How ready are we to move species threatened from climate change? Insights into the assisted colonization debate from Australia

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Abstract Assisted colonization, the intentional movement of species beyond their native range, has been proposed as a climate change adaptation tool for biodiversity conservation. The risks and benefits of its implementation are still being debated but already the climate is changing, species are moving and the pressure on at-risk species must therefore be increasing. However, instances where moving species beyond their natural range purely for conservation purposes due to climate change are few, and the opportunity for science to inform practice is limited. Here we survey active participants in flora translocations and/or flora conservation in Australia in order to investigate the gap between theoretical and conceptual ideas about assisted colonization and to gauge preparedness for its implementation. We found that actions that mitigate proximal threats are preferred over those that move species beyond their current range. A lack of knowledge of species biology and ecology is an impediment to the acceptance of assisted colonization. In addition, prohibitive costs and the potential increased risk of the spread of diseases, pests and/or pathogens are viewed as more important obstacles of successful assisted colonization than potential for invasion at the recipient site. Full approval from all stakeholders at the source and recipient sites was found to be the most important factor for the successful assisted colonization of flora.

Key words: assisted migration, climate change adaptation, managed relocation, survey, translocation.

INTRODUCTION

The term ‘assisted colonization’, and its synonyms (including assisted migration and managed relocation), is collectively used to describe the intentional movement of species beyond their current range to locations predicted to become suitable under future climate scenarios (Hoegh-Guldberg et al. 2008; Richardson et al. 2009; Vitt et al. 2010; Burbidge et al. 2011; Schwartz et al. 2012). Assisted colonization has been proposed as one tool in a suite of climate change adaptation strategies with a goal of saving species from extinction where dispersal or in situ adaptation cannot match the pace of climate change (e.g. Miller et al. 2012; Corlett & Westcott 2013; Mitchell et al. 2013).

The idea that some species and communities will not be able to keep pace with climate change is not new. Local extinctions and disruptions to functioning ecosystems due to a rapidly changing climate were first predicted approximately 30 years ago (Peters & Darling 1985). Since then, for each of the past three decades, the earth’s surface has been successively warmer than all of the previously recorded decades (Hartmann et al. 2013). Furthermore, since the 1950’s, it is likely that extreme weather events, such as the number of heavy precipitation events over land has increased in many regions and that heatwaves have increased in parts of Europe, Asia and Australia (IPCC 2012). In addition, globally, snow cover has decreased and sea levels have risen (Hartmann et al. 2013). Concurrently, atmospheric concentrations of CO2 have continued to rise, for example 3.1% from 2005 to 2011 (Hartmann et al. 2013). Even if CO2 emissions ceased today, atmospheric temperatures are not estimated to drop significantly for at least 1000 years after emissions abate (Solomon et al. 2009). In other words, the climate has already changed, the level of confidence in future climatic predictions has improved, and in some regions, novel environments may emerge (Williams et al. 2007; Dunlop et al. 2012). In addition, some species are already shifting their range to track optimal conditions for growth and survival and altering their phenology (Parmesan 2006; Chen et al. 2011). Despite these actualities, projections and a growing theoretical understanding of the need to expedite adaptation measures to conserve biodiversity, we may be no closer to implementing the practice of assisted colonization.

From a theoretical perspective, assisted colonization has spawned much debate. A recent review found 63 articles explicitly referring to this form of climate change adaptation (Hewitt et al. 2011) and there are multiple examples of frameworks, decision trees and
guidelines to advise on best practice for assisted colon-ization (McLachlan et al. 2007; Hoegh-Guldberg et al. 2008; Williams et al. 2008; Richardson et al. 2009; Vitt et al. 2010; Dawson et al. 2011; McDonald-Madden et al. 2011; Thomas et al. 2011; Haskins & Keel 2012; Moir et al. 2012; Chauvenet et al. 2013; Foden et al. 2013; Rout et al. 2013; Schwartz & Martin 2013; Shoo et al. 2013). Despite the plethora of theoretical information, excluding for-estry trials and species moved in a ‘climate-ready’ direction for reasons other than climate change (Liu et al. 2012), the practice of moving species beyond their natural range primarily for climate change is limited (Willis et al. 2009; Van der Veken et al. 2012). However, some field trials and modelling in prepara-tion for assisted colonization have occurred (e.g. Keel et al. 2011; Mitchell et al. 2013).

