Is Australia ready for assisted colonization? Policy changes required to facilitate translocations under climate change

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Assisted Colonization (AC) has been proposed as one method of aiding species to adapt to the impacts of climate change. AC is a form of translocation and translocation protocols for threatened species, mostly for reintroduction, are well established in Australia. We evaluate the information available from implementation of translocations to understand how existing policies and guidelines should be varied to plan, review and regulate AC. While the risks associated with AC are potentially greater than those of reintroductions, AC is likely to be the only available method, other than germplasm storage and establishment of captive populations, of conserving many taxa under future climate change. AC may also be necessary to maintain ecosystem services, particularly where keystone species are affected. Current policies and procedures for the preparation of Translocation Proposals will require modification and expansion to deal with Assisted Colonization, particularly in relation to risk management, genetic management, success criteria, moving associated species and community consultation. Further development of risk assessment processes, particularly for invasiveness, and guidelines for genetic management to maintain evolutionary potential are particularly important in the context of changing climate. Success criteria will need to respond to population establishment in the context of new and evolving ecosystems, and to reflect requirements for any co-establishment of interdependent species. Translocation Proposals should always be subjected to independent peer review before being considered by regulators. We conclude that consistent approaches by regulators and multilateral agreements between jurisdictions are required to minimize duplication, to ensure the risk of AC is adequately assessed and to ensure the potential benefits of AC are realized.

Key words: Assisted Colonization, assisted migration, Managed Relocation, translocation proposal, translocation risk assessment, translocation genetic management, translocation success criteria, translocating associated species.

INTRODUCTION

RAPIDLY changing climates are affecting the distributions of many plants and animals worldwide (Parmesan 2006) and elements of the Australian biota are particularly susceptible to human-derived climate change (Steffen *et al*. 2010). In particular, the ability of species to disperse may be physically restricted in human-altered landscapes, where populations are naturally isolated (e.g., mountain tops) or across flat landscapes where climatic thresholds may migrate rapidly across large distances. For many species, naturally slow rates of dispersal may be inadequate to allow species to track their climatic niche. Assisted colonization (AC, also termed assisted migration and managed relocation) has been proposed as one method of aiding plants and animals to adapt to the impacts of climate change (Hoegh-Guldberg *et al*. 2008; McLachlan *et al*. 2007; Richardson *et al*. 2009). AC refers to the purposeful movement of species or genes to sites where habitat is predicted to become suitable as the climate changes. While AC may prevent extinction in the wild of threatened species, AC of keystone species may also be required to maintain ecosystem services at sites where ecosystem collapse is occurring or predicted (Lunt *et al*. in review). However, due to the perceived risks to recipient ecosystems, AC is often proposed as a last resort for conservation management, only to be implemented when all *in situ* options are considered unlikely to succeed (Hoegh-Guldberg *et al*. 2008; Mueller and Hellmann 2008; Richardson *et al*. 2009; Vitt *et al*. 2009). We support this proposition, while also noting that a failure to implement AC is effectively a decision to favour those taxa that are able to disperse without assistance (Thomas 2011).

Demand for AC in Australia has so far been small. The proposed translocation of the western swamp tortoise *Pseudemydura umbrina* to sites well to the south of its current range in the south west of Western Australia, where rainfall has declined significantly and is expected to decline further (CSIRO 2009), is one example. McIntyre

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(2011) has provided examples of low risk translocations from Australian grassy woodlands. While demand may be low at present, we anticipate that demand will increase and believe that resolving issues in advance of major demand is good conservation management and policy.

AC is a form of translocation (Seddon 2010). Translocation protocols are well established as a conservation action to achieve persistence of species under immediate threat (e.g., CALM 1995; NSW NPWS 2001). AC is an introduction according to the IUCN Position Statement on Translocation of Living Organisms (IUCN 1987); however, that Statement does not specifically discuss translocations to reduce the risk of extinction due to climate change. The IUCN definition of translocation is restricted to movements for biodiversity conservation purposes, including restoration activity, and generally not for salvage from developments or conflict avoidance (e.g., Linnell *et al.* 1997; Mueck 2000), although there may be opportunities for AC arising from these situations (Chambers and Keatley 2010). The wealth of information and knowledge garnered from implementation of past conservation translocations, mostly reintroductions, should provide a solid basis for evaluation of AC, but the current policy positions of jurisdictions that will regulate AC are unclear.

