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Managing islands in the context of climate change

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Summary

Climate change seems one of the grimmest of threats – slow, inexorable and inevitable. For island species, the problem seems even worse as island taxa cannot readily escape to more suitable climates. There are several sources of comfort. First, most island taxa have experienced much climate change before, including hotter times with higher sea levels. Those that could not survive have been selected against already. Second, as now, climate extremes are likely to be ameliorated by the surrounding ocean. Third, island biodiversity managers are among the most innovative. Many taxa will adapt by themselves, and should be left to do so. 'No action' may be the best action unless monitoring indicates a problem. If species are reacting adversely, the first step should be alleviating the pressure from other threats so that taxa have greater opportunity for natural selection to favour individuals best adapted to altered climates. Only then are more intensive interventions justified. Most will be *in situ* but a few taxa populations may need to be moved to more suitable climates, either on other islands or in captivity. In summary, climate change needs to be seen as another threat to be managed, but losses are not inevitable.

Introduction

That climate change is happening at a global level is unequivocal (Glikson 2016). There is empirical evidence that the changing climate is having a profound effect on biodiversity (Burrows *et al*. 2011; Poloczanska *et al*. 2013) and consequently on conservation management (Jones *et al*. 2016). There has already been one extinction attributable to sea-level rise driven by climate change (Watson 2016; Waller *et al*. 2017) – the Bramble Cay melomys (*Melomys rubicola*) – even though the extinction could have been prevented (Woinarski *et al*. 2016, 2017). This illustrates that climate change is a real and present danger to island biodiversity, alongside invasive species and habitat alienation (McCreless *et al*. 2016; Harter *et al*. 2015). It is also a pervasive long-term driver of change: all current action needs to be placed in the context of a rapidly changing climate. As a result, all conservation management needs to build in provision for anticipating climate change and reacting in time to ameliorate the threats that the changes will bring. Some of this management needs to be proactive because responding after an event, such as the waves that drowned the Bramble Cay melomys, may be too late. In other cases, delaying action will result in higher costs and fewer benefits (Hannah *et al*. 2007). Given that we are increasingly aware of the threats posed by climate change and their probabilities, a failure to take timely anticipatory management is inexcusable.

Action to counter the effects of climate change is also possible. Unlike finite manageable threats such as invasive species for which permanent solutions are often possible and proven, managing for climate change can seem overwhelming and so far beyond the control of island managers that it is tempting to focus instead on other threats. But climate change need not be disempowering. Rather, it needs to be incorporated into management in the same way as other threats. It may, however, require managers to adopt innovative approaches to conservation that would conventionally be unacceptable. Many conservation managers are still unwilling to accept innovative approaches (Hagerman *et al*. 2010) but, as chapters in this book attest, radical approaches have often been embraced by people managing islands (Alderman and Hobday 2016). As a result, they are often better equipped in terms of skills and 'can-do' attitudes than many managers of protected areas and threatened species in places where threats have not yet required the desperate conservation interventions too often necessary on islands.

This chapter reviews the interaction between climates and biodiversity, the impacts that can be anticipated and potential solutions. Then, using birds as a lens, we review the actions required to retain Australian island species that models suggest are the most vulnerable to climate change over the next 50 years. We conclude with a summary of approaches to management and climate change planning principles.

Past climate change and island biodiversity

The first point about managing islands in the face of climate change is to appreciate that island biodiversity is a product of past climate change – indeed, many islands exist only because of relatively recent sea-level rise. Despite often having small population sizes with low genetic capacity to cope with change and low functional redundancy or available area of habitat, many species must have persisted through a range of climates during their evolutionary history. For instance, following the last glacial maximum ~20 000 years BP, when the sea level was ~125 m lower than today and continental islands were connected to mainland Australia, sea levels sometimes rose at rates far faster than predicted for the near future: between 14 300 BP and 14 600 BP it rose ~5 cm a year, totalling ~16 m over the 300 years (Hanebuth *et al*. 2000, 2009). This means that coastal-dependent species have proven sufficiently adaptable in the past to survive rapid sea-level rise under the conditions at the time. Many island taxa also persisted on islands that were much smaller than they are today. During the Eemian, just 120 000 years ago – well within the evolutionary history of most taxa – sea levels were 10 m higher than they are currently (Rijsdijk *et al*. 2014). For continental islands, extinctions could have been reversed by recolonisation during subsequent glacial lowstands, but around Australia sea levels were over a metre higher than current levels for at least a thousand years, around 6000 BP (Lewis *et al*. 2013). During that time all islands would have been smaller than they are now. This fluctuation in sea levels is reflected in the higher than expected number of endemics on islands that were once much larger (Weigelt *et al*. 2016).

