Adapting to a changing climate

A proposed framework for the conservation of terrestrial native biodiversity in New Zealand

J.E. Christie

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Department of Conservation
Te Papa Atawhai

Cover: South Westland tussock landscape on an unnamed ridge of Mt Adams. *Photo: DOC*.

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J.E. Christie

Department of Conservation, PO Box 11089, Christchurch 8443, New Zealand
Email: jchristie@doc.govt.nz

Abstract

New Zealand's terrestrial biodiversity will come under increasing pressure as a result of global climate change. Furthermore, climate change will likely exacerbate other existing threats, such as pests and human disturbance. This report describes a framework that will guide how the Department of Conservation (DOC) manages the impacts of climate change on terrestrial native biodiversity in New Zealand. This framework comprises five broad strategies: improve knowledge; develop adaptation methods and decision-support tools; incorporate climate change adaptation into existing management, research, planning and policy; improve current management to facilitate native resilience; and raise awareness outside DOC. Within these strategies, a total of 14 actions, covering a range of conservation practices, have been identified.

Keywords: climate change, terrestrial biodiversity, freshwater biodiversity, impacts, threats, conservation management, adaptation

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1. Introduction

New Zealand's terrestrial biodiversity will come under increasing pressure as a result of global climate change, which will have both direct and indirect impacts. Indirect impacts will occur through the exacerbation of existing biological and human threats, with the latter arising as a result of activities undertaken to mitigate or adapt to climate change by other land management sectors (e.g. Glova 1990; Hay 1990; Hollinger 1990; Keys 1990; McFadgen 1999; McGlone 2001; Green 2006; Arand 2007; McGlone et al. 2010). Therefore, there is a need to identify practical management strategies that will mitigate the anticipated negative effects of climate change on biodiversity (Mawdsley et al. 2009).

Worldwide, countries are investigating how climate change will affect their terrestrial biodiversity, and developing strategies for adapting to climate change that are tailored to their specific needs and statutory requirements (e.g. Pickering et al. 2004; Hobday et al. 2006; Hilbert et al. 2007; Hopkins et al. 2007; NSW Inter-agency Biodiversity and Climate Change Impacts and Adaptation Working Group 2007a, b; CCSP 2008; Dunlop & Brown 2008; Lemmen et al. 2008). Amongst other things, these strategies aim to maintain and enhance ecosystem resilience, and to conserve biodiversity and ecosystem services.

As a signatory to a number of international agreements (e.g. the Convention on Biological Diversity, the Ramsar Convention and the Convention on Migratory Species), New Zealand is obliged to make efforts to preserve its biodiversity against all threats. As the lead agency for biodiversity management in New Zealand, the Department of Conservation (DOC) is responsible for both facilitating and managing the response to climate change impacts on biodiversity in this country. Furthermore, anticipating the effects of climate change will create opportunities to manage impacts before they become critical and make effective management difficult, costly or impossible.

1.1 Report objectives and scope

The main aim of this report is to provide guidance to DOC for managing the impacts of climate change on New Zealand's terrestrial native biodiversity. This report presents a framework that has been developed for that purpose. The framework focusses on the effects of climate change on terrestrial native biodiversity, which includes land-based, or predominantly land-based, native species, ecosystems and natural processes. This is consistent with conservation management's focus on the negative impacts on native biodiversity. This framework also identifies positive benefits to native biodiversity from climate change. An up-to-date review of the likely and possible impacts of projected climate change on terrestrial biodiversity in New Zealand (McGlone & Walker 2011) has provided the basis for this framework.

The report does not address the impacts of climate change on marine ecosystems, historic heritage, recreational assets or other ecosystem services, and nor does it identify trade-offs between reducing carbon emissions and optimising biodiversity, as these have either already been, or will be, assessed separately (e.g. Walton 2007; Willis et al. 2007).

2. Background

2.1 Climate change in New Zealand

2.1.1 Current changes

New Zealand has already experienced detectable changes in climate since the start of the 20th century, including temperature increases, warmer winters, decreased frost frequency, decreased snowfall, retreating snowlines, retreat of South Island glaciers and a rising sea level (Salinger & Griffiths 2001; Mullan et al. 2008). Furthermore, over the last 40 years, westerly circulation has increased and rainfall patterns have changed, decreasing in the north of the North Island and eastern South Island, but increasing in most other regions. These trends are outlined in detail in Salinger & Griffiths (2001).