In this paper we evaluate the information available from implementation of plant and animal translocations in Australia to understand how existing policies and guidelines should be varied to plan, review and approve (or not) proposals to conduct AC. Translocation Proposals (TPs) will need to be prepared in a risk management framework where the benefits and risks are clearly identified and rigorously assessed. Moreover, AC requires modifications to current procedures for preparing, reviewing and assessing TPs, particularly in assessment of risks at target sites, genetic management, success criteria, moving associated species and community consultation. Our review may also help improve the translocation planning and approval process for reasons other than climate change.

CURRENT AUSTRALIAN KNOWLEDGE, POLICIES AND APPROVAL PROCESSES

Translocations of animals and plants for conservation reasons have been practised in Australia for several decades (Short *et al.* 1992; CALM 1995; Fischer and Lindenmayer 2000; Vallee *et al.* 2004; Short 2009) and there are well-established guidelines and approval processes in most States and Territories, although these vary in their process and rigour between jurisdictions (Short 2009). Most Australian State and Territory conservation agencies are actively reviewing translocation policies. Some State policies are undergoing revision (South Australia, New South Wales) while others are establishing policy and procedures (Tasmania, Victoria). Some convergence of policy principles for translocation is occurring through policy transfer amongst a small epistemic community with additional ideas taken from New Zealand (Department of Conservation 2004).

Draft national guidelines for fauna translocations were prepared in 1999 by the Australian and New Zealand Environment and Conservation Council (ANZECC) (superseded in 2002 by the Natural Resource Management Ministerial Council) (NSW NPWS 2001). The guidelines, which drew heavily on IUCN (1987) and a Policy Statement on Translocations developed by the then Western Australian Department of Conservation and Land Management (CALM 1995), required the preparation by the proponent of a TP linked to a Recovery Plan and required approval by an animal ethics committee. Under the guidelines, the TP is referred to independent referees before consideration by regulators. The draft national guidelines have been generally adopted by Australian regulatory authorities (e.g., NSW NPWS 2001) and most jurisdictions require an approved TP before any proposed translocation is undertaken. The TP template is a checklist of questions prompting the proponent to consider the actual and likely consequences of the translocation as well as requiring a description of procedures to be followed. Plant translocations have been assisted by guidelines produced by the Australian Network for Plant Conservation (ANPC) (Translocation Working Group 1997; Vallee *et al.* 2004). In most jurisdictions, plant translocation guidelines follow the same procedures as outlined for fauna.

The large number of translocations undertaken in Australia should provide a basis for evaluation of the benefits and risks. However, most information derived from past Australian translocations is not readily accessible in the peer-reviewed literature. For vertebrate translocations, Short (2009) has undertaken a detailed synthesis that allows for a more holistic understanding, but there are a large number of organisms (i.e., vascular plants and invertebrates) where translocations have been undertaken without yielding any summary or analysis.

In his review of vertebrate translocations, Short (2009) found that 22% of the 380 translocations in Australia were introductions, although many were not for conservation reasons. Most recent animal conservation translocations in Australia have been reintroductions (i.e., movements within the original range); of the few recent conservation introductions (outside the original range), many have been to islands (often termed "marooning", e.g., Short and Smith 1994; Langford and Burbidge 2001; Rankmore *et al.* 2008). Plants have been introduced more widely for a range of reasons, primarily related to agriculture and horticulture. Only recently have plant introductions outside the original range been undertaken for conservation purposes: several plants threatened by *Phytophthora* dieback in Western Australia have been moved to new sites because of the lack of suitable disease-free sites within their natural ranges (Monks *et al.* in press).