Other climatic trends that have affected the evolutionary history of island species are reductions in rainfall during the Pleistocene, when large volumes of the world's freshwater were frozen, the world experienced both lower and higher temperatures, major climatic drivers like the monsoon and the El Niño Southern Oscillation changed (Reeves *et al*. 2013) and patterns of winds and currents differed because major marine connections between oceans were closed (e.g. Torres and Bass Straits). However, unlike sea-level rise, our understanding of these patterns remains incomplete (Kohfeld *et al*. 2013), and we have little knowledge of their impact on the climate of individual islands. What we do know is that all island taxa have persisted through a range of climates during their evolutionary history.

Box 15.1: Helping Australian island birds cope with climate change

A recent analysis of the effect of climate change on Australian birds found that current climatic conditions of 101 Australian terrestrial and inland water bird taxa would no longer overlap their current range by 2085, that 16 marine birds have breeding sites for which the surrounding seas are predicted to be at least 10% less productive than today, and 55 terrestrial taxa are likely to be exposed to more frequent or intense fires (Garnett *et al*. 2013; Garnett and Franklin 2014). Among the places where birds were most exposed to climate change were Tiwi, King and Kangaroo Islands while marine birds nesting on Lord Howe and Norfolk Islands, the Great Barrier Reef and the Houtman Abrolhos were thought likely to face substantial declines in local marine productivity. Many seabirds were considered potentially highly sensitive to climate change, based on a set of ecological and morphological metrics, while small island taxa were the most likely to be both exposed and sensitive to climate change, followed by marine taxa, most of which use islands for breeding.

An adaptation plan was drawn up for each of the 101 most vulnerable bird taxa, of which 34 occurred on islands, 26 exclusively, classifying potential actions into those that could usefully be initiated immediately and those that may be necessary in the future. These actions were then divided into those that constituted single, one-off projects and those that were likely to be ongoing, such as monitoring. Finally, all projects were costed over a 50-year period at current costs (Table 15.1).

All taxa require monitoring from now onwards and a baseline survey was required, to enable monitoring to begin. Without monitoring, interventions cannot be justified and may not be needed. One intervention – for the orange-bellied parrot (*Neophema chrysogaster*) – was likely to need the purchase of habitat likely to support salt marsh as the sea level rises. The major costs, however, were for the eight taxa likely to require retention in captivity indefinitely (about A$420 million, largely for construction of appropriate facilities) and ongoing research to follow seabirds (about A$1.2 million) and determine whether and where greater regulation of fishing is required.

Table 15.1. Management actions and their estimated costs (A$'000) recommended for Australian island bird taxa predicted to be the most vulnerable to climate change up to 2070

Timing	Extent	No. of taxa	Habitat enhancement	Intensive management	Preservation	Research	Monitoring
Immediate	Defined	15	1600 (3)	1000 (1)	–	584 (12)	10 (1)
	Ongoing	34	–	107 (5)	220 (1)	-	2716 (34)
Future	Defined	18	–	2700 (3)	–	14 756 (26)	–
	Ongoing	20	371 (8)	4499 (17)	–	–	–
Total		34	1971 (8)	8306 (18)	220 (1)	15 340 (22)	2726 (34)

Immediate actions are those that should start now, future actions should start when there is evidence of climate change impacts. Defined actions are one-off; ongoing actions continue indefinitely. Figures in parentheses are number of taxa, with some taxa in multiple categories. Source: Garnett *et al*. (2013).

Indeed, for birds in Wallacea and the West Indies, Dalsgaard *et al.* (2014) found that the current fauna reflects current conditions with no echo of past climates, and suggested that climatic variation during the Pleistocene may have been too mild to induce extinction among endemic species. This means that, barring additional pressures, many species have an inherent capacity to cope with a wide range of climates, including those soon to be visited upon modern humans. Climate change will be a problem for some taxa (Box 15.1) but largely because the impacts are exacerbated by other changes wrought by humans.