Industry bodies such as the IUCN/SSC (2013) expect that the practice of assisted colonization will increase and 60% of the articles in the most recent review on the subject generally supported its use as a climate change adaptation strategy (Hewitt et al. 2011). However, endorsements from proponents often come with the caveat that assisted colonization has risks and obstacles to surmount and that it is likely to be costly in financial terms.

The main concerns surrounding the use of assisted colonization are the potential problems that may occur at the recipient site(s) such as the invasiveness of the translocated species (Mueller & Hellmann 2008; Ricciardi & Simberloff 2009); changes to the composi-tion, development and/or functioning of ecosystems (Hunter 2007; Davidson & Simkanin 2008); the disrup-tion of key ecological interactions (i.e. plant–animal mutualisms) (Hellmann et al. 2012); and the loss of fitness and/or extirpation of populations due to potential hybridization and introgression of the target species with close relatives at or nearby the recipient site (Ricciardi & Simberloff 2009; Hewitt et al. 2011). The uncertainties involved in forecasting ecological costs and the reliability of climatic predictions and species distribution models (SDM) are also cited as potential problems (McLachlan et al. 2007; Chauvenet et al. 2013). The potential risks and obsta-cles need to be balanced against the potential benefits of assisted colonization; namely the ability to save species/assemblages/communities from extinction. The optimal timing of assisted colonization is complex and likely to be context specific. For example, moving at-risk species while they are still relatively healthy offers advantages, but the decision is multi-faceted and should incorporate the use of a quantitative decision framework (McDonald-Madden et al. 2011).

People designing and implementing translocations in real-world situations are at the coal-face of this conservation strategy and their opinions and practice will be crucial for success. There is potentially a large divide between theoretical and conceptual ideas about assisted colonization in the literature and the practical implementation and logistics in the field. How this dichotomy is navigated will ultimately determine the success of assisted colonization as an adaptation strategy. That is, if researchers and practitioners are not clear about each other’s interpretation and understand-ing of assisted colonization concepts, then projects risk failure.

In this context, we surveyed practitioners and researchers active in flora translocations and/or flora conservation in Australia to assess their attitudes to the use of assisted colonization as a climate change adap-tation measure. In particular, we compared the opinions of the respondents to the theoretical literature on:

1. Preparedness for the practice of assisted colonization.
2. The perceived risks, obstacles and benefits of assisted colonization.
3. The potential impacts of climate change on flora translocations.

METHODS

Survey sampling frame and distribution

The survey targeted Australian practitioners and researchers active in flora translocations and/or flora conservation. Historically, the majority of flora translocations in Australia have been limited to threatened species. Accordingly, our target audience have experience in threatened species, rather than more common taxa. Potential participants from the practi tioner community included those nominated as Australian State and Territory threatened species project officers, case study presenters at past Australian Network of Plant Conservation (ANPC) workshops (since 2004) on ‘Translocation of Threatened Plants in Australia’; recent speakers from the Australian Association of Bush Regenerators seminar ‘Working with Natural Processes for Ecological Restoration’; and Australian authors from the IUCN Reintroduction Specialist Group case study reports: 2008, 2010 and 2011.

Researchers were chosen by searching within the Scopus database for authors of papers that included the terms ‘assisted colonisation’, ‘managed translocation’, ‘plant’ and ‘Australia’.

The survey was distributed via email directly from the authors and also through the email networks of the Office of the Environment and Heritage (OEH) Threatened Species Network, the ANPC and the Ecological Consultants Association of NSW.

