted migration projects are unique, and each comes with its own set of ecological, economic, legal, and societal considerations and challenges. Additionally, it seems the overall lack of more

[9] A range of experimental designs in which organisms from different provenances are grown together under the same environmental conditions (Berend et al., 2019).

specific guidance (system or taxon-specific) is due to the relatively low number of projects that have been implemented, monitored, found to be successful, and published. It is thus up to the project teams to navigate challenges appropriately. More on this follows.

Empirical Evidence

One purpose of our literature review was to look for evidence of success to support the application of assisted migration as a climate change strategy. We defined success as *a translocated organism that establishes a self-sustaining population pre-adapted to the changing climate and does not negatively impact the existing community or ecosystem at the recipient site.* While assisted migration is an active area of research, there is not yet a robust body of literature documenting evidence of success as defined in this way. We found relatively few studies that reported long-term, empirical data from experimental or conservation implementation studies, as compared to theoretical or modeling studies. Available empirical data report success mostly in terms of individual survival and growth, less on population-level metrics such as reproduction, and very little on community level impacts. Our conclusions are drawn from three key review papers (Prober et al., 2019, Hansen et al., 2023, and Twardek et al., 2023), our own **Google Scholar search** for recent papers, and literature recommended by our advisory committee.

Prober et al., 2019 and **Hansen et al., 2023** assessed climate adaptation interventions broadly, including but not limited to assisted migration. Prober et al. reviewed 473 studies and found most drew conclusions from ecological reasoning and modeling, with only 16% offering new empirical evidence (Figure 10). These authors also noted a significant bias in the number of studies related to forest ecosystems, trees, and vertebrates. Hansen et al. screened hundreds of papers and found only 13 studies that experimentally tested adaptation efficacy, two of which focused on assisted migration (Gray et al., 2011, and Wilson et al., 2016). Hansen et al. also noted that they found compelling case studies on adaptation in the gray literature and called for greater collaboration between academic researchers and conservation practitioners ‘who may be too busy on the ground conducting management to integrate the types of experiments and monitoring that could help quantify and communicate their efforts’.

Twardek et al., 2023 focused specifically on assisted migration, which they defined as ‘the human assisted movement of individuals to more climatically suitable areas within or outside of their current species range to help species respond to climate change’. These authors identified 204 assisted migration studies pertaining to climate change and conducted in natural settings. Few of these studies report results beyond 5 years (but see Drayton and Primack, 2012 who found that their high 5-year success rates for eight perennial plant reintroductions were completely reversed after 15 years). Most studies report individual outcomes (generally survival and/or growth) but not community-level effects in the recipient ecosystem (but see Keith et al., 2023, Vandegehuchte et al., 2011 for the effect of translocations on the invertebrate populations at recipient sites and Wilson et al., 2016 for the effect of non-locally sourced dominant prairie species on the non-dominant prairie plant community). Consistent with Prober et al., these authors also found that assisted migration was most common for trees in forested ecosystems. Twardek et al. categorized each study’s outcomes as ‘positive’, ‘neutral’, or ‘negative’, based on how authors reported translocated organisms performed in their new site, but noted that applying consistent criteria for this categorization was difficult given the broad range of study designs, taxa, and objectives. That was our experience as well, in our attempt to determine which studies provided examples of 'successful' assisted migration, even in the less ecologically meaningful sense of short-term growth and survival.

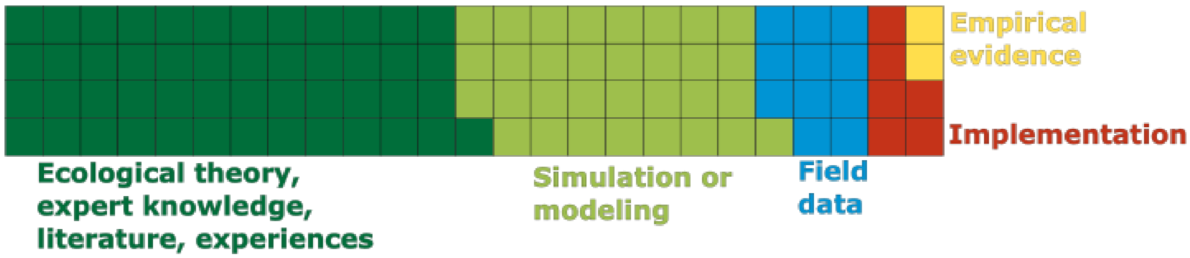

Figure 10 Relative number of study types, based on literature review of climate-adaption conservation interventions. Adapted from Prober et al., 2019.