Modelling future island climates

Modelling future changes in climate is done at a global level. Regionalisation of climate models is improving for mainland areas but is by no means certain (Fowler *et al*. 2007), and robust atmospheric climate data are available only for major landmasses such as continental Australia and some larger associated continental islands (Franklin *et al*. 2014). Nevertheless, a range of climate impacts that will affect island taxa can be predicted with modelling (CSIRO and Bureau of Meteorology 2015) for Australian regions and are likely to apply to nearby continental islands. These include temperature rises of 0.5–1.4°C by 2030 and up to 5°C by 2090, more frequent atmospheric and oceanic heat waves, heavier rainfall (when it occurs), more severe bushfire weather in the south and less frequent but higher-intensity cyclones in the north. The greatest uncertainty is around rainfall, with lower winter and spring rainfall predicted in the south and east, summer and autumn rainfall trends uncertain, and wet season rainfall uncertain in northern Australia.

The climate of Australia's six oceanic island groups – Norfolk, Lord Howe, Macquarie, Heard, Christmas and Cocos (Keeling) – is tied closely to surrounding marine environments. Given that the sea is likely to increase in temperature more slowly than land, the climate of these islands may be buffered from temperature extremes, as appears to be the case with biodiversity hotspots in New Caledonia (Pouteau and Birnbaum 2016). Furthermore, for Australian islands, projections of climate models suggest that changes in marine productivity in the southern hemisphere are likely to be lower than in the north (Cabré *et al*. 2015). Patterns of, and projected change in, marine productivity in Australian waters are complex (Steinacher *et al*. 2010) and constantly being refined. For example, recent and better models on eddy dynamics suggest that the Tasman Sea, previously expected to become less productive, may become more so (Matear *et al*. 2013).

Sea level will certainly rise. As evidenced by the Bramble Cay melomys, higher seas are already causing extinctions on low-lying atolls. However, such endemism is rare on atolls, which have always been relatively transient as sea level has fluctuated. By contrast, most Australian islands extend well above most projections of sea-level rise for the rest of the 21st century. Elsewhere, the impact of sea-level rise on biodiversity will be greatly exacerbated by the response of island peoples to occupy lands further inshore (Wetzel *et al*. 2012). However, most Australian islands with substantial biodiversity have small human populations, with little likelihood of major additional impacts on biodiversity should settlements be displaced.

Solutions

Potential options for conserving biodiversity under climate change have been reviewed by Mawdsley *et al*. (2009) and Shoo *et al*. (2013), and incorporating climate change into systematic conservation planning has been reviewed by Jones *et al*. (2016). Options include doing nothing in the hope that species will respond to climate change without assistance, maintaining and enhancing existing habitat, intensive species management and preserving populations *ex situ*. Underpinning all these strategies is the need to monitor so that we can understand how species and ecosystems are responding to the changes in climate, so that strategies can be adapted as required and intervention hastened.

Do nothing

Doing nothing to help species cope with climate change can sometimes be the best strategy because they may be able to cope with change on their own. However, monitoring needs to be in place, as well as contingency plans for when monitoring indicates intervention is necessary. As noted, most island species have had to cope with climate change in the past so may have retained an inherent capacity to cope in the future. Of course, the difference is that humans have greatly altered the environment of many island species, reducing ecosystem resilience and exposing vulnerabilities not previously evident (Brook 2008).

Maintain and enhance habitat

The least specific and easiest intervention is to increase ecosystem resilience, which generally means maintaining habitat in a favourable state, and reducing threats. Where habitat loss is the most pressing threat, the simplest and most passive form of this adaptation strategy is to expand the protected area estate. Retaining areas of natural habitat in protected areas is known to be an effective strategy for conserving species under climate change (Thomas *et al*. 2012; Thomas and Gillingham 2015). However, expanding the protected area estate without at least commensurate increases in management funds can be worse than doing nothing. More intensive is active habitat management to improve the quality for targeted species. This can include restoring degraded or lost habitat, for example replanting or controlling weeds to allow for natural regeneration. For Australian environments, this can include more active fire management, where burning has been poorly controlled, or invasive species control. For some islands, strengthening of biosecurity can significantly reduce the risks of invasive species establishment. These are standard procedures for conservation managers whether on islands or elsewhere.