2.1.2 Predicted future changes

Climate change predictions for New Zealand indicate that temperatures will be warmer (especially in winter and in the north), it will be windier and there will be more extreme weather events. The Fourth Assessment Report from the Intergovernmental Panel on Climate Change (Parry et al. 2007) predicted that global temperatures will increase by between 1.8°C (range = 1.1–2.9°C) and 4.0°C (range = 2.4–6.4°C) by 2090–2099 (compared with 1980–1999). Temperature changes in New Zealand, however, are expected to be less, as a result of the delayed warming of the surrounding oceans (Mullan et al. 2008). Precipitation is predicted to vary on a regional and seasonal basis in response to east–west and north–south gradients (Mullan et al. 2008). For example, the south and west are expected to have more rainfall, particularly in winter and spring, which would bring more rain to the west of both islands and to the south of the South Island. Conversely, the north and east are predicted to receive less rainfall, and be particularly dry in summer and autumn; thus, there would be less rain in the north and east of the North Island, and in coastal Canterbury and coastal Marlborough in the South Island. Climate change is also predicted to exacerbate both inter-annual and inter-decadal variations in temperature and precipitation caused by the El Niño Southern Oscillation cycle (ENSO) and the Inter-decadal Pacific Oscillation (IPO), respectively. Both of these are natural cycles that drive major regular shifts in Pacific atmospheric and oceanic circulation. Specific predicted changes to New Zealand's climate are outlined in Table 1.

2.2 Response of terrestrial biodiversity to climate change

An increasing number of changes to native terrestrial biodiversity in New Zealand have been attributed to climate change (e.g. Arand 2007; McGlone & Walker 2011). These include population declines in seabirds, such as red-billed gulls (*Larus novaehollandiae scopulinus*; Mills et al. 2008), yellow-eyed penguins (*Megadyptes antipodes*; Peacock et al. 2000) and sooty shearwaters (*Puffinus griseus*; Scott et al. 2008); earlier egg laying by some bird species, such as welcome swallows (*Hiroundo tahitica*; Evans et al. 2003); changes in tuatara sex ratios to increasingly male (Mitchell et al. 2008); and establishment of invasive pests in new habitats, such as rabbits (*Oryctolagus cuniculus*) being found above the treeline on Mt Ruapehu (Flux 2001). Changes in the quality of natural ecosystem services (such as water quality and supply, soil stability, flood protection, carbon storage, and coastal protection (McAlpine & Wotton 2009)) can also likely be attributed to climate change. However, unlike in the Northern Hemisphere, few of these changes have yet to be proven with scientific confidence (McGlone & Walker 2011). This is partly due to a lack of sufficient long-term data, but also because New Zealand's fluctuating oceanographic climate makes it difficult to find a relationship between climate and species, and has likely led to species developing a level of resilience to fluctuating weather. Furthermore, the distributions

Table 1. Mid-range projections for climate change variables relative to 1980–1999 averages for New Zealand (summarised from Mullan et al. 2008). '–' = estimate not available or substantial variation on a regional basis.

CLIMATE VARIABLE	DIRECTION AND DESCRIPTION OF CHANGE	ESTIMATED LEVELS	
		2040s	2090s
Average ambient temperature	Increase—greater in winter and in the north	0.9°C	2.1°C
Temperature extremes	Decrease in frost intensity and frequency, but increase in the risk of high temperatures	–	–
Average rainfall	Varies according to location and season—tends to increase in the south and west in winter and spring	5% (west)	10% (west) 5% (east & north)
Rainfall extremes	Increase in frequency of extreme daily rainfalls and drought; extension of droughts into spring and autumn, rather than only summer	–	–
Westerly wind	Increase in average westerly winds, especially in winter and spring; also increase in severe wind risk	10%	>50% (winter) 20% (spring) 20% (summer & autumn)
Snowfall	Decrease in snowfall, rise in snowline and shortening of the snow season	–	–
Glaciation	Reduction in glacier volume and length	–	–
Sea level	Increase in sea level	–	18–59 cm*
Storm surges and waves	Increase in frequency of heavy swells and storm surges, especially in regions exposed to prevailing westerlies	–	–
Ocean temperature and currents	Changes possible but little research or modelling to date	–	–

* A further 10–20 cm rise above current levels is predicted if Greenland and Antarctica melt rates increase linearly.

of many native species are restricted by invasive pests and habitat loss rather than climate. However, with rapid warming (+1°C by AD 2040) and decreased rainfall in eastern regions being predicted for the future (Mullan et al. 2008), a more obvious response to climate change from biodiversity seems likely in the long term (McGlone & Walker 2011).

