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**Abstract**

The current rate of climate change poses a threat to a substantial portion of species worldwide, increasing the need for a varied range of conservation management strategies. Effective and timely actions will be required to counter the additional pressure that will be placed on vulnerable species as the climate changes. The Hawaiian Islands hold the highest rate of extinction per square area on earth. Models suggest that climate change will lead to the loss of many of the five hundred endangered species in alone. Given the high potential for further loss of biodiversity, the Pacific Islands are a prime location to implement novel conservation strategies. Assisted colonization, the intentional movement and release of an organism outside its indigenous range, is one management alternative for species that are predicted to lack suitable habitat under likely climate change scenarios. Despite existing policies that allow for assisted colonization in cases where it is warranted, this action is rarely considered. First person interviews with employees of federal, state and non-profit agencies, surveys, as well as literature searches were used to evaluate both the perceived and existing obstacles concerning the use of assisted colonization, with a focus on cases where this action may provide a reasonable hedge against extinction. Several potential barriers to the use of this management tool were found. Assisted colonization is considered by many to be a high-risk tool, due to the cost of preparing the target habitat, the mortality often experienced by translocated individuals, and a lack of familiarity with this method among managers. Since assisted colonization is best carried out when populations are robust enough to tolerate the removal of individuals for translocation, this management action should be considered in planning for the conservation of endangered species projected to have little or no suitable habitat remaining under future climatic conditions.

**Keywords** endangered species; translocation; assisted migration; climate change; Pacific Islands

**Taxonomy** Global Change, Environmental Management

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March 3, 2017

Dear Sir or Madame,

Thank you for considering our manuscript "Nowhere to Go: Barriers to the Use of Assisted Colonization for Climate Sensitive Species" for publication in Biological Conservation.

Hundreds of species globally face likely extinction due to downstream effects of climate change, such as sea level rise, habitat loss, and disease. For some species, refugia may exist outside of their historical range, but they may need human assistance to reach these refugia. This practice of human-mediated translocation to sites outside of the historical range, here referred to as "assisted colonization", has been successfully utilized to expand species ranges and decrease the likelihood of extinction in several documented cases, but is woefully under-utilized in the Pacific region, compared to the number of species facing extinction due to climate change. In this manuscript, we utilized structured surveys and first-person interviews with natural resource management professionals and researchers within federal, state and nongovernmental agencies to characterize perceived and existing barriers to the use of assisted colonization.

Since the USFWS began incorporating climate change mitigation into recovery plans, there have been several notable papers on the topic of assisted colonization:

Hoegh-Guldberg et al. 2008. Science, 321, 345–357.
Shirey & Lamberti. 2010. Conservation Letters, 3, 45-52.
Loss et al. 2011. Biological Conservation, 144, 92–100.

However, most papers on this topic have focused on when assisted colonization *should* be utilized, and *which species* could benefit most from this tool. To our knowledge, no study yet has examined the perceived and existing barriers to implementation of this tool.

Our results show that despite existing policies that allow for assisted colonization, this action faces considerable resistance from management professionals. The single over-arching barrier inhibiting the use of assisted colonization in the Pacific Islands is a lack of expertise and experience in the use of assisted colonization, which leads to delays in consideration and implementation. When assisted colonization is only considered as a last resort strategy, population numbers often decline below those recommended for successful translocations. Fortunately, a recent series of successful translocations has increased both the number of management professionals with experience, and willingness of some managers to consider this tool. Our manuscript contains lessons of interest to a global audience concerned about species likely to decline or become extinct due to climate change, that might benefit from timely implementation of assisted colonization.

This manuscript contains original research that has not been previously published and has not been submitted elsewhere while under consideration at Biological Conservation. The authors declare no conflict of interest.