Similarly, proactive identification of refugia followed by their protection is a management action that pre-empts climate change while benefiting current conservation objectives. For example, Keppel *et al.* (2015) applied a three-step process in Tasmania that involved:

- defining the scope, scale and resolution of refugia;
- identifying and quantifying their characteristics;
- prioritising them for conservation.

The most important refugia for plants on the largest of Australian islands were in cool, wet and topographically complex sites. For smaller islands, refugia are likely to be at correspondingly reduced scales with a heavy reliance on microclimatic conditions (Ashcroft *et al.* 2009, 2012). They will be at least partly defined by past land use with few alternatives, such as the last substantial remnants of Norfolk Island flora in the island's national park. Others will long ago have been identified as refugia through traditional knowledge, such as spring-fed rainforests on the Tiwi Islands (Tacon 2010; Hoverman and Ayre 2012). Such sites are refugia under current conditions, and will continue to be so as the climate changes.

Finally, habitat enhancement can include the creation of new habitats. Novel ecosystems are emerging as a direct result of climate change (Chapin and Starfield 1997) and potentially have an important role to play in climate change adaptation (Hobbs *et al*. 2009). Deliberate creation of novel ecosystems in the face of climate change can enhance both biodiversity conservation and the provision of ecosystem services (Lunt *et al*. 2013).

One management strategy that is commonly cited for mainland habitats but has little relevance for islands (except perhaps for the largest island landmasses) is the maintenance and extension of landscape connectivity to facilitate species moving to track suitable climate. In fact, in many cases islands maintain their qualities because they lack connectivity. Their isolation is both their major vulnerability and their source of distinctiveness.

Intensive species management

The next level up in intensity of management is to adopt approaches that aid target species rather than the habitats in which they live. This includes many of the standard management practices applied to islands and practices that might equally be grouped with habitat enhancement, such as predator control. The difference is one of degree: some invasive species control programs assume benefits to a range of species in the ecosystem, while others closely target invasive species known to have a deleterious effect on target native species.

This category of interventions also includes some approaches such as assisted colonisation, which has been used in conservation since the 19th century. However, this approach is now being used to avoid species going extinct because they are unable to disperse sufficiently to keep up with changing climates. While the introduction of novel species to an island ecosystem is often bad for species established there naturally, shifts in climate will mean that islands are sometimes the only place where the environment is likely to remain suitable. For example, the current distribution of the rufous scrub-bird (*Atrichornis rufescens*) is in north-east New South Wales and south-east Queensland, where the climate is thought likely to become unsuitable for this species over the next 50 years, but parts of Tasmania may develop a suitable climate (Garnett *et al*. 2014). A key element of any such intervention will not only be the standard risk assessments that are undertaken for translocations but policy changes that allow movements of taxa between states (Burbidge *et al*. 2011) and surveys of social acceptability (Garnett *et al*. 2017).

More subtle is the potential use of genetic enhancement to improve the capacity of species to adapt to climate change. The increasing sophistication of genetic analysis is allowing identification of genes that enable species to cope with increased temperatures (Grover *et al*. 2013) or drought (Deikman *et al*. 2012). It may also allow the introduction of such genes into vulnerable native populations in the same way as they are being engineered into commercial crops. Less targeted genetic enhancement is already being proposed for some small populations, such as those of the helmeted honeyeater (*Lichenostomus melanops cassidix*) (Harrisson *et al*. 2016), because levels of inbreeding are so high. New CRISPR-9 and gene drive technologies are allowing far more targeted interventions for gene fragments of increasing length. They create opportunities not only to introduce favourable genes to stressed populations but also to enhance invasive species control – although not without controversy (Webber *et al*. 2015; Corlett 2017).

Preserving populations

Ultimately some species may become so scarce and the probabilities of survival in the wild so low that their only chance will be to remove some individuals out of the wild population until conditions have ameliorated. *Ex situ* conservation can occur in two ways – through maintaining and breeding adult organisms and through the preservation of tissue or seeds.