Survey format

Potential participants were invited to participate in an on-line survey: https://www.surveymonkey.com/ (see Appendix S1

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for a copy of the survey). Included with the invitation were an introductory letter of explanation and a glossary of terms used in the survey (Appendix S2). Hard copies of the survey were available upon request.

Respondents who answered ‘no’ to the question: *In your opinion, do you believe that projections of future climate change (e.g. more extreme weather events, increased temperatures, changes in rainfall patterns) are relevant to translocation projects* were not required to answer the survey questions on assisted colonization (on the basis that assisted colonization is deemed not necessary). Participation in the survey was voluntary.

**Data analysis**

Where closed-ended questions gave numerous answer options, a rating average was applied to each option. The rating average was calculated as follows:

\[
\frac{(w_1 \times n_1) + (w_2 \times n_2) + (w_3 \times n_3)}{T}
\]

where \(w\) = weight of the answer choice; \(n\) = the number of responses for that option; \(T\) = total number of responses.

**RESULTS**

**Survey participation**

A total of 158 potential participants were invited to complete the survey, and 70 responses (44%) were received. The largest group of respondents were practitioners (51%), followed by researchers (33%) and those who work as both practitioners and researchers (16%). A small minority of respondents (6%) indicated that they do not believe that the projections of future climate change are relevant to translocation projects and did therefore not complete any questions pertaining to assisted colonization.

There was no discernable difference between practitioners and researchers regarding their opinions on assisted colonization. There was a slight difference in the average rating of importance for a small number of questions by those that work as both practitioners and researchers. These responses were not analysed separately due to the small number of respondents (11).

**Opinions on assisted colonization and climate change adaptation strategies**

**Maximizing success of assisted colonization**

The most important factor, from the list provided, for the successful assisted colonization of flora (assuming best practice), was that the project has full approval from all stakeholders at the source and recipient sites (3.59 average rating) (Table 1). Of almost equal importance (3.57), was that *risk assessments or experimental evidence has identified minimal risk of harm or damage to ecosystems at the recipient site*. Evidence that climate change is the main or a contributing cause of the focal species’ decline was thought to be of least concern (2.98).

**Potential benefits of assisted colonization**

The order of importance of the potential benefits of assisted colonization for flora and fauna were:

- *The ability to preserve species that are predicted to have no other means of avoiding extinction* (3.79). The majority of respondents (79%) thought that this potential benefit was ‘very important’.
- *The ability to use focal species as an ecological replacement to restore and/or improve ecosystem function at the recipient site* (3.3). The majority of respondents (50%) thought that this potential benefit was ‘important’ and 36% thought it was ‘very important’.
- *Costs associated with saving dominant or keystone species are likely to be high but will be offset by the costs associated with losing the species* (3.12). The majority of respondents (50%) thought that this potential benefit was ‘important’ and 26% thought it was ‘very important’.

**Obstacles to assisted colonization**

A lack of knowledge about the focal species ecology to confidently move it was thought to be the most important obstacle to the success of the assisted colonization of flora (assuming best practice) (3.18) (Table 2).
Prohibitive costs (3.17) and the potential increased risk of the spread of diseases, pests and/or pathogens (3.16) were also highly rated as important obstacles. Of least concern was the accuracy of predictive modelling (2.79).

Prioritizing conservation actions under climate change

Respondents were given a list of strategies that could be considered to actively manage for better biodiversity conservation outcomes under climate change and asked to select a time frame for their action (Table 3). The strategy most favoured for action now and which also received the overall highest average rating (2.96) was to Increase and/or restore habitat connectivity. The strategy that was most often elected as Should not be done in the foreseeable future, received the lowest average rating (1.98) and for which most people chose not to answer was to Move wide spread but non-dominant plant species to locations where the species is likely to have persisted before anthropogenic alterations and has a high probability of being suitable under climate change. Other low risk recommendations to actively manage for better biodiversity conservation outcomes under climate change (apart from those presented in Table 3) suggested by respondents included:

- Use existing translocations and restoration projects as experiments (e.g. reciprocal transplant experiments; including edge vs. core populations).
- Licenses given to organizations to restore, rehabilitate or revegetate (e.g. the mining sector at the end of production) to include a provision that the end product is ‘climate ready’.
- Conduct intraspecific diversity assessments to ascertain the amount of in situ genetic diversity to maximize evolutionary potential.