Thank you for your consideration,

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on behalf of all authors

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# Nowhere to Go: Barriers to the Use of Assisted Colonization for Climate Sensitive Species

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**Running head**: Assisted Colonization in Hawaiʻi

**Keywords:** endangered species, translocation, assisted migration, climate change, Pacific Islands

## Abstract

The current rate of climate change poses a threat to a substantial portion of species worldwide, increasing the need for a varied range of conservation management strategies. Effective and timely actions will be required to counter the additional pressure that will be placed on vulnerable species as the climate changes. The Hawaiian Islands hold the highest rate of extinction per square area on earth. Models suggest that climate change will lead to the loss of many of the five hundred endangered species in Hawai‘i alone. Given the high potential for further loss of biodiversity, the Pacific Islands are a prime location to implement novel conservation strategies. Assisted colonization, the intentional movement and release of an organism outside its indigenous range, is one management alternative for species that are predicted to lack suitable habitat under likely climate change scenarios. Despite existing policies that allow for assisted colonization in cases where it is warranted, this action is rarely considered. First person interviews with employees of federal, state and non-profit agencies, surveys, as well as literature searches were used to evaluate both the perceived and existing obstacles concerning the use of assisted colonization, with a focus on cases where this action may provide a reasonable hedge against extinction. Several potential barriers to the use of this management tool were found. Assisted colonization is considered by many to be a high-risk tool, due to the cost of preparing the target habitat, the mortality often experienced by translocated individuals, and a lack of familiarity with this method among managers. Since assisted colonization is best carried out when populations are robust enough to tolerate the removal of individuals for translocation, this management action should be considered in planning for the conservation of endangered species projected to have little or no suitable habitat remaining under future climatic conditions.

## Introduction

Climate is an important component helping to shape various ecosystems and species distributions around the globe (Gallagher et al., 2015). As the climate changes, landscapes begin to shift and species respond by adapting and migrating to match the optimal conditions for their growth and reproduction (Brandon, 2014). While it may be possible for species to adapt when the climate gradually shifts over time, we are now seeing abrupt climatic fluctuations due to anthropogenic influences (Calfaro, 2015). As a result, the current rate of climate change poses a threat to a substantial portion of species worldwide (Urban, 2015). Changing climatic conditions are already imposing significant ecological consequences for many species (Rosenzweig et al., 2008; Chen et al., 2011; Wiens, 2016) increasing the need for a varied range of conservation management strategies (Vitt et al., 2010; Bellard, 2012; Schwartz, 2012; Fortini et al., 2015). Optimally, species will respond to climatic shifts by migrating to more suitable climates (Parmesan and Yohe, 2003; Dawson et al., 2011). However, migration will be especially challenging for species with limited dispersal capabilities, specialized habitat requirements, or other restrictions (Bellard, 2012; Taylor and Kumar, 2016). Additionally, climatic shifts are happening at such an accelerated rate that local adaptation is impossible for many species, since adaption can take thousands of years to occur (Visser, 2008; Williams, 2008; Quintero and Wiens, 2013). With such limitations, as much as two-thirds of the world's extant terrestrial species may perish by the end of this century (Raven et al., 2011) leading to an immense loss in biodiversity (Pimm et al., 2014; Calfaro, 2015; Ceballos et al., 2015). Advanced conservation efforts and novel solutions are of critical importance in the face of this extinction crisis.

Two taxonomic groups in the Pacific Islands, endemic forest birds and plants, illustrate this crisis. With the arrival of Polynesians in Hawaiʻi, the highly diverse and charismatic native forest birds became a critical component of an emergent Hawaiian culture (Amante-Helweg et al., 2009). Today, only 20 of the 46 known species may remain in the wild. The ʼAlalā (*Corvus hawaiiensis*) only persists in captivity (U.S. Fish and Wildlife Service, 2009) and since the early 1980's, 9 others may now be extinct (Camp et al., 2009). The Hawaiian avifauna has the unfortunate designation of having the highest modern extinction rate in the United States (Loope, 1998). Today, most remaining forest birds are constrained to higher and cooler elevations where they find refuge from avian malaria and its mosquito vector (van Riper et al., 1986; Samuel et al., 2011). Unfortunately, with a warming climate, several studies indicate the possible loss of much of these disease-free areas across the state (Benning et al., 2002; Fortini et al., 2015; Liao et al., 2015).