For threatened plants, the contribution of *ex situ* collections of live plants to conservation is so well established (Knapp *et al*. 2014) that, by 2020, the Global Strategy for Plant Conservation (Convention on Biological Diversity 2011) aspires to have 'at least 75 per cent of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes'. In relation to animals, the strategy is less accepted. While careful breeding using stud books to maximise retention of genetic variability can work for short periods, long-term consequences can be substantial because the process of captivity inevitably leads to selection of individuals that thrive under such circumstances, rather than under wild conditions (Tschirren *et al*. 2009). This potentially compromises return to the wild, should circumstances ever allow (Araki *et al*. 2007).

Plants also lead the way in cryopreservation, both for tissue (Popova *et al*. 2015) and seed storage (Fu *et al*. 2015). The role of this form of *ex situ* conservation for animals is still being debated but the steady advances in techniques suggest that such approaches may soon become reliable tools for genetic conservation (Mandawala *et al*. 2016).

Supporting tools

There are data and tools available to help guide selection and prioritisation of management actions for species conservation under climate change. For example, models can help predict the location of future suitable climate for species, and these are available online (http://climas.hpc.jcu.edu.au/ for Australian birds, Garnett *et al*. 2014) and for other vertebrates (Reside *et al*. 2013). Tools are available to use these climate predictions for species, to prioritise areas to be the focus of conservation action (Ball *et al*. 2009; Moilanen *et al*. 2014) and to prioritise the actions themselves (Pouzols and Moilanen 2013), bringing in priorities for species currently and in the future. Importantly, these tools can help quantify uncertainty surrounding the climate predictions, such as unknown severity of climate change, species' ability to disperse to new habitats and the population responses. Furthermore, the tools can assist with examining the trade-offs between different actions, or acting in different areas or at different times, and help to identify synergies between proposed actions. More data are clearly needed, as many Australian islands have not been extensively surveyed or monitored for plants or invertebrates (Chapter 3). However, the existing data and tools provide a good starting point that may reflect the broader changes across the island ecosystems.

Australian adaptations

Using birds as a basis (as an adaptation plan has been developed for all Australian birds including seabirds; Garnett *et al*. 2014), two approaches illustrate the range of options for managing climate change on islands. One is to describe the actions recommended to help Australia's most vulnerable taxa (Box 15.1). The other is to describe what might be done for a set of exemplar islands.

Case study islands

Houtman Abrolhos

This set of low-lying islands off the Western Australian coast supports large populations of seabirds, including the only population of the Australian lesser noddy (*Anous tenuirostris melanops*). There are also distinctive populations of landbirds including a subspecies of painted buttonquail (*Turnix varius scintillans*) that is among the taxa most likely to go extinct in the next 20 years (H. Geyle, *pers. comm*.) because of habitat degradation by introduced wallabies. While sea-level rise is unlikely to be a problem over the next 50 years (Zhu *et al*. 1993), shifts in the Leeuwin Current may affect both the availability of food in surrounding waters (Surman and Nicholson 2009) and the climatic suitability of the islands for the distinctive landbirds. Apart from more frequent monitoring, options for adaptation include supplementary feeding of the buttonquail, eradicating introduced wallabies and the establishment of new colonies of the lesser noddy on islands further south.

Norfolk Island

The climate of Norfolk Island is expected to be hotter, potentially with longer droughts (Director of National Parks 2011). Drought may reduce food availability for the distinctive suite of landbirds that persist in the small national park that is all that remains of the forest that once covered the island. Among the birds most threatened by climate change are the local subspecies of boobook (*Ninox novaeseelandiae undulata*), which was once reduced to a single female (Garnett *et al*. 2011). Hot dry weather could also increase the risk of fire, especially from a grove of eucalypts planted beside the native forest, which could destroy owl nesting habitat. Adaptation options include assisted colonisation of Lord Howe Island, where a closely related subspecies of the owl was extirpated in the 1930s, and replacement of the eucalypt plantation with local rainforest species. The island group also supports several seabird species which forage in seas expected to decline substantially in productivity (Steinacher *et al*. 2010). Options include tracking of foraging individuals to identify feeding sites, which may vary in location both within and between years, to identify areas that may require conservation action such as regulating fishing or provision of supplementary feeding.