Ninety-one per cent of respondents required more detailed ecological information of the focal species to assist in their ability to minimize the impacts of climate change on future flora translocations (Fig. 1). Conversely, only 51% required more genetic information to perform the same task.

Current flora translocation practices

No preparatory measures for climate change were taken in 72% of previously executed translocation projects. For current planning of future translocation projects, 59% of respondents said that their organizations are taking preparatory measures for climate change. Common themes of preparatory measures involved changes to seed collection methods (collecting more widely than previously) and recipient site selection to reflect future climate. In regard to when their organizations should be considering the impacts of climate change, 38% believe it should be for all current translocations; 43% for all future projects; 43% think that it depends on the species and the site and 9% think only when it is certain that the effects of climate change have or will impact on the focal species (note that this question allowed multiple answers).

The most commonly used flora translocation guidelines were the Australian Network for Plant Conservation (ANPC) Guidelines for the translocation of threatened plants in Australia (Vallee et al. 2004); singularly (36%) or in conjunction with one or several guidelines (41%). Conversely, 12% have not used the ANPC guidelines. A (slight) majority of respondents believe that the guidelines that they use do not adequately address the potential climate change effects on biodiversity.

Opinions on flora translocations

Prioritization of flora translocations

For flora translocations in general, the order of urgency for translocations were where:

1. Populations of the species are few, small and declining (2.61).
2. The species is extinct in the wild and ex-situ material is available and can/has been propagated (1.85).
3. The species’ population(s) are currently stable but has a high risk of extinction without human intervention (1.54).
Use of volunteers in flora translocations

On the use of volunteers in the long-term monitoring of flora translocations (Table 4), assuming appropriate motivation, training and supervision, respondents thought that volunteers are most effective in increasing the awareness of the project, leading to better conservation outcomes (3.15). Volunteers were thought to be least effective in situations where it is necessary to have the ability to recognize that adaptive management is required (2.15).

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DISCUSSION

Preparedness for assisted colonization

There are several lines of evidence to support the inference that the practice of assisted colonization is not readily accepted by those actively involved in flora translocations/conservation in Australia. First, when presented with a list of proposed strategies for better biodiversity conservation outcomes under climate change, the only option that considered the movement of species beyond their current range, averaged the lowest rating (Move wide spread but non-dominant plant species to locations where the species is likely to have persisted before anthropogenic alterations and has a high probability of being suitable under climate change) (McIntyre 2011). In addition, this option also attracted the largest percentage of respondents who believed that this action should not be taken in the foreseeable future. We note, however, that there was support for this action to be taken now. The magnitude of negativity towards assisted colonization is also highlighted by this response because this action could be regarded as relatively low risk; it could be seen as a reintroduction rather than an assisted colonization. This scenario highlights a dilemma regarding translocation terminology and our understanding of historical distributions. Thomas (2011) argues that assumptions made on species distributions are questionable. For many species, the native range has been defined from records from the past several hundred years, whereas, it has been dynamic throughout glacial and interglacial periods (Thomas 2011). This argument has important implications for distinguishing a species ‘known’ distribution (current or historic), and its potential future distributional envelope under changed climatic conditions. It therefore questions whether a translocation is within or beyond a species current range.

Second, in regard to preparation for climate change in relation to future translocation projects, only one respondent indicated that they are considering transplanting beyond the species current range. In addition, a few respondents directly commented that assisted colonization, as a tool to prevent extinctions, should only be used as a last resort.

Third, the level of urgency for translocations of species population(s) that are currently stable but have a high risk of extinction without human intervention received a lower rating than the other scenarios: the species is already extinct (and ex-situ material is available and can has been propagated) or where populations are few, small and declining. This question did not mention moving species beyond their current range but it indicates a reluctance to pre-empt threats and take preparatory actions. This question was answered largely by practitioners, rather than researchers. We note that the majority of practitioners are involved in the translocation of threatened species and may therefore have a natural inclination to prioritize species that are currently vulnerable.