Habitat loss and introduced plant and animal species have radically transformed the composition and structure of island plant communities in the Pacific, leading to a well-recognized state of biodiversity crisis (Gemmill et al., 1998; Wagner et al., 1999; Sakai et al., 2002; Wood et al., 2007; Pratt et al., 2009). Within the context of 109 historical plant extinctions and over 300 endangered native plant species in Hawaiʻi alone, conservation practitioners lead a herculean effort with few resources to avoid further losses (U.S. Fish and Wildlife Service, 2013). With a growing concern that global climate change may further impact the beleaguered Pacific island biota (Sadler, 1999; Pratt and Gon, 2002; Ziegler, 2002), past research efforts have evaluated the vulnerability of nearly all native Hawaiian plant species to climate change (Fortini et al., 2013). Considering a diverse set of factors related to habitat area, quality, and distribution for each species, a comprehensive assessment identified a group of over 100 native plant species as particularly vulnerable to climate change. These so called 'no-overlap' species have projected end-of-century distributions completely disjointed from current distributions. It is highly unlikely all of these species will be able to keep pace with a shifting climate given most are narrowly distributed species with very few individuals left. Additionally, the natural colonization of these species into new climate-compatible areas is further hindered by the interaction with other threats such as the preferential predation of seeds and fruits by invasive animals, and the pre-empting of available niche by aggressive invasive plant competitors (Mack et al., 2000; Courchamp et al., 2003).

Assisted colonization, the intentional movement and release of an organism outside of its indigenous range (IUCN), may be one conservation action suitable for species at risk of extinction in their historical range (Vitt et al., 2010; Schwartz, 2012). This tool has been successfully utilized to expand the range of single-island populations and resolve human–wildlife conflict (Fischer and Lindenmayer, 2000; Freifeld et al., 2016). Despite these successes, and the dire situation facing managers in the Pacific Islands and globally, assisted colonization is still rarely used. A number of studies have considered whether assisted colonization should be used as a management tool (Fazey and Fischer, 2009; Ricciardi and Simberloff, 2009; Sax et al., 2009; Schwartz et al., 2009; Seddon et al., 2009; Vitt et al., 2009), but to our knowledge, no study has examined perceived barriers to the use of this tool by natural resource managers and decision makers.

In this study, we aimed to identify barriers to the use of assisted colonization in the Pacific Islands, utilizing first person interviews and questionnaires with natural resource management professionals and researchers. We then illustrate the results utilizing case studies in two taxonomic groups, endemic Hawaiian forest birds and native Hawaiian plants.

## Methods

A total of 14 participants (n=14) were selected based on their experience and expertise as professionals in the field of resource management and wildlife biology. To establish transferability, participants were selected based on reputation, experience, professional achievement and excellence in conservation to ensure trustworthiness of the attained data. Together, the participants came from national and international backgrounds, having 14 to 20 years of experience. Following the model from Glaser and Strauss (1967), data collection was deemed complete once saturation of material was reached; meaning the number of participants interviewed ended when no additional data could be found that developed properties of the conceptual categories.

**2.1 First-person interviews**. A semi-structured interview protocol was designed, and six personal interviews were carried out from February to December 2016. Information sheets were provided to each participant via email to inform them of the study and to gain formal consent in their involvement. The initial participants could suggest other participants with knowledge and experience that they felt could be beneficial to the study. After the interviews were conducted, findings were sent back to the participants for a member-check, to ensure accurate communication. Interviews were conducted in person and via telephone and were recorded by hand-written notes. We recognize that the different settings could conceivably result in differences in responses.

The protocol included five questions that served as a guide for the interview. Probing, or follow-up questions differed at each interview, and were used to further clarify responses. The protocol consisted of the following questions: (1) Describe the barriers you face in the process of implementing assisted colonization? (2) Are there any cases that you are familiar with that assisted colonization could be considered for? (3) What are your top concerns when considering the use of assisted colonization? (4) Are there any policies or procedures that would ease your use of assisted colonization? If yes, please explain what would make implementing assisted colonization easier. (5) In your expertise area, where has this management option failed, succeeded and where has it not been considered?