We did not dive deeply into the large body of literature related to traditional conservation translocation done for species recovery efforts rather than climate change adaptation. On the one hand, this literature demonstrates that translocations are challenging, although success rates are improving as we learn more about the factors more critical for success (Morris et al., 2021, Bellis et al 2023). Adding the complication of climate change would presumably only decrease the average success rate. On the other hand, evidence from species recovery impact may be interpreted as reassuring on the issue of impacts to the receiving ecosystem. Novak et al., 2021 analyzed past conservation translocations of 1,014 taxa, focused on US endangered species. Those authors found only one instance that caused biodiversity loss (watercress darter – but see also Schiffman,1994) and argue that the well-known cases of invasive species resulted from translocations done for economic or aesthetic reasons, without the safeguards of conservation practice and regulation. Strayer, 2022 questioned this conclusion pointing out that: "small unintended impacts have been a product of the kinds of translocations that have been most common: small to modest augmentations or reintroductions of specialized species whose populations are kept small by multiple factors." We may not be able to generalize evidence from recovery efforts for endangered or specialist species to conservation translocations of foundational species for climate change adaptation.

Because the science around assisted migration is still very much in development, and because many of the drivers of success will be context specific – both in terms of geography and ecological system – we urge TNC staff considering assisted migration to build or tap into local networks of academic partners and practitioners working in similar geographies on similar systems and taxa.

Moral and Ethical Implications

No discussion of assisted migration would be complete without a recognition of the ethical debate around the controversial practice of intentionally moving species. This report and the guidance that follows does not take a particular stance on the ethical debate but rather aims to inform practitioners of the basis of the debate should it be brought to light by stakeholders or the public while considering an assisted migration project.

Proponents of assisted migration argue that it may be a necessary and critical tool in saving species from extinction and/or preserving some ecological or economic value (Minteer and

Collins, 2010; Novak et al., 2021), Opponents point to the inherent risk of moving plants and animals to new areas both to the species and to the recipient ecosystem. They further argue that assisted migration in not a viable strategy to counter the scale of impacts expected given the hundreds of thousands of species affected by climate change (Maier and Simberloff, 2016, Strayer, 2022).

Schwartz et al. (2012) provides a summary of the debate, and **Aubin et al. (2011)** dives deeper into the debate's ethical framework. An exchange between **Strayer and Novak** (Novak et al., 2022, Strayer 2022) captures an important facet of the debate, that the definition of 'success' should be carefully evaluated to ensure that conservationists do not conflate the success of individual species translocations with the more complex and holistic system-level successes needed for nature to adapt and transform in-step with the changing climate (see also Empirical Evidence for more discussion).

Debate also highlights the values we place on the things we are trying to protect (whether they be species or ecosystems) and on who gets to decide those values. By participating in assisted migration, the argument goes, we are inherently accepting that the value of one species (the one being considered for assistance) is greater than another (the ones that were not considered for this level of investment, or who may be put at risk by the action). This occurs both when deciding on which species to select for actions and when deciding on identifying recipient sites. *Is the new species more valued than the ones that they may displace at the recipient site?* Such concerns can lead to conservation practitioners being accused of 'playing God' (Stimpson, 2020). Similar questions can be drawn from assisted gene flow projects where we must be sure that the genes introduced to the new system have the value that we are ascribing them. It is worth mentioning that these arguments for assigning value go beyond assisted migration and extend to virtually every ecological intervention. Tackling these questions and others is an important step when first considering a project. Both Aubin et al (2011 – Box 3) and Schwartz et al., (2012 – Box 1) provide a list of important ethical questions that should be discussed when considering a project.

One perspective largely missing from this debate, in the scientific literature at least, is that of local communities, particularly indigenous populations (Pelai et al., 2021). Engaging local stakeholders, especially those at the recipient site, might reveal additional ethical and cultural concerns to the project that may have been overlooked by an ecocentric view. One attempt to address this oversight is the Tribal Climate Adaptation Menu developed by collaborators representing tribal, intertribal, academic and federal entities in Minnesota, Wisconsin, and Michigan (Tribal Adaptation Menu Team, 2019). In addition, recent revisions to the Endangered Species Act have added a requirement for consultation with affected Tribal governments in developing and implementing experimental populations, meaning populations that do not overlap geographically with existing nonexperimental populations of the same species (US Fish and Wildlife Service, 2023).