Finally, in addition to biodiversity conservation, assisted colonization also has the potential benefit to restore and/or improve ecosystem function as replacements for taxa that are no longer able to perform ecological processes (Lunt et al. 2013). This broader benefit of assisted colonization, whilst still involving some risk, was seen as ‘very important’ by only one third of respondents (compared with 80% of respondents who thought that avoiding extinction was ‘very important’). The complexity and a lack of knowledge of ecosystem functioning, together with limited experience in ecological replacements were given as reasons for the lower rating. However, it may also imply a preference to leave an ecological niche vacant, rather than introduce a species from beyond its range. Ecological replacements have rarely been mentioned in conservation translocation reviews (e.g. see Fischer & Lindenmayer 2000; Short 2009; Guerrant Jr 2012; Sheean et al. 2012).

Benefits of and obstacles to successful assisted colonization

The respondents’ opinions of the potential benefits of assisted colonization concurred with those of the wider research community (Hewitt et al. 2011). In particular, the ability to preserve species that are predicted to have no other means of avoiding extinction was recognized as being very important (McLachlan et al. 2007; Hoegh-Guldberg et al. 2008; Thomas 2011).

Where the responses from the survey differed from the literature, is the importance placed on the perceived obstacles to successful assisted colonizations. Generally, the obstacles to (or risks of) assisted colonization referred to in the literature stem from invasion ecology, particularly concerns of invasiveness and other damages from pests, diseases and pathogens at recipient sites (Ricciardi & Simberloff 2009; Hewitt et al. 2011). However, the perceived risks of the source population becoming invasive at the recipient site rated relatively low in the survey. The importance placed on the use of risk assessments or experimental evidence to identify minimal risk of harm or damage to ecosystems at the recipient site may have alleviated respondent’s concerns about invasiveness. However, concerns about the potential of the spread of diseases, pests and/or pathogens were not similarly alleviated and were relatively highly ranked as an obstacle to success.

According to the survey respondents, the biggest obstacle to successful assisted colonization is a lack of knowledge of species ecology. Insufficient knowledge of species biology and ecology was highlighted throughout the survey in many contexts and...
concurring with other studies that have identified that the knowledge gap is problematic (Hewitt et al. 2011). Addressing this obstacle is difficult and it has been argued that the pace of climate change may dictate that assisted colonization may have to be implemented with imperfect knowledge, especially when the different values of multiple stakeholders are incorporated (Richardson et al. 2009). However, to address knowledge shortfalls, collaboration and the sharing of biological data with other organizations with commonalities, for example neighbouring states and organizations with research capabilities, is encouraged (Burbidge et al. 2011). Further studies that can predict species plasticity and/or adaptive capacity would be particularly useful in closing the knowledge gap (Urban et al. 2014; Franks et al. 2014).

Prohibitive costs and a general lack of resources (e.g. long-term funding and monitoring support for existing translocations from which to learn) were also rated highly as obstacles to success. Adequate funding for monitoring is important to the success of all translocations (Vallee et al. 2004; Menges 2008) and its importance in actions that are still experimental, such as assisted colonization, cannot be underestimated (Chauvenet et al. 2013). In a butterfly assisted colonization project, Willis et al. (2009) noted that their costs could have been reduced by using ‘amateurs’. The results from this survey indicated that the costs involved in the training and organization of volunteers may reduce the benefits gained in their participation in long-term monitoring of flora translocations. The survey also highlighted that volunteers are less effective in situations where management practice needs to be adaptive. Assisted colonization is still in its infancy so adaptive management is essential and therefore the use of volunteers would require dedicated supervision and management.