In a review of plant reintroductions worldwide, Godefroid *et al.* (2011) analysed 249 species, examining how successful they have been in establishing or augmenting plant populations to achieve viable self-sustaining populations. They identified various parameters that positively influenced plant translocation outcomes, such as mixing material from diverse populations. They also identified shortcomings in experimental designs that significantly limited the interpretation of translocation studies. Such analyses could also yield information relevant to AC such as effect of distance moved, whether dependent or co-evolved taxa were considered, and the influence of life history on success.

The current criteria for successful establishment vary (Short 2009). The only detailed definition available is that of CALM (1995), which defined "successful translocation" as "one that provides a self-perpetuating population with at least 90% of the genetic diversity of the source population, without expensive, non-routine management" (p. 1). Success criteria are often constrained by a short-term view of the translocation, lack of consideration of the spatial dynamics of species undergoing large movements or occupying confined sites (Hayward *et al.* 2007) and limited monitoring, especially in relation to the generation time of the translocated organism (Breitenmoser *et al.* 2001; Macdonald 2009). The progression of climate change increases the challenge of determining success criteria and highlights the importance of ongoing monitoring of translocations. The inadequate monitoring of translocations has been highlighted by several authors (Short *et al.* 1992; Fischer and Lindenmayer 2000; Griffith *et al.* 1989; Macdonald 2009; Short 2009). Generation time is a particular limitation in determining success criteria for long-lived plants (Monks *et al.* in press). Most information used to determine reintroduction success in plants, such as vegetative growth, reproductive output and recruitment, is aimed at a specific step or process in the translocation programme and may take decades to be assessed effectively in long-lived species. In these cases, the assessment of translocation success may be achieved in a timelier manner by utilizing additional measures such as the level of genetic variation, mating system variation and population viability analysis (Monks *et al.* in press).

REQUIRED CHANGES TO POLICY AND PROCEDURES FOR ASSISTED COLONIZATION

Current policy and procedures for translocations do not take into account the complexity of issues that will be encountered in undertaking AC. Improvements to existing translocation policies and practice will be required to facilitate AC, particularly in the areas of risk analysis, genetic management, identification of success criteria, monitoring, associated species and evaluation and approval (Table 1).

Risk Analysis

Risk analysis will be a critical component of the planning process for AC. Risk is a function of the likelihood of an event and the consequence of the event should it occur (Anon 2004). Assessment of the risk of AC will need to be comprehensive, transparent and defendable. Complete risk assessments assess all stages of the risk management cycle from formulating the problem, to analysis of data, to characterization of the risk. The risk management cycle should be guided by stakeholders, a melding of risk analysis methods, adaptive management, decision tools, monitoring and validation. Honest risk assessments take into account the uncertainty embedded in the assessment, carry these uncertainties through chains of calculations and judgements and communicate these uncertainties reliably and transparently (Burgman 2005).

Whilst all aspects of AC are amenable to assessment of risk, including the risk of extinction if no action is taken, the major area that generates the most concern amongst scientists is risk of a negative impact on the recipient ecosystem because of invasiveness of species or genes (Ricciardi and Simberloff 2009a, 2009b). The potential for invasiveness needs to be given serious consideration in AC strategies, since traits of species that increase the likelihood of AC success may also be common in pest animals and weeds (Mueller and Hellman 2008). Risk assessment tools are available to predict the likelihood of invasiveness and should be conducted for AC as part of the planning and approval process. Weed risk assessment is promoted for movement of all

Table 1. Recommended improvements to existing translocation policies and practices in light of climate change.