Kangaroo Island

Models predict that Kangaroo Island will become drier, resulting in a climate unlike that which currently occurs there. This may make it difficult for a suite of endemic bird subspecies to persist. There is the option of establishing a costly captive population in perpetuity, which would be difficult for the endangered glossy black-cockatoo (*Calyptorhynchus lathami halmaturinus*), of which there are only a few hundred left (Crowley *et al*. 1996). Rather, for this and other island subspecies, genetic supplementation may be appropriate, importing genes from mainland populations that live in climates more closely resembling that predicted to occur on Kangaroo Island. Alternatively, cockatoos could be re-established on the mainland, where they used to occur in the 19th century. Reintroduced populations could be supported by irrigating and fertilising food trees to increase food availability, and refugia for the cockatoos could be identified through modelling and provided with special protection.

Tiwi Islands

The Tiwi Islands have a wetter climate than most of the adjacent mainland and contain distinctive fauna that includes endemic subspecies of masked owl (*Tyto novaehollandiae melvillensis*) and yellow-tinted honeyeater (*Ptilotula flavescens melvillensis*). Models predict a drying of the climate, so that the best future climate space for the Tiwi Islands taxa is Cape York Peninsula. However, long before monitoring reveals any climate-related decline, there is time to create detailed models from which refugia can be identified. These could then be the focus of management by the Tiwi natural resource management group, minimising threats and maximising the birds' productivity. The other alternatives are genetic supplementation, as on Kangaroo Island, or captive breeding.

Tasmania

Tasmania will be subject to less extreme warming than other parts of the country; therefore, one of the issues it will face is whether to receive biodiversity refugees from places further north that are likely to become too hot and dry. Such decisions are more political and ethical than technical, requiring a social licence if they are to be successful: initial research suggests that most Tasmanians are willing to entertain the idea (Garnett *et al*. 2017), even if they blanch closer to the event. However, there are technical questions on the potential for overstocking of refugia, some of which have already been identified for plants (Keppel *et al*. 2015). For instance, Tasmania may contain the last areas with habitat suitable for both species of scrub-bird – the noisy scrub-bird (*Atrichornis clamosus*) from south-western Australia and the rufous scrub-bird (*A. rufescens*) inland from Brisbane. One of the first stages of planning must therefore be some form of prioritisation. The other distinctive climate adaptation strategy for a Tasmanian bird is for the orange-bellied parrot (*Neophema chrysogaster*), a species that feeds largely in coastal salt marshes during the non-breeding season, including in northern and western Tasmania. Such areas will become inundated as the sea level rises. One potential adaptation response is to purchase land that is unlikely to be inundated when the seas rise and can act as a land bank for the parrots in the future.

King Island

Once covered in forest, the remnants of native vegetation support two bird taxa from the top five most likely to go extinct in the next 20 years (H. Gelye, *pers. comm.*) – the King Island subspecies of brown thornbill (*Acanthiza pusilla archibaldi*) and King Island scrubtit (*Acanthornis magnus greenianus*). As with the orange-bellied parrot, both need active management regardless of climate change. In fact, they are typical of many island species – in need of active conservation management to counter a whole suite of non-climate-related threats so that when climate change does start to become a more prominent driver of ecological processes, the King Island taxa have as much genetic diversity as possible on which natural selection can act.

Concluding comments

Climate change is one of many threats that conservation managers of islands need to incorporate into all their plans. The evolutionary history of the climates through which species have survived gives hope that they may cope with climate change again. Many, however, will need help. This can range from more passive habitat protection and improvement, though active interventions of the sort familiar to most island managers such as invasive animal and plant eradication or control. For a small number of taxa, *ex situ* conservation will be the most appropriate strategy, but that is likely to be some time coming. The most important message from this chapter, therefore, is that climate change is one of the more manageable environmental challenges that managers are likely to encounter in their working lives.

Fortunately, for Australian islands the dangers of climate change are far less than elsewhere because their human population are small, and probably diminishing as part of an ongoing process of urbanisation. Indeed, the danger in some areas is not that there are too many people but that there are too few with the skills and interest to undertake the necessary conservation management. Probably the single most important thing managers can do is to monitor what they have now so they have timely evidence of change as it occurs, which can act as triggers to put long-established contingency plans into play when needed.

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