**2.2 Questionnaires.** A standardized questionnaire was designed and delivered to a group of eight participants in December 2016. For the purpose of this model, the questionnaire was completed as a highly-structured, open-ended questionnaire form (Merriam, 2009) that was filled out and handed in. Information sheets were provided to each participant to inform them of the study and to gain formal consent in their involvement. The questionnaire sheet remained anonymous and had no identifying inscriptions or questions of any kind. The questionnaires were delivered in person and distributed in a group setting. We recognize that the chosen setting could conceivably result in differences in responses. The survey included eleven questions, five of which were based on a quantitative ranking system: (1) How would you rank your understanding of assisted colonization? (2) How would you rank the ease of working through policy as it pertains to assisted colonization? (3) How would you rank the ease of working with other managers and stakeholders as it pertains to assisted colonization? (4) How would you rank the importance of vulnerability modeling as it pertains to the consideration of assisted colonization? (5) How would you rank the importance of budget concerns as it pertains to the consideration of assisted colonization? The remaining five (6-10) questions were formatted to gather written answers to the same five questions asked at in-person interviews described above.

**2.3 Analysis.** Interviews and questionnaires were qualitatively analyzed using the constant comparative qualitative method. The constant comparative method is a process that compares all collected data and codes for recurring themes (Glaser and Strauss, 1967). Coding is used to ensure consistency within the study. Constant comparative methodology integrates four stages: "(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory" (Glaser and Strauss, 1967). The documented interviewee responses were grouped by topics relevant to existing and perceived barriers to the use of assisted colonization.

## Results

Perceived barriers to use of assisted colonization could be generally categorized as technical barriers (policy, permitting) or ecological and economic uncertainties (Table 1). All study subjects indicated that avoidance of risk was a significant barrier to the use of assisted colonization. Participants noted that decision makers tend to be conservative and rely on proven management actions that have been successful in the past. When a key decision maker for a geographic region is particularly conservative, they may not allow discussion or consideration of novel options. This can result in institutional opposition and resistance to innovative solutions.

**3.1 Policies and permitting.** Our analysis revealed that four participants did perceive policy as a barrier to the practice of assisted colonization, six participants do not perceive policy as a barrier, and four did not mention policy in their dialogue. The majority of participants observed that assisted colonization was a potential option under both federal and state law as it is allowed for under the Endangered Species Act (ESA); primarily under Section 10(j) and the experimental population provision (16 U.S.C. §1539(j). Several participants recognized that maneuvering through translocation policy and the permitting process is restrictive and difficult. Only one participant knew of no policy pertaining to assisted colonization, but was familiar with policies associated with translocations.

**3.2 Economic constraints.** Our research identified limited finances, and uncertainty regarding future financing of projects, as a significant barrier in the decision-making process. Participants noted that substantial operating costs are associated with obtaining risk assessments, conducting a thorough permitting process, providing ongoing monitoring, captive propagation, animal husbandry and habitat restoration. Some participants noted that translocations are a long-term commitment, and future financing is uncertain. Furthermore, moving the last remaining individuals from one island to another might result in a reduction in funding for the source island, if the translocated population acted as an umbrella species, garnering funding for the geographic region. As a result of these combined concerns, all interview participants and nearly all survey participants recognized economic constraints as a top concern.

**3.3 Ecological risk and uncertainty.** Participants recognized that impact models exist for many species of concern, such as forest birds and plants. Impact models do not exist for most invertebrates and many plants. Even if impact models exist, uncertainties which are inherent with modeled projections, or even a lack of comfort with understanding computer models, may result in resistance to acting on information generated by modeling. Out of 14 participants, 12 identified concerns about ecological uncertainties as potentially outweighing the possible benefits of assisted colonization. Ecological risks that were mentioned involved risks to translocated individuals (i.e, direct mortality, genetic bottlenecks, inbreeding depression, hybridization) and risks to the recipient ecosystem (i.e., disease transmission, the potential for introduced species to become invasive). Nine participants raised concerns about knowledge gaps for candidate species, particularly cryptic or rare species which may lack pivotal information regarding behavior, such as foraging or breeding habitat preferences.