Predicting the direct responses of terrestrial biodiversity in New Zealand to future climate changes will be challenging. In the Northern Hemisphere, biodiversity experiences changes in phenology, interactions across trophic levels, local abundance and range shifts, and increased species extinctions in response to climate change (Parmesan 2006). However, in New Zealand there is more uncertainty surrounding climate predictions, species' responses to climate change and the ability of species to adapt (McGlone et al. 2010), especially given the existing pressures of invasive species and human-related habitat loss on native biodiversity. While some long-term climate trends can be predicted with reasonable confidence (e.g. average temperature, rainfall), others (such as extreme events) will be much more difficult to predict (Mullan et al. 2008). There is also a lack of systematic long-term biodiversity records for New Zealand, and only a limited understanding of the factors (including climate) that drive species distribution and abundance. The capacity of native species and ecosystems to adapt to a changing climate is unknown, especially given New Zealand's oceanic setting and existing highly variable climate regime (McGlone et al. 2010), and the response and resilience of native biodiversity to climate change is complicated by other pressures, such as invasive species and human-related habitat loss. This has resulted in many native species and ecosystems occupying relictual distributions that have little relationship to climatic optimums. As a result, opinion is divided over both the extent and types of impacts that New Zealand terrestrial biodiversity will experience, with some researchers predicting major losses of biodiversity (e.g. Halloy & Mark 2003) but others suggesting few potential impacts, at least in the short term (McGlone et al. 2010). Nevertheless, any changes to biodiversity that do occur are likely to follow the same patterns observed in the Northern Hemisphere.

In contrast, the indirect responses of terrestrial biodiversity to climate change can be predicted with more certainty. Indirect impacts involve the exacerbation of existing invasive species problems and human-related threats, such as habitat loss. Invasive species problems will likely get worse, as many invasive species (e.g. hedgehogs (*Erinaceus europaeus occidentalis*; Jones & Sanders 2005), ship rats (*Rattus rattus*; Studholme 2000) and wasps (*Vespula vulgaris*; Barlow et al. 2002)) are either known to be or are suspected of being climate restricted. Human-related threats will also be exacerbated by other land use sectors changing their land management practices in anticipation of climate change, which will result in further restrictions of native species abundance and distribution.

The impacts of climate change on native biodiversity can be divided into three different types: direct, indirect biological (i.e. invasives) and indirect human. These differ in terms of their immediacy and size (Fig. 1). In terms of immediacy, exacerbation of human threats will likely cause the greatest damage to biodiversity over short to intermediate timeframes (McGlone & Walker 2011), with exacerbation of existing biological threats, such as pests and weeds, being felt over the medium term. Direct impacts of climate change on biodiversity will most likely occur over the long term. These three impact types are covered in more detail below.