Policies and Regulations

There is a lack of consistent policy on assisted migration. Cooke et al., (in press) suggests the controversial nature of the practice makes policy makers hesitant to take a stand. Brodie et al., 2021 argues for the importance of coordinated policies nationally and internationally, particularly given that some assisted migration efforts are already being undertaken in the absence of such policy. While we do not propose a formal organizational assisted migration policy for TNC, the information provided in this report and the accompanying **Assisted Migration Screening Form** could inform future development of an internal policy.

When considering assisted migration or any conservation translocation, practitioners will have to consider federal, state, and local policies and regulations that may restrict the ability to move organisms from one place to another. The U.S. Fish and Wildlife Service, U.S. Geological Survey, National Park Service, Bureau of Land Management, and U.S. Department of Agriculture and their state level equivalents are among the agencies that conduct and regulate translocations in the United States (Novak et al., 2021). Even within-range translocations may be restricted, as is the case with some state seed zone guidelines (Etterson et al., 2020). If a proposed translocation crosses jurisdictional boundaries, particularly international boundaries, navigating policy implications and the permitting process will be even more complicated. Moreover, federal and state laws and applicable agencies will vary depending on 1) the taxa you are considering moving, 2) the conservation status of the organism you are considering moving, and 3) the ownership (private, state, federal) of the source site and recipient site. In the case of private land adjacent to a release site, there may be the need to establish a Safe Harbor Agreement to address landowner concerns about future property-use limitations if the released species moves onto their property. TNC's California chapter undertook a comprehensive review of legal and regulatory issues related to species reintroductions in the state, most of which would likely apply to assisted migration as well.

Cooke et al., (in press) notes that the variety of approaches to assisted migration and the diversity of species and systems in which it might be deployed adds significant challenges to creating overarching policy and points out that forestry-related assisted migration work is ahead of other systems. The British Columbia Ministry of Forests, in collaboration with the US Forest Service and timber companies, runs the Assisted Migration Adaptation Trial (AMAT), a long-term climate change research study of 15 tree species planted in restoration sites across British Columbia and neighboring American states (Marris, 2009). In Minnesota, with TNC as collaborators, Superior National Forest recently developed the US Forest Service's first Assisted Migration Pilot Plan for a national forest (Frerker et al., 2023).

In July of 2023, the US Fish and Wildlife Service (USFWS) revised the Endangered Species Act (ESA) to allow for the introduction of experimental populations of threatened and endangered species into areas outside of their historical range (USFWS, 2023). While this change only applies to species listed as threatened or endangered under the ESA, it is significant because USFWS explicitly states that the revision reflects a new understanding of the impact of climate change on many species' suitable habitat. A narrow provision under the 1982 ESA amendment allowed experimental populations outside a species historical range only in extreme cases where the species primary habitat had been entirely destroyed. In removing the historical range restriction, the USFWS recognizes the need for greater flexibility in the face of increasing threats from climate change and invasive species. The 2023 revision also adds a requirement to consider adverse effects that may result to the receiving ecosystem, referencing the IUCN Guidelines and their recommendation to conduct an ecological risk assessment (IUCN/SSC, 2013), and it requires coordination with affected Tribal governments when establishing experimental populations.

As discussed in Terms and Definitions, linguistic ambiguity surrounding assisted migration complicates the development and implementation of policy. It is particularly difficult to find clear and consistent definitions of what constitutes a 'native' or 'indigenous' species in a particular geography. Partly, it depends on your historical baseline, which in North America is commonly set as the time of European colonization. As species ranges shift in response to climate change, should they be considered native in new areas that they move into? Does it make a difference whether they arrive there on their own or by human-mediated range expansion? Can native species be considered invasive (see Shah, 2020)? These distinctions have implications for TNC's legal protection work. Our current conservation easement template language prohibits planting or release of 'non-native' species. While the Conservation Easement Practice Team recently decided that it was premature to change the language in the standard template to specifically refer to 'assisted migration', attorneys do sometimes insert language into particular easements to allow for the use of non-native organisms if 'the species are intended for climate adaptation using the best available science' (Hampton, 2023, personal communication). There has also been discussion among attorneys and land management staff suggesting that rather than prohibiting non-native species, it may be better to prohibit noxious and/or invasive species as listed on federal or state invasive species lists. It is hard to imagine a situation where TNC would want to promote a species that is already identified as invasive on a government list. One difficulty, however, is that these lists are often not consistent across jurisdictional boundaries and fail to proactively identify invasive species that may spread into a jurisdiction from a neighboring area (Bradley et al., 2022). Linguistic ambiguity also results in unintended consequences from some policies. The USDA Conservation Reserve Program requires the use of native seed for restoration but does not limit where the seed is obtained, leading some practitioners to speculate that the cat is already out of the bag in regard to mixing the genetics of different local genotypes (Eerkes, 2023, personal communication).