## Case studies

**4.1 Native Hawaiian plants**. The potential for assisted colonization for some native Hawaiian plant species aligns with several factors that make it a less controversial option for managers locally. First, the complex Hawaiian geography gives many options of assisted colonization with increasing degree of novelty. Managers can consider out-planting outside the historical range of a species but still within the same watersheds, or out-planting across different watersheds, mountain ranges, or islands. Second, for many plant species the difference between standard out-planting and assisted colonization is quite fuzzy, as their pre-historical ranges were likely wider and/or largely unknown **(**Cuddihy and Stone, 1990; Gagne and Cuddihy, 1990; Athens, 2009**).**

A recent meeting with several land managers at the island of O'ahu resulted in widespread agreement for the need to consider out-planting beyond the known historical range of species. This agreement was likely bolstered by surprisingly successful trial plantings of *Cyanea superba* at higher elevations, which also highlighted the possibility that some species may already be under stress from the documented multi-decadal drying trend across the state (Bassiouni and Oki, 2013, Frazier and Giambelluca, 2016). Still, as assisted colonization is increasingly considered, some challenges are eminent. Hawaiian botanists recognize subtle differences in morphology across plant populations and many islands have closely related species and subspecies. The possible mixing of some of these distinct populations will be undoubtedly controversial, due to concerns about loss of distinctive morphotypes or genotypes, as well as concerns about outbreeding depression. The subdivision of the landscape into multiple management units with differing management goals also means that not many areas will be available for the introduction of endangered plants and their associated legal burdens, limiting target areas to conservation lands managed by the state or federal government.

Looming above these considerations is the disastrous history of plant introductions in Hawai'i. One clear reason for the challenging state of Hawaiian plant conservation is the relentless pace of species introductions since human arrival, thousands of times more frequent than pre-historical introductions (Ziegler, 2002). However, while this history highlights the caution that must be taken to avoid unintended consequences of assisted colonization; it also makes inaction a rather absolutist option. Nevertheless, for some managers, the idea of assisted colonization may seem analogous to fighting fire with fire.

**4.2 Kaua'i forest birds**. Two of Kauai's endemic forest birds, the ʻAkikiki (*Oreomystis bairdi*) and ʻAkekeʻe (*Loxops caeruleirostris*) are particularly vulnerable given their susceptibility to avian malaria and the fact that they have no higher disease-free habitat available (Paxton et al., 2016, Fortini et al., 2015). Given that other islands in Hawaiʻi have seemingly compatible habitat at higher elevations, assisted colonization has been a topic discussed by the Hawaiian forest bird conservation community. Recent research has shown that, for both species, the islands of Maui and Hawaiʻi indeed offer climatically suitable habitat that is likely to endure at least until the end of the century under mild to moderate warming (Fortini et al, 2016, unpublished results). Yet, while the very clear threat of climate change and the potential candidate locations for assisted colonization for these two species suggest an ideal setting for assisted colonization, further considerations highlight the multiple complexities involved.

Both Maui and Hawaiʻi islands have highly endangered forest bird species. Past research suggests the competition and range overlap among native bird species may not be too large (Mountainspring and Scott, 1985; Scott et al., 1986, Fortini et al, submission date, unpublished results), but the possibility of any additional pressure on endemic Maui and Hawaiʻi species is a concern by managers. Another source of biological uncertainty pertains to prior extinctions of related species. ʻAkekeʻe is closely related to the extinct Maui ʻĀkepa (*L. ochraceus*). On one hand, the introduction of ʻAkekeʻe in to Maui can be considered as a rare opportunity to restore ecological function lost by past extinction. On the other hand, without an understanding of the causes of extinction of Maui ʻĀkepa, such introduction faces a higher than normal risk of failure.