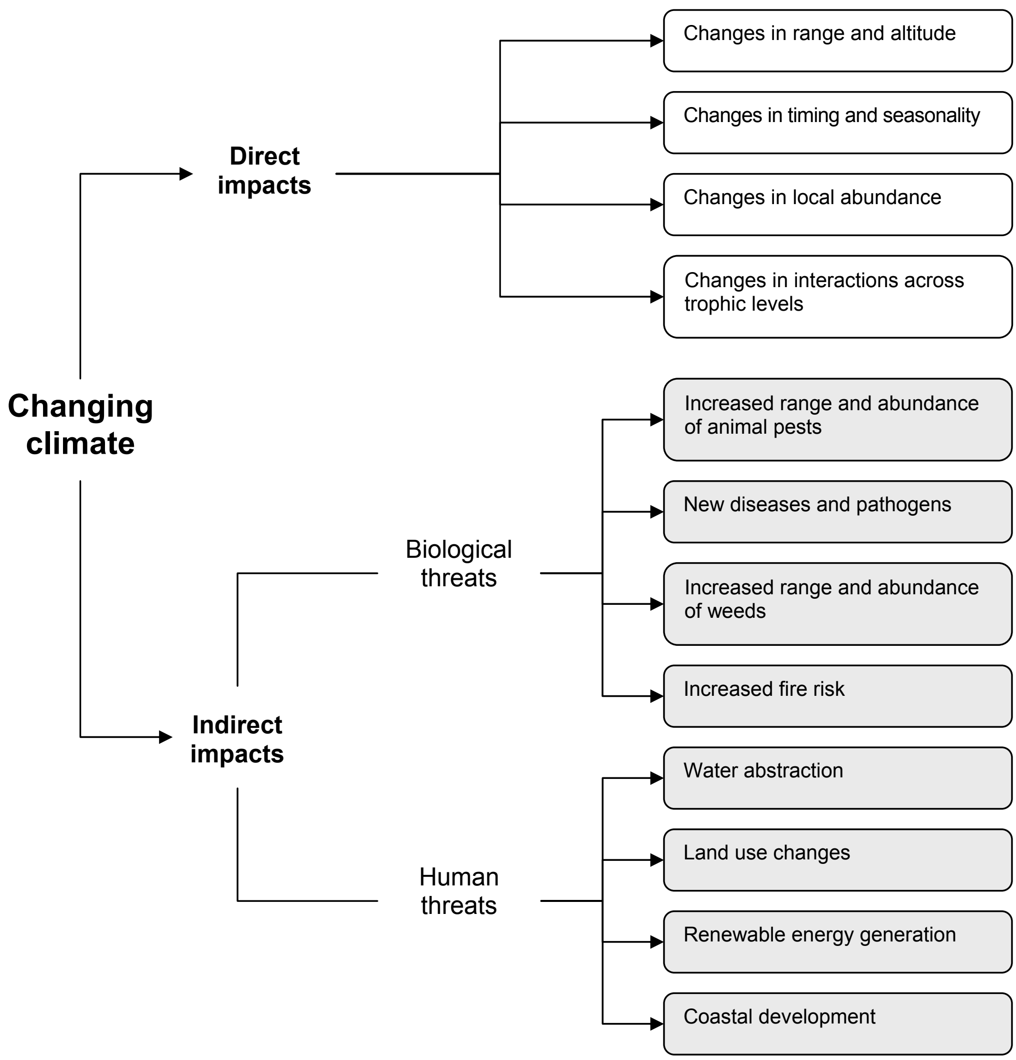


Figure 1. Examples of both new (white) and existing (light grey) threats, and their relationship to direct and indirect impacts caused by a changing climate.

2.2.1 Direct impacts of climate change on native biodiversity

Species distributions are predicted to shift southwards in latitude and upwards in altitude in response to climate change (Parmesan 2006; McGlone & Walker 2011). For example, researchers predict that native tree lines will increase in altitude, with a subsequent loss of alpine species (Wardle & Coleman 1992; Halloy & Mark 2003), although debate exists about whether beech (*Nothofagus* spp.) tree lines will shift (Cullen et al. 2001). Changes in the timing of both annual and seasonal events are also expected (Parmesan 2006; McGlone & Walker 2011), including changes in the frequency of annual plant mast cycles for species such as beech and tall tussock (*Chionochloa* spp.) (McKone et al. 1998; Richardson et al. 2005). Changes in the timing of life-cycle events are predicted, with plant flowering and fruiting expected to occur earlier, and the possibility of the seasonal cycles of interdependent species becoming unsynchronised (Parmesan 2006). Changes in species abundance may also occur, especially where breeding success is directly linked to weather or ocean currents, e.g. red-billed gulls and rockhopper penguins (*Eudyptes chrysocome*) (Cunningham & Moors 1994; Hilton et al. 2006; Mills et al. 2008). Loss of suitable nesting habitat, and subsequent reduction in breeding success, may occur for some ground-nesting bird species; for example, nest sites of the shore plover (*Thinornis novaesellandiae*) are likely to be vulnerable to sea-level rise and storm surges (Davis 1994); and the predicted spring increase in flood frequency in the eastern South Island (Mullan et al. 2008) could result in recruitment failure for wrybills (*Anarhynchus frontalis*)—for which one of the major causes of nest failure on braided river beds is spring floods (Dowding & Murphy 2001; Sanders & Maloney 2002)—as well as other braided river species (McGlone & Walker 2011).