Preliminary Conclusions

Despite the lack of conclusive evidence supporting assisted migration as a broadly viable climate adaptation strategy, there is a lot of momentum and energy around the use of assisted migration for conservation as evidenced by the growing body of literature on the topic (Twardek et al., 2023, Prober et al., 2019). As the environment faces escalating threats from climate change it is projected that conservation projects will need to consider and deploy this tactic as part of their work more frequently. While some may see assisted migration as just one necessary tool in the conservationist's toolkit, we must acknowledge the weight of the decision to utilize it. As advocated by many authors, and supported here, assisted migration should be included in the suite of options, but 1) only after other avenues have been pursued, and 2) when it is part of a broader conservation plan and 3) when ethically, culturally, ecologically and economically feasible. This stance poses challenges; the guidance on how to deploy this approach safely and effectively is not fully developed, and the science or data needed to support that development is lagging, in part because more time is needed to assess and address the use of the approach thus far. Despite this mismatch, there is also a growing sense of urgency as the climate-driven biodiversity crisis rages on.

As the urgency around the climate crisis grows the tolerance for risk-taking also grows. Care must be taken to intentionally balance that reduced guard for unintended consequences through prudent conservation planning supported by risk assessments (Karasov-Olson et al., 2021b, and the NPS tool) and the review of alternative conservation actions while following structured decision-making approaches (Van Kleunen et al., 2023, Hemming et al., 2021). As an organization, The Nature Conservancy must also be mindful of non-ecological risks, as well as those that may raise reputational and legal issues. Of course, planning will not remove all risk or eliminate the potential for unintended consequences, but as the science grows and informs the conservation community about the appropriate ecological, legal, and cultural considerations that need to be made, wiser decisions will follow.

There has already been progress in understanding many aspects of this approach, and several robust conclusions were apparent in our literature review and discussion with TNC staff. These include:

- Distance matters; both geographic and climatic. Broadly speaking, greater distance between donor and receiving sites results in greater risk with reduced likelihood of success. The greater the distance, or more extreme the climate differences are for the translocated species or genotype, the more stress can be expected (Skikne et al., 2020, Keith et al., 2023, Grady et al., 2015). Additionally, the greater the distance of the proposed movement, the greater the likelihood of introducing a novel pest or pathogen to the receiving site.
- Tradeoffs are inevitable and very challenging to predict. Moving a species to a new geography or climate may provide an advantage for one characteristic but come to the detriment of another. For example, a migrated population may flourish with individual growth at its new location but fail to reproduce. These tradeoffs will be species- and genotype-specific and should be investigated before large investments are made.
- Temporal and spatial scales are important for planning actions and measuring success. Ecological systems tend to require long-term monitoring to understand the full extent of a conservation intervention or action. The resolution of the scale (both time and space) necessary to detect success will depend on the species and system one is working in. Lepidoptera mature much faster than the trees they rely upon so monitoring will depend on if you are more interested in the fate of the butterfly or the tree. Spatial resolution also becomes important when using climate models or species distribution models. Microclimates, which can act as critical stepping stones for many species, may be missed by coarse climate projection models.
- It's more than just climate; Simply finding a matching climate (current or future) at the recipient site will not guarantee success. Other ecological and environmental conditions, that may not be fully captured in modeling or planning efforts, such as inter- and intra-species interactions, may be important to the long-term success of the project. Those interactions are particularly difficult to predict under changing climate especially when projecting out at the time scales that are relevant to some long-lived species.