From a logistical point of view, the current situation of ʻAkekeʻe and ʻAkikiki also highlight the complexities of fitting assisted colonization into a broader long-term conservation strategy for these species. As disease-related declines for the two species continue (Atkinson et al., 2014, Paxton et al., 2016), efforts to collect eggs for captive populations for the two species have recently started. If successful, captive populations offer a possible stepping stone towards future assisted colonization by avoiding take of individuals from wild populations. However, this stepping-stone approach requires successfully large and reproducing captive populations, which are far from certain given the challenges in collecting and hatching enough individuals. To make the decisions space more uncertain, there is a growing possibility of new mosquito control techniques that may reduce prevalence of the disease across the landscape and thus reduce the need for assisted colonization for these species. This complex decision making environment makes a seemingly clear case for assisted colonization a lot more challenging under closer considerations.

## Discussion

In this study, participants identified a lack of expertise and experience in the use of assisted colonization as the single most significant barrier inhibiting the use of assisted colonization in the Pacific Islands. Participants recognized that all other identified barriers, including uncertainty regarding ecological impacts to both the translocated species and recipient ecosystem, as well as permitting or policy issues, could be ameliorated through experience with this management tool. Efficiencies gained through experience might also decrease costs associated with translocations.

Encouragingly, study participants recognized that existing policy at the state and federal level allows for assisted colonization. According to the language of the ESA, the legal framework allows for translocation of endangered populations to new habitats (i.e. Section 10(j); 16 U.S.C. §1539(j); Shirey 2009). However, there is some potential for misinterpretation of policy, as noted by seven participants. In 1984, a primary habitat restriction was added by U.S. Fish and Wildlife Service (USFWS), restricting relocation to inside the species historical range unless “the primary habitat of the species has been unsuitably and irreversibly altered or destroyed” (50 C.F.R. §17.81(a)). The agency’s position provided “that the relocation or transplantation of native listed species outside their historic range will not be authorized as a conservation measure” (49 FR 33890). This discouraging wording can lead to misinterpretation of policy since USFWS will still authorize release outside the current range if “release will further the conservation of such species” (16 U.S.C. §1539(j)).

Impact modeling is still lacking for most invertebrate fauna, and some plants and mammals, but has been completed for all Hawaiian forest birds and 1100 species of Hawaiian plants. However, once impact modeling has been completed, decision makers may be uncomfortable taking action based on these models. Impact modeling must be seen as one of several tools that may be used to identify species at risk.

Many decision makers will also want to see empirical evidence that species are declining due to climate-related factors, along with experimental studies that assess the risk to both translocated species and the recipient ecosystem.

Management professionals were perceived in our interviews and questionnaires to be cautious by nature, preferring conservative, tested, and familiar approaches to conservation. As funds are limited, and managers prefer to take actions that produce visible, immediate results that can be demonstrated to funding agencies.  Some managers and researchers also pointed out that management action in preparation for climate change is a relatively novel concept. A person's perception of climate change was found to strongly influence the implementation of certain management policies. Due in part to political influence; 87% of species recovery plans through 2008 didn't mention climate change at all (Povilitis and Suckling, 2010). Endangered species recovery plans in the United States are now required to consider climate change, but many plans have not been updated and lack guidance in regards to current threats such as climate change (Fischman et al., 2014).

The most notable hesitation regarding the use of assisted colonization revolved around the ecological risk of translocations, including the risk of introduced populations becoming invasive, or encountering adverse ecological interactions in the recipient ecosystem. Two participants specifically mentioned the potential for predation or competition following translocation. These are legitimate concerns that have also been raised by other studies (McLachlan et al., 2007; Etterson, 2008; Hoegh-Guldberg et al., 2008; Ricciardi and Simberloff, 2009; Loss et al., 2011; Schwartz et al., 2011). However, by addressing these risks within a structured decision-making framework (McLachlan et al., 2007; Ricciardi and Simberloff, 2009; Loss et al., 2011; Schwartz et al., 2011), we may provide decision makers with a means of weighing out the likelihood of success under various scenarios.

Resistance was also due to practical considerations, such as economic or time constraints (Shirey, 2009). Translocations require years of planning and long-term monitoring, as mentioned by two participants. The lengthy process of attempting a translocation outside of the species' historical habitat could deter a management team from considering the option (Wolok, 2001). In some cases, assisted colonization is looked at as not being relevant on the time scale many managers are working on. Regional politics may play a role, as assisted colonization may be perceived as the conservation community giving up on a geographic region. The loss of charismatic umbrella species could also mean a loss of funding.