2.2.2 Indirect impacts of climate change on biological threats

Climate change is likely to exacerbate a number of the existing biological threats to biodiversity in New Zealand. Predator irruptions in beech forests may increase in frequency (Hay 1990; McGlone 2001; Green 2006) in response to an increase in temperature-driven mast seed fall events (McKone et al. 1998; Richardson et al. 2005). Populations of species such as ship rats and stoats (*Mustela erminea*), which are major predators of many native animal species (Innes 2005; King & Murphy 2005), may steeply increase. Furthermore, if the distribution of ship rats is temperature limited (Studholme 2000), this species may become increasingly widespread through beech forest and alpine ecosystems as a result of warmer temperatures. Likewise, exotic pest plant species, such as wilding pines (*Pinus contorta*) and heather (*Calluna vulgaris*) (Arand 2007), are also expected to shift their distribution upwards in altitude in response to warming temperatures. The incidence, intensity and extent of fire are also likely to increase as a result of warmer temperatures and decreased rainfall, especially in dry eastern areas, which would favour fire-tolerant weed species (Hollinger 1990) over natives.

2.2.3 Indirect impacts of climate change on human threats

A good example of how climate change adaptation and mitigation actions taken by various land management sectors (e.g. agriculture, forestry) could exacerbate the human threat to terrestrial biodiversity and ecosystem services relates to increases in exotic afforestation. Increased tree planting for the purposes of storing carbon has the potential to compromise biodiversity by displacing native vegetation, providing weed sources, changing patterns of water availability, and increasing fire incidence and intensity. Furthermore, schemes aimed at reducing carbon emissions, such as the development of renewable power generation (i.e. hydro, geothermal and wind) (Renwick et al. 2010) and bio-fuel production, may also impact on biodiversity and ecosystem services. Increased irrigation of farmland in response to decreased rainfall and increased temperatures in dry eastern areas (Dynes et al. 2010; Kenny 2010) will also likely result in further drying of wetlands, streams and rivers, and will increase saltwater intrusion in coastal areas that are already impacted by sea-level rise.

3. Proposed framework for adaptation to climate change

Much has been written about climate change adaptation strategies in both the scientific literature and public policy documents (e.g. Pickering et al. 2004; Hobday et al. 2006; Hilbert et al. 2007; Hopkins et al. 2007; NSW Inter-agency Biodiversity and Climate Change Impacts and Adaptation Working Group 2007a, b; CCSP 2008; Dunlop & Brown 2008; Lemmen et al. 2008). Many of these are high-level national strategies and thus are, by necessity, broad and general. Mawdsley et al. (2009) recently compiled a comprehensive review of national adaptation strategies from countries around the world (summarised in Table 2), in which they found that no single document provided a comprehensive set of strategies. The variety likely reflects the variation in both biodiversity and management requirements between countries.

The climate change adaptation framework, which aims to protect New Zealand biodiversity from the impacts of climate change, is presented below. It is based on approaches used in adaptive management frameworks from countries such as Australia (Hilbert et al. 2007) and the United Kingdom (Hopkins et al. 2007), but is adapted for New Zealand's biodiversity requirements and conservation management context. Adaptation recommendations from two recent reviews of the impacts of climate change on biodiversity in New Zealand (McGlone et al. 2010; McGlone & Walker 2011) have also been taken into account. Amongst other things, these reviews recommended that the best management responses to climate change are to maintain and strengthen current efforts to protect biodiversity, increase monitoring of vulnerable ecosystems, and increase surveillance of pests and weeds at greatest chance of spreading.

Table 2. Summary of climate change adaptation strategies for wildlife management and biodiversity conservation (from Mawdsley et al. 2009).