On top of these findings and others discussed in this document, practitioners should be on the lookout for other challenges unique to their specific project. The challenges may be too complex to guarantee project success but by applying sound science and carefully assessing a project plan against a set of standards, assisted migration may be a viable climate adaptation strategy for a given situation. The guidance developed here will help guide practitioners through the early stages of project planning.

Guidance on Decision Making

From the listening session, case studies and review of the science it was clear that assisted migration is a controversial, not fully proven, but perhaps necessary strategy for climate change adaptation. TNC has so far taken a cautious approach to assisted migration, mostly moving organisms only within their known historical range. TNC does not have a formal process for review and approval of conservation translocations. Instead, we rely on the judgment and expertise of on-the-ground staff to make determinations of when and how to proceed, and staff strongly expressed the desire for more organizational guidance. In response to these findings, we developed an **Assisted Migration Screening Form** with assessment questions and resources intended to guide TNC staff in North America considering the implementation of assisted migration. It does not provide a conclusive recommendation (go/no-go decision), but rather provides general principles, guiding questions, and assessment resources intended to empower staff to make informed decisions. The general principles, described in more detail on the screening form, are:

1) Consider assisted migration within a larger conservation planning framework,
2) Only engage in assisted migration if more well established and less interventionist approaches are not sufficient,
3) Assess risk (ecological, social, reputational) and feasibility (technical, administrative, legal) before deciding to engage in assisted migration,
4) Document unknowns and assumptions,
5) Include monitoring design and cost upfront in the project plan, and
6) Build or tap into local networks of academics and practitioners.

Although focused on assisted migration as a climate change adaptation strategy, the screening form may also be helpful when considering conservation translocations not related to climate change, such as traditional species rescue efforts.

Emerging Issues and Conclusion

This report could not possibly cover all the facets of assisted migration, but we hope that it provides a solid starting point for those considering assisted migration in their work or for those interested in continuing the discussion on this strategy further. A few important emerging and underexplored topics surfaced during the preparation of this report that were not thoroughly incorporated but are worthy of further investigation.

- The issue of pests and pathogens was raised numerous times and is a common top concern when considering assisted migration. While the general threat was captured within the suite of ‘unintended consequences’, the mechanism of those introductions was not deeply investigated. While the most obvious mechanism is the introduction of pests and pathogens that accompany translocated organisms to a recipient site, neighboring areas may also be exposed if those pests and pathogens move through the soil or water. In addition, known pest and pathogens may have a greater impact in the novel environment of a recipient site due to unforeseen ecological interactions. Each species and system will have its own suite of pests and pathogens that need to be investigated further.

- In a similar vein, the vast literature on invasive species management was not fully reviewed to extract best-practices as part of developing implementation guidance. We felt this would be too species- and system-specific to capture but should be part of the review process for all projects.
- There are emerging climate ‘conservation strategies’ similar to assisted migration that were not discussed, particularly those involving more directed genetic manipulations that are possible with new methods and technology. These genetic interventions include sophisticated breeding programs such as that used in the American chestnut recovery, directed hybridizations to overcome disease or maladaptation, gene-splicing using CRISPR methods, and the more extreme de-extinction efforts now being proposed and pursued.
- The broader role that genetics play in assisted migration should be included in future discussions. Evidence shows that the genetics of an individual being moved may influence which symbionts associate with that individual (Keith et al., 2023), which in turn may play an important role in the ecosystem value provided by that individual. More discussion is also needed to fully understand the risks associated with genetic drift, outbreeding depression, and inadvertent hybridization through genetic introgression.

Although the concept of assisted migration was introduced as early as 1985 (Peters. 1985) there continues to be debate about its practical application within the world of conservation. The premise of moving species to adapt to our changing climate is straightforward, but the question of how those species respond to their new environment, how the recipient system responds to them, and the resulting long-term viability of the conservation action will remain a complex challenge. As the biodiversity crisis presses on, we should expect to face an increasing number of challenges that require tough decisions, including whether to use strategies such as assisted migration in our conservation efforts or to let some species go. The best path forward will be to continue learning from scientific inquiry, making transparent decisions based on that science, and openly sharing the results to further our collective understanding. The Nature Conservancy should continue to base its work in science, increase collaborative efforts to appropriately incorporate traditional ecological knowledge (Climate and Traditional Knowledges Workgroup, 2014), and prioritize communication and transparency as we engage with partners to forge ahead through the challenging future of conservation in a changing climate.