- Develop risk management as a key aspect of AC including:
  - Risk of invasiveness
  - Risk of moving beyond the area of suitable climate
  - Risk of failure to establish in the recipient area
  - Risk of foregone opportunity and competing use of land
- Manage genetic basis
  - Maximize genetic diversity by sourcing founder population from as diverse a range of populations as possible
  - Use knowledge of genetic variation within and between populations to select source individuals
  - Maximize population size to maximize genetic diversity
  - Review local provenance policy/guidelines as current policies promote using propagules only from local sources
- Define new/appropriate criteria for success (see Table 2)
  - Longer term criteria (decades) to account for time of climate change
  - Relate to life history and body mass, etc.
  - Sustainability of receiving environment
- Interaction with progressive climate change
- Incorporate dependent and co-evolved species into evaluation
- Consider and address critical interactions with the receiving environment that might also be impacted by climate change
- Apply uniform monitoring standards across jurisdictions, taking into account generation time
- Instigate cross-jurisdictional cooperation in administration of translocations
  - Develop multilateral agreements between jurisdictions
  - Develop consistent definitions
  - Incorporate invertebrates and plants into system.

plant species in Australia and there are risk assessment protocols in use in various State jurisdictions (e.g., Setterfield *et al.* 2010; Virtue 2010) and research programmes (Stone *et al.* 2008) that are consistent with the National Standards for Post-Border Weed Risk Management (Anon 2006). An evaluation of consistency in the outputs of five weed risk assessment models in use in Australia found high correlation between the invasiveness and impacts criteria but significant variability in the potential distribution criterion (Stone and Byrne 2011), which may be exacerbated in assessments of predicted distribution under climate change. In some jurisdictions, these protocols are also applied to pest animals (Walton 2005; Williams 2010). These systems provide a means of undertaking rigorous and objective assessments of species risk and highlight areas where further data are required for effective evaluation, thus playing an important role in the translocation process.

Invasiveness at the genetic level should also be considered, as it can arise through interspecific hybridization with congeners or through intra-specific hybridization between genetic lineages when one is moved into the range of another. Such hybridisation can lead to negative impacts on the affected population through both heterosis (where hybrids out-compete local progeny) and outbreeding depression (where fitness is reduced) (Edmands 2007). Outbreeding depression has been often cited as an argument against moving individuals from peripheral areas of their existing range into areas where genetically divergent lineages or closely-related species occur and hybridization might result. The genetic risks associated with translocations can also be placed in a risk assessment framework (Byrne *et al.* in press). While the likelihood of adverse impacts is predictable, the consequences of outbreeding depression are difficult to evaluate or predict as genetic and ecological processes are complex, local adaptation is hard to measure and impacts may not be evident until the second generation following hybridization (Hails and Morley 2005; Edmands 2007). Therefore, genetic risk assessment evaluates factors influencing the likelihood of genetic exchange between populations that are sufficiently divergent that some negative impact is possible, rather than the consequences of the exchange (Potts *et al.* 2003).

Risk of genetic invasion at the recipient site is not often considered in movement of plants and animals in Australia, although genetic risk is considered in eucalypt plantations (Potts *et al.* 2003; Barbour *et al.* 2008a, b) and a genetic risk assessment has recently been developed for implementation in revegetation programmes (Byrne *et al.* in press). In addition, a decision tree for prediction of outbreeding depression in rare species translocations of both plants and animals has recently been developed (Frankham *et al.* 2011). Predictions of genetic risk involve assessment of taxonomic status, chromosomal and genetic differentiation, mating system, dispersal distance and sink/source dynamics of the relocated and local species/lineages (Byrne *et al.* in press; Frankham *et al.* 2011). Monitoring of local populations at the recipient site for both weed/pest and genetic invasion should be incorporated into TPs as has been proposed for revegetation programs (Laikre *et al.* 2010).

Another potential risk of AC is moving species beyond the area of currently suitable climate. Most recent TPs consider where, within the historic range, could a species be moved. With AC, the TP must consider where, within future climate scenarios, the species should be moved.

For example, species x could be moved y km poleward of its historical range to remain within its climatic tolerance. In order to achieve this, ecological niche models that incorporate bioclimatic variables (Yates *et al*. 2010a, b), along with information on population dynamics (Elith *et al*. 2010), will be an important addition to the standard requirements of TPs. Once the decision has been made to implement AC, the next area of uncertainty is when and how many individuals should be moved to a new site (McDonald-Madden *et al.* in review) and whether translocations need to be carried out in a staged manner through several suitable sites over time.