Survey respondents believe that the most important factor of successful assisted colonizations (from the list of factors provided) was that the project has full approval from all stakeholders at the source and recipient sites. This response was unexpected because the importance of stakeholder involvement as a success factor is not highly prioritized in the literature (but see Burbidge et al. 2011; Hewitt et al. 2011; Schwartz & Martin 2013). The survey revealed that volunteers are very effective in increasing the awareness of projects that lead to better conservation outcomes. Volunteers may therefore be helpful in acquiring stakeholder approval at the source and recipient sites.

Inconsistencies between actions and belief

There were three areas of inconsistencies between respondent’s actions and their beliefs within the survey: preparation for climate change, the use of scenario-based modelling and the importance of genetic factors.

Overwhelmingly (94%), respondents believe that the projections of future climate change are relevant to translocation projects. However, only 59% of respondents organizations are taking preparatory measures for climate change in relation to future translocation projects. In comparison with a 2012 survey of restoration practitioners in NSW, preparatory actions for climate change is now greater (59% compared with 45%) but the percentage of respondents who believe that climate change is relevant to their projects is also higher (94% compared with 80%) (Hancock & Hughes 2012).

Access to predictive modelling, for both regional climate change projections and future species distributions at the local level was identified as an area where further investment is needed in some instances but not in others. For example, 76% of respondents indicated that climate projections at a local/regional level are required to assist in the ability to minimize the impacts of climate change on future flora translocations. However, inaccurate predictive modelling of species future distributions was rated the lowest obstacle to successful assisted colonization. A common theme throughout the survey was that recipient site selection that incorporates future climate change is one preparatory measure currently being undertaken. The use of predictive models should make site selections quicker and more cost-effective and therefore deliver better project outcomes (e.g. site selection for the assisted colonization of the western swamp tortoise (Mitchell et al. 2013)). However, there is still considerable debate about the accuracy and scale of some modelling projections (Chauvenet et al. 2013).

Burbidge et al. (2011) argue that genetic considerations are more important for assisted colonization than for other conservation translocations because of the greater role of evolutionary responses. Generally, throughout the survey, genetic considerations rated relatively low, but several comments were made that sufficient genetic diversity is critical to translocation success. This inconsistency may reflect the difficulty that some respondents have in accessing genetic information and the high allocation of resources needed to establish in-house genetic testing.

Other strategies to mitigate proximal and climate change threats before assisted colonization is adopted

The challenge for biodiversity conservation managers is to pre-empt the adverse effects of climate change but without the assistance of substantial empirical evidence of successful assisted colonizations, policy direction and down-scaled climate projections. It is generally recognized that assisted colonization will not be effective as the sole form of climate change adaptation and that many other steps should be
taken to address the impeding decline in biodiversity, (Lindenmayer et al. 2010; Burbidge et al. 2011; Corlett & Westcott 2013; Shoo et al. 2013). Respondents clearly indicated that they prefer actions that mitigate proximal threats over those that move species beyond their current range. The ‘low-risk’ biodiversity conservation action that respondents most favoured to implement now was to *Increase and/or restore habitat connectivity*. Corridors that increase connectivity to allow the migration of organisms was also the most highly ranked strategy for biodiversity management in the face of climate change in a recent meta-analysis (Heller & Zavaleta 2009). Of the proposed actions to actively manage for better biodiversity conservation outcomes under climate change, the only action with similarities to assisted colonization attracted the lowest support (as discussed earlier).

**CONCLUSIONS**

The survey comprised a set of oversimplified questions pertaining to a very complex subject and highlights the difficulty in generalizing situations such as assisted colonization that is often context specific. The responses given therefore sometimes contained conflicting messages but it is clear that climate change is expected to impact on translocation projects. Currently, to conserve biodiversity, actions that mitigate proximal threats are preferred over those that move species beyond their current range. Additional resources to enable the gathering of species ecological and biological data would be helpful in assisting the acceptance of assisted colonization as a climate change adaptation strategy in Australia.

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**REFERENCES**


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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher’s web-site:

Appendix S1. Copy of the survey form used.
Appendix S2. Definition of terms used in the survey.

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