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Appendices

Appendix 1: Glossary

Assisted Colonization - The intentional movement and release of an organism outside its indigenous range, to avoid extinction (IUCN/SSC, 2013). Often used as a synonym for assisted migration.

Assisted Gene Flow – Intentional translocation of individuals within a species range to facilitate adaptation to anticipated local conditions. (Aitken and Whitlock 2013)

Assisted Migration – As used in this report, assisted migration is the human-mediated movement of an organism for conservation benefit to the translocated organism and/or the recipient ecosystem, in response to or anticipation of climate change impacts. For brevity's sake and to align with our project scope, we use the term 'assisted migration' broadly, to include movement of an organism within the species range or outside the species range. Note that some definitions of assisted migration limit the term to movement outside the species range. Movement within the species range is sometimes referred to as assisted gene flow or assisted population migration. See Terms and Definitions for further discussion of the ambiguous and inconsistent definition of assisted migration in the literature and popular media.

Assisted Population Migration - Moving seed sources or populations to new locations within the historical species range (also assisted genetic migration or assisted gene flow) (Handler et al., 2018)

Assisted Range Expansion – Moving seed sources or populations from their current range to suitable areas just beyond the historical species range, facilitating or mimicking natural dispersal (Handler et al., 2018)

Assisted Species Migration - Moving seed sources or populations to a location far outside the historical species range , beyond locations accessible by natural dispersal (also species rescue, managed relocation, or assisted long-distance migration) (Handler et al., 2018)

Common Garden Experiment - A range of experimental designs in which organisms from different provenances are grown together under the same environmental conditions (Berend et al 2019).

Conservation Introduction – The intentional movement and release of an organism outside its indigenous range, to avoid extinction (assisted colonization) or to perform a specific ecological function (ecological replacement). (IUCN/SSC, 2013)

Conservation Translocation - Conservation translocation is the deliberate movement of organisms from one site for release in another. It must be intended to yield a measurable conservation benefit at the levels of a population, species or ecosystem, and not only provide benefit to translocated individuals (IUCN/SSC, 2013).

Managed Relocation - 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 (Schwartz et al., 2012). Often used as a synonym for assisted migration.

Appendix 2: TNC Projects

The projects listed below are examples of work by The Nature Conservancy that are relevant to the topic of assisted migration or conservation translocations more generally. This list is not comprehensive and intentionally lacks detail to reduce potential misrepresentation of the projects while still providing an overview of the types of projects in which TNC has been involved. Many of these projects were undertaken in partnership with other organizations or agencies, and in some cases TNC was not the lead partner. While not explicitly named in the list below, the identity of partner organizations and agencies can be found in the linked materials. This list is sorted by the project biome and taxa, and then by geography. Links to published material provides additional information about each project.

Desert / Biocrusts

Colorado Plateau

Biocrust restoration: Assisted migration of biocrust communities from hotter, drier climates and large-scale cultivation of climate-adapted biocrusts in “biocrust farms” on the Colorado Plateau.

Published Materials:

Biocrust Fact Sheet

Video: Finding Ways to Help Biocrust Will Benefit People and Nature

Forest / Tree

Southern Wisconsin

Forest management guidance: Includes assisted migration considerations.

Published Materials:

Climate Change Field Guide for Southern Wisconsin Forests: Site-level considerations and adaptation

Northern New York

Forest restoration: Includes planting species anticipated to be adapted to future climate conditions.

Published Materials:

The Nature Conservancy: Setting Northern New York Forests on Climate-Adapted Trajectories by Improving Regeneration & Forest Structure

Keep Forests Healthy - A Tool to Assess Resilience, Health & Productivity

Central Appalachian Mountains of Maryland, West Virginia, and Virginia

Red spruce restoration: Used genetically diverse, climate-adapted seed sources.

Published Materials:

Restoring Red Spruce Forests

From common gardens to candidate genes: exploring local adaptation to climate in red spruce

Genotypic variation and plasticity in climate-adaptive traits after range expansion and fragmentation of red spruce (Picea rubens Sarg.)

Northern Minnesota

Reforestation: Seedlings from more southern seed zones planted in northern Minnesota.

Published Materials:

Assisted migration across fixed seed zones detects adaptation lags in two major North American tree species

Can We Grow Enough Trees to Reforest Minnesota?