In addition to the risks of negative biological impacts from invasiveness, AC will also require a comparative risk assessment in relation to alternative management actions. Using decision science thinking (Keeney and Raiffia 1976; Martin *et al*. 2007; Wilson *et al*. 2006), this would include assessment of feasibility, probability of success, costs, forgone opportunity, and competing use of land and resources. Risk analysis should also include an examination of whether the translocated taxon might pose a risk to human life or property.

Genetic management

Genetic considerations are more important for AC than standard translocations because of the potential evolutionary responses required to cope with new and changing climates. Recent studies of contemporary evolution have demonstrated rapid evolution of traits, particularly in short-lived species (Salamin *et al*. 2010). Many, but not all, organisms may have the capacity to respond to climate change within time frames of a few decades (Skelly *et al*. 2007). Exceptions include species with long generation times, poor dispersal ability, and those with specific habitat or eco-physiological requirements.

An ideal strategy for AC would be to match the local adaptation of the source population with that of the translocation site (Marsico and Hellmann 2009); however, this information is rarely available. A more realistic option would be to maintain adaptive potential by strategically mixing populations as a practical and cost-effective method of establishing populations with maximum genetic diversity to evolve to cope in the face of rapid environmental change (May 1991; Broadhurst *et al.* 2008; Vitt *et al*. 2009; Weeks *et al*. in press). A strategy for mixing could be based on natural patterns of gene flow, providing opportunities for adaptation and persistence in both established and new environments. In plants, for example, it may be reasonable to simulate leptokurtic gene flow patterns where most propagules disperse proximally but with a significant proportion moving over longer distances (Bacles *et al*. 2006; Nathan 2006; Byrne *et al*. 2007, 2008; Sgrò *et al*. 2011). Such an approach would involve mixing locally-sourced material from genetically-healthy sources and a smaller proportion of material, depending on natural gene flow dynamics, sourced from more distant populations to increase genetic variation and promote adaptation. This approach has been described as "composite provenancing" by Broadhurst *et al.* (2008) and is recommended in the case of broadscale restoration in significantly-degraded landscapes. It represents a cautious strategy that might also be appropriate for species where local adaptation is considered to be strong but where the predicted changes in climate are small or unknown (Weeks *et al.* in press).

There is a commonly held view that outbreeding depression is likely to occur when individuals from differently-adapted populations are crossed, and that translocations that combine distinct lineages will have increased risk of failure. However, this risk has most likely been significantly overstated and over emphasized in the literature and elsewhere by academics and managers (Frankham *et al*. 2011). There are some clear, predictive risk factors for strong outbreeding depression (Frankham *et al*. 2011; Byrne *et al*. in press; Weeks *et al*. in press). These include taxonomic status, fixed chromosome differences, historical isolation, the environments of the source/recipient populations, the degree of adaptive differentiation among source and recipient populations, and rates of environmental change that populations are likely to experience. Conversely, these factors may also indicate whether population fitness and adaptability will be affected by a loss of genetic diversity and evolutionary resilience, and whether gene flow will improve fitness through a genetic rescue effect (e.g., Madsen *et al.* 2004). In this case, mixing of populations in translocations can be beneficial through increasing genetic diversity and heterosis. Therefore, when consideration is given to mixing of populations in translocations, the risk of outbreeding depression needs to be weighed against the potential benefits of increasing genetic diversity.

Success criteria and monitoring

Success criteria have been largely confined to measuring the performance of the organism in its new environment (Short 2009), but little attention has been directed to the sustainability of the organism's interaction with the receiving environment, particularly the provision of environmental services, or to the maintenance of cultural and social values (Richardson *et al.* 2009). Social and cultural values are likely to be of significant concern in consideration of AC as a climate change adaptation strategy, and success criteria need to address both the focal organism and the ongoing condition of the receiving environment.

Existing criteria for success and the timeline for monitoring in TPs tend to be short-term. AC will require success criteria and associated monitoring that apply over significantly longer periods, such as decades, as the climate will continue to change in the foreseeable future. The proponent will need to commit to a monitoring regime and demonstrate that long-term funding for monitoring is likely to be available. Factors that we consider will improve the success criteria used in translocations for AC are provided in Table 2.