For many species in the Pacific region, population sizes are below numbers that would support assisted colonization efforts, even with an intermediate captive propagation step (Lenton et al., 2008; Vitt, 2010). Several participants suggested that captive propagation may serve as a bridge to assisted colonization. Once a captive population is established, adults or juveniles can be introduced to novel, suitable habitats. However, it is worth to contrast the differences in perception between assisted colonization and captive propagation among participants. Captive propagation was considered by our study participants to be less controversial than assisted colonization because many managers are familiar with *ex situ* propagation of plants or animals. But captive propagation is also a highly manipulative management strategy that is also expensive, subject to a high degree of uncertainty and with few examples of successful reintroductions.

## Conclusions and Future Directions

Assisted colonization is by no means the answer to every situation, but with species extinction happening at a rate faster than the last five mass extinctions (Raven et al., 2011; Calfaro, 2015) and climate change perpetuating species loss at unprecedented rates (Bellard et al., 2012; Fortini et al., 2015; Gallagher et al., 2015), it could very well be a viable option for many species. The use of adaptive management, site-specific frameworks, comprehensive ecological knowledge, and pre-translocation assessments (Gallagher et al., 2015) will increase the success of all types of translocations, including assisted colonization (McLachlan et al., 2007).

Assisted colonization is often considered when population numbers have dwindled below those that recommended for successful translocations. For assisted colonization to be a viable option, decision frameworks must be developed that allow assisted colonization to be considered, alongside other management options, for all viable candidates for this tool. By using a structured decision-making framework, managers may be able to numerically assess risk, particularly in cases where a species is certain to go extinct if left alone, but has a chance of survival if novel actions, such as assisted colonization, are taken. Exceptions to this are extremely rare species with a declining population (e.g., Mariana Crow) and species that are only found in captivity because their home island no longer provides suitable habitat, making these species "refugees" (e.g., Guam Kingfisher, U.S. Fish and Wildlife Service, 2008).

Much of the apprehension surrounding assisted colonization, and all translocations for that matter, can be alleviated with experienced leadership proficient in translocation procedures. Lack of expertise was identified as a significant hindrance to the consideration and especially the implementation of using assisted colonization as a conservation technique. Trailblazers familiar with this management option must be encouraged to support others considering the strategy, through both formal and informal networking and training opportunities. Building leaders with experience in areas such as permitting, habitat preparation, husbandry and cultural knowledge will also reduce barriers.

Momentum is needed to reach the point where a sufficient number of conservationists began to consider assisted colonization as a viable option. To achieve this, managers and researchers from regions with a high number of species likely to benefit from assisted colonization could develop communities of practice around translocations in general, and assisted colonization in particular. Creating a community of practice is an important step toward reducing barriers to use of novel management tools, particularly as effective conservation often requires collaborative relationships across multiple stakeholders. We suggest designing an approach to document translocation successes as well as failures. Many regions may also benefit from a regionally-specific framework of planning steps. One important such step is pursuing comprehensive efforts to identify candidate species for assisted colonization. With a network of practitioners, and a best practices framework, assisted colonization may be considered in a timely manner for species grappling with a tenuous future.

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Table 1. Barriers to the use of assisted colonization in the Pacific Islands.

| **Barriers** | **Participant Acknowledgement** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Significant Barriers** | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 | P9 | P10 | P11 | P12 | P13 | P14 |
| Risk aversion | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Economic constraints | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| Ecological uncertainty | X | X | X | X | X | X | | | X | | X | X | X | X |
| Lack of species data | | | | | X | X | | X | X | X | X | X | X | X |
| Lack of expertise | | | | | X | X | X | X | X | X | X | X | X | X |
| Policy | | X | | X | X | | X | | | X | X | | | X |
| Permitting | | | | | | | | X | | X | X | | X | |
| Timescale issues | X | X | | | | | | | | | | | | |
| Impacts to receiving system | X | X | | | | | | | | | | | | |