New Mexico

Reforestation: Seedlings grown from populations living in warmer/drier parts of New Mexico were planted in high-severity areas of the Las Conchas fire.

Published Materials:

The Clock is Ticking to Reforest New Mexico

Southwestern Washington

Reforestation: Research to compare growth and survival of western hemlock and Douglas-fir seed sources from local and historically drier climates

Published Materials:

Case study: Post-harvest reforestation in a coastal forest in southwestern Washington

What is 'assisted migration' and what are the risks?

Forests / Conservation Planning

US National Forests

Conservation guidance: Incorporating climate change & evolutionary potential into conservation planning. Assisted migration and facilitating gene flow included as potential strategies.

Published Materials:

Toward a Shared Understanding of Climate-Smart Restoration on America's National Forests

Climate-Smart Conservation: Putting Adaptation Principles into Practice

Supporting the adaptive capacity of species through more effective knowledge exchange with conservation practitioners

Connecting research and practice to enhance the evolutionary potential of species under climate change

Grassland / Herbaceous Plant

Minnesota, North Dakota, South Dakota

Grassland restoration: Used genetically diverse seed mixes and development of a spatially explicit seed sourcing tool.

Published Materials:

[Climate-Proofing Our Prairies]

[Seeds of Change: Ensuring the Future for Healthy Prairies]

Island / Bird

Pacific Islands

Island bird introduction: Proposed introduction of the sihek (Guam kingfisher, Todiramphus cinnamominus), native to Guam but extinct in the wild, to a TNC preserve on Palmyra Atoll.

Published Materials:

[Final Rule for the Experimental Population of Sihek]

[Draft Environmental Assessment: Experimental Release of Sihek (Guam Kingfisher) at Palmyra Atoll]

[Finding of No Significant Impact (FONSI): Environmental Assessment for Experimental Release of Sihek (Guam Kingfisher) at Palmyra Atoll]

California Channel Islands

Island bird conservation: Evaluating the suitability of the California Channel Islands to play a role in Hawaiian albatross conservation through managed relocations, given climate change impacts to low elevation breeding islands in the North-West Hawaiian Islands.

Published Materials:

[Managed Relocation of Albatross to the California Channel Islands: Conservation Basis and Preliminary Suitability Assessment]

California Channel Islands

Island bird conservation: Potential managed relocation of Island scrub jay and albatross

Published Materials:

[Proactive Conservation Management of an Island-endemic Bird Species in the Face of Global Change]

[Managed Relocation of Albatross to the California Channel Islands: Conservation Basis and Preliminary Suitability Assessment]

Island / Multiple

Florida Keys

Conservation guidance: Includes translocation within the Keys and to the mainland as potential climate change adaptation options.

Published Materials:

[Florida Keys Case Study on Incorporating Climate Change Considerations into Conservation Planning and Actions for Threatened and Endangered Species]

[Florida Keys Case Study on Incorporating Climate Change Considerations into Conservation Planning and Action for State Listed and SGCN in the Florida Keys]

Marine / Scallop

Virginia Coastal Bays

Bay scallop restoration: Climate-informed restoration efforts used the southern subspecies bay scallop rather than the northern subspecies.

Published Materials:

Bay Scallop Restoration in Virginia's Coastal Bays

Marine / Seagrass

Mid-Atlantic and New England Coast

Eelgrass restoration: Considers assisted gene flow as one potential option for increasing the thermal resilience of eelgrass.

Published Materials:

Building Eelgrass Resilience along the Mid-Atlantic and New England Coast

Savanna Woodland / Trees

Eastern Shore of Maryland

Savanna woodland restoration: Includes assisted range expansion of longleaf pine.

Published Materials:

As climate changes, longleaf pines move north - with help

Playing the hand of God: scientists experiment aims to help trees survive climate change

Outdoors Delmarva - Playing with Fire

Sky Island / Multiple

Madrean Sky Islands of Arizona, New Mexico, and Mexico

Various projects including climate-smart reintroductions and restoration.

Published Materials:

Sky Island Restoration Collaboration

Wetland / Mangrove

Gulf and Atlantic Coasts

Mangrove management: Includes description of climate-influenced range expansion of mangroves.

Published Materials:

Ensuring a Future with Mangroves: Mangrove Engagement, Restoration, and Management in the Gulf of Mexico and on the Southeast Atlantic Coast

Ensuring a Future for Mangroves in the U.S.