Associated species

The potential for loss of species through co-extinction and extinction of dependents and co-evolved (including symbiotic and mutualistic) species, is likely to be high (Dunn *et al*. 2009; Moir *et al*. 2010), particularly given the number of hosts that are becoming rare or threatened. For example, it is now estimated that one in five (76,000) of the world's plant species is in danger of extinction from a broad range of threats (IUCN Sampled Red List Index for Plants 2011). This will have further impacts since most plants are host to numerous invertebrates (Pellini *et al*. 2010) and some 90% of flowering plants are reliant on biotic pollination for reproduction (Menz *et al.* 2011). Many, such as orchids that require a mycorrhizal fungus to trigger germination (e.g., Harley and Smith 1983), have obligate relationships. Although programmes and strategies are being developed to save host species from extinction, often little or no thought is given to the suite of dependent or co-evolved species such as symbionts and parasites. Some dependent species are highly specific to their hosts (Vesk *et al.* 2010) and may be located on just a single subpopulation within the host's range (e.g., Taylor and Moir 2009). Dunn *et al*. (2009) argue that most endangered species are actually parasites and mutualists.

The Save the Tasmanian Devil (*Sarcophilus harrisii*) programme is an example of one that specifically aims to maintain wild populations of devils with a full natural suite of associated organisms (DPIPWE 2010) and is applying this principle to proposed translocations. Extreme specialisation in the use of pollinators is another example where conservation efforts need to focus on plant-pollinator interactions and networks that support those interactions (Menz *et al.* 2011). For example, in the Orchidaceae a significant number of species use sexual deception to attract a single specific pollinator with little sharing of pollinators among orchid species (Stoutamire 1983; Hoffman and Brown 1998; Phillips *et al*. 2009). Dependent and co-evolved taxa have rarely been considered in past TPs, but this needs to be incorporated into AC planning and practice in a much more comprehensive manner than is currently the case, otherwise co-extinction may result (Moir *et al*. 2010).

Consistent evaluation and approval processes

AC will require the movement of species between bioregions and across State and Territory borders more often than is currently the case for reintroductions, indicating the heightened need for a nationally-consistent approach to translocation policy and approvals.

Table 2. Recommendations for enhancing success of Assisted colonization.

- Sustainability of receiving environment — the influence of the organism on the receiving environment needs to be evaluated in relation to acceptable level of impact
- Include number of individuals to be moved. Genetic theory suggests an effective population of at least 1000 individuals is a minimum required to ensure that 90% of a population's genetic variation is retained (Brook *et al*. 2006). Traill *et al.* (2006) has recently suggested this be revised to over 4000. However, recent work in New Zealand has shown that under moderate growth rates c. 60 individuals of a bird species should be released onto an island to achieve at least 95% certainty of alleles at an initial frequency of 0.05 being retained after five generations (Tracy *et al*. 2011).
- Metapopulation management — this is a critical factor in ensuring the effective population attains 1000 individuals. For example, this is already the stated aim of the South African wild dog *Lycaon pictus* and cheetah *Acinonyx jubatus* conservation management groups (Davies-Mostert *et al*. 2009; Lindsey *et al*. 2011).
- Criteria for success — this can be measured in four key areas (Pavlik 1996). It should include a time component consistent with the generation time of the organism being translocated:
  - Abundance (establishment, individual and population growth, fecundity and recruitment)
  - Extent (dispersal, range expansion)
  - Resilience (genetic variation)
  - Persistence (over generations)
- Monitoring — this will be a vital component of measuring success.
  - Initial period of "establishment" monitoring
  - Ongoing monitoring should be at least every five years or a fixed number of generations (e.g., two), whichever is the lesser
- Over-success — excess in abundance or extent can facilitate transition to invasiveness and requires:
  - Risk analysis
  - Monitoring of abundance and range
- Influence of progressively changing climate — evaluate how the above factors interact with climate change.

Once a set of policy principles is agreed, individual jurisdictions can seek policy innovation within the agreed framework. An efficient method of assessment is also desirable given the likely large increase in the number of taxa for which AC will need to be considered in coming decades.

The Commonwealth government maintains a statutory list of nationally threatened species. This list only partially overlaps with the larger, separate statutory and non-statutory lists maintained by Australian States and Territories, although processes to align these lists are underway (Commonwealth of Australia 2010). While involvement in recovery actions for nationally-listed species typically involves both tiers of government, actions for species on State lists may not involve adjoining jurisdictions. A nationally-consistent approach should specify a principle that all relevant agencies would become involved in any cross-jurisdictional translocation proposal for a State-listed species.

There may also need to be changes to existing environmental legislation to facilitate AC. The legal status of hybrids, for instance, is not always clear. Under current Australian or United States legislation hybrids of threatened species may not have the same legal protection as the pure-bred entities (Walker *et al*. 2009; Garnett *et al*. in press), yet sometimes a small number of genes of introduced organisms can move far in advance of detectable phenotypic change (Fitzpatrick *et al*. 2010). In this case, the legal status of introgressed populations (natural populations with novel genes from a related taxon) of a threatened species is unresolved. This is despite the potentially positive effect of new genetic variation that might be vital for a species to persist under environmental change.

The same ambiguity occurs in the IUCN Red List guidelines (IUCN 2010). Currently, local populations introduced for non-conservation purposes, outside the natural range of the taxon, are not assessed globally as contributing to the conservation status of a species (IUCN 2010). Under this restriction, AC may not make a positive contribution to IUCN Red List conservation status (Butchart *et al*. 2004, 2007) or to the Millennium Assessment Goals (United Nations 2010). Only under IUCN regional guidelines can naturalized populations of species that are "Extinct in the Wild" be assessed using the IUCN Red List criteria and guidelines, an exception reluctantly allowed because "if a taxon is extinct over its entire natural range the presence of the taxon within the region must be considered important to highlight and preserve even though the region is not part of the taxon's natural range" (IUCN 2003, p 12). Under climate change, these conditions need to be amended to accommodate deliberate movements outside a taxon's natural range for conservation purposes.

Current practice usually requires a TP to be independently refereed by experts from outside the proponent's organisation(s) before consideration by regulators. This is perhaps even more important with AC to ensure all facets have been appropriately considered and addressed. Referees will need to be familiar with risk analysis as well as the biology of the organisms concerned. Modifications to current TP preparation procedures are required and a framework for a new TP preparation process is provided in Table 3.

Communication and consultation with stakeholders is recommended with all translocations. Whereas conservation reintroductions are generally well received by stakeholders and the general public because they value conservation measures, AC proposals may not receive such ready public support. Introduction of a novel species at the target site may challenge people's "sense of place" while introduction of threatened species to an area currently lacking them may foreclose options for development. Public support may also be limited if AC could lead to major environmental change (Ricciardi and Simberloff 2008) or if cultural factors were affected by the AC (e.g., impacts of an introduced organism on a site's cultural values such as a totem species of Australian Traditional Owners). However, such concern is only likely to be manifest if change from the AC is expected to overshadow those changes occurring from climate change. Communication of the benefits and risks of AC compared with other management actions, or of taking no action, will be important to highlight the role of AC in each case. Involvement of community groups in AC will be important, not only to facilitate understanding and support for this adaptation strategy, but also because it may reduce costs of implementation through the provision of volunteer labour.

CONCLUSIONS

Assisted colonization, while having a higher risk of failure or of disrupting the target environment than reintroductions, is likely to be the only available method of conserving many taxa in the wild under future climate change. AC may also be necessary to maintain ecosystem services, particularly where keystone species, such as trees, are affected (Seddon 2010). Clear articulation of objectives and measurement of outcomes will be imperative for AC, while analysis of success and failure of recent translocations would inform development of success criteria for AC. Knowledge derived from the current practice of translocations provides

Table 3. Framework for preparation of a translocation proposal incorporating assisted colonization.

Title of proposal. Should adequately describe what is proposed and why.

Name and affiliation of proponent(s).

The taxon. Include summary of taxonomic status of source population(s), biology and ecology, former and current distribution, conservation status, threats other than climate change, current conservation management.

Current and predicted future climate of taxon's range. Describe modelling used and provide an estimate of reliability of predictions, state why the future climate at current site will not be suitable.

The translocation. State type of translocation (reintroduction/introduction/restocking or supplementation); include status of land at target site, population(s) from which individuals will be removed, effect of removing individuals on source population(s), life history stage to be moved (adults, juveniles, eggs, seeds), whether intermediate captive breeding or propagation will occur and why. For animals state whether release will be "hard" or "soft"; (i.e., whether animals will be held in semi-captivity at target site and whether water and/or food will be provided) and why. For plants state whether watering and/or mulching, protection from grazing or other management will be used and why.

Risk analysis. Describe the risk analysis undertaken and its outcomes. In particular, state why the taxon is considered unlikely to become invasive. Does the translocated taxon pose any risks to human life or property or to other taxa resident at the target site? Estimate the time frame over which climate at the source and target site will change sufficiently to lead to imminent extinction.

Genetic management. Consider the principles of conservation genetics. In particular, discuss the number and source(s) of individuals to be translocated in relation to maintaining genetic variability and allowing the translocated population to adapt to new conditions. State the proposed strategy for sourcing individuals, i.e. number of individuals from how many and which populations and provide justification.

Associated taxa. Identify whether the taxon to be translocated is dependent on other taxa (e.g., mycorrhizae, pollinators) or whether there are co-evolved, symbiotic, mutualistic or parasitic taxa. Describe whether, why and how such taxa will be translocated with the target taxon.

Disease. Describe procedures for minimising the risk of death due to parasites and pathogens being moved with the taxon.

Translocation methodology. Describe how individuals will be moved. For animals describe how the animals' welfare will not be compromised.

Success criteria. List the criteria to be used to measure the success or otherwise of the translocation. Success criteria should take account of the life history and generation time of the organism, impacts/sustainability of receiving environment and trends in climate at the target site.

Monitoring. Details of post-release monitoring must relate to the success criteria and include a commitment to monitor the translocated population in the medium to long term, ie, a commitment to monitor closely the fate of a proportion of the translocated organisms. Where experience with translocating the taxon (or related taxa) is limited or where the translocation is to an environment into which the taxon has not previously been translocated, greater detail and longer-term monitoring is required.

Consultation and communication. Define the stakeholders. Have they been consulted and what has been the response? Provide evidence of support for the translocation.

Funding. Identify the source of funds for the translocation and demonstrate that long term management and monitoring resources for the translocated population are available and committed.

Approvals. Include endorsement by proponent's institution, approvals by owner of source and target locations. For vertebrates other than fish, approval of an Animal (Experimentation) Ethics Committee must be obtained, noting that specialists with knowledge about translocations may need to be added to such committees.

References.

a solid basis for consideration of the practical aspects of implementation of AC, and highlights the areas that require modification and further development. A more explicit consideration of risk assessment is required for AC than is currently the case for translocations within historic range. Consideration of maximising genetic diversity whilst minimising risk of outbreeding depression will be important in the context of climate change to ensure ongoing evolutionary potential of translocated populations. Peer review of TPs before consideration by regulators is even more important with AC, as dealing with climate change is complex. Monitoring at the recipient site is also more important, not only to determine whether the translocation has been successful, but also to determine whether unacceptable environmental impact is occurring. Moving associated species has had little or no consideration in past translocations, but with AC it requires careful consideration to prevent co-extinction and to promote necessary favourable interactions, such as pollination and symbiosis. Finally, a consistent approach by regulators and multilateral agreements between jurisdictions is required to minimize duplication by proponents and regulators, and to ensure the benefits of AC are realized.

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undertaken, and which species should be considered for AC.

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