BROAD CATEGORY	ADAPTATION STRATEGY
Land and water protection and management	• Increase extent of protected areas • Improve representation and replication within protected area networks • Improve management and restoration of existing protected areas to facilitate resilience • Design new natural areas and restoration sites to maximise resilience • Protect movement corridors, stepping stones and refugia • Manage and restore ecosystem function rather than focussing on specific components (i.e. species or assemblages) • Improve environmental conditions by increasing the ability of landscapes to accommodate species' movements
Direct species management	• Focus conservation resources on species that might become extinct • Translocate species at risk of extinction • Establish captive populations of species that would otherwise go extinct • Reduce pressures on species from sources other than climate change
Monitoring and planning	• Evaluate and enhance monitoring programmes for wildlife and ecosystems • Incorporate predicted climate change impacts into species and land management plans, programmes and activities • Develop dynamic landscape conservation plans • Ensure wildlife and biodiversity needs are considered as part of the broader societal adaptation process
Law and policy	• Review and modify existing laws, regulations and policies regarding wildlife and natural resource management

The framework comprises five broad strategies, each entailing two or more specific actions, providing a total of 14 actions. These strategies and actions are aimed at a national level and cover a comprehensive range of conservation practices (Table 3). Once implemented, the framework will likely affect all native biodiversity work undertaken by DOC, as climate is all encompassing.

Some of the strategies and actions appear to overlap. However, these apparent overlaps are generally the result of dependencies between those particular actions and strategies. The relationships between strategies are outlined in a conceptual diagram, which shows their urgency ratings and indicates where the ownership of the strategy is located within DOC (Fig. 2A). A similar, but more detailed, diagram is provided for the actions (Fig. 2B).

A brief description of each strategy is provided in the following section, which follows the methodology used by Hunt (2007). The actions relevant to each particular strategy are listed, with tasks that need to be undertaken in order to solve the issue listed underneath. For each

Table 3. Summary of the national adaptation framework for protecting native biodiversity in New Zealand from the impacts of climate change.

STRATEGIES	ACTIONS
1. Improve knowledge of the impacts of climate change on species and ecosystems	1.1 Develop and implement a programme of climate change biodiversity research and monitoring that utilises links and/or identifies synergies with other related projects
	1.2 Identify: (a) Species and ecosystems, ecosystem processes and services that are: • Most vulnerable to climate change • Suitable indicators sensitive to climate change (b) Climate change-induced changes in invasive pests and land use
	1.3 Identify key information requirements necessary for refining impact scenarios, developing practical adaptation responses and designing a monitoring programme to measure success
2 Develop decision-support tool and adaptation methods	2.1 Inform existing or develop new decision-support tools for prioritising management of climate change impacts
	2.2 Identify conservation management techniques that can be adapted for use as practical adaptation methods
	2.3 Develop decision-support tools for selecting the appropriate practical adaptation technique
	2.4 Identify planning and policy measures that increase biodiversity resilience to the impacts of climate change
3. Incorporate climate change adaptation strategies into existing management and research programmes, planning and policy	3.1 Provide decision-support tools, practical adaptation methods, and planning and policy measures to managers, planners and policy makers
	3.2 Integrate climate change priorities into existing monitoring, research and management programmes, planning and policy
4. Improve management and restoration of existing species and ecosystems to facilitate resilience to climate change	4.1 Focus management and monitoring effort on species and ecosystems that are most vulnerable to the direct and indirect impacts of climate change
	4.2 Design and implement operational projects that aim to improve: • Ecosystem representation and replication within the protected areas network • Species and ecosystem resilience • Ecosystem services
5. Raise awareness and understanding of the impacts of climate change on biodiversity	5.1 Engage the support of DOC staff for measures of biodiversity adaptation to climate change
	5.2 Engage the support of key external stakeholders for measures of biodiversity adaptation to climate change
	5.3 Increase public awareness and understanding of the impacts of climate change on native biodiversity

action, the relevant DOC organisational level is identified and at least one example given. The status, urgency and level of each task are also identified and are summarised as follows:

- **Status:**
  - ○ Completed
  - ○ Underway
  - ○ Underway and ongoing
  - ○ Not yet started
- **Urgency:**
  - A. Short term (1–2 years)
  - B. Short–medium term (2–3 years)
  - C. Medium term (3–5 years)
  - D. Medium–long term (5–10 years)
  - E. Long term (> 10 years)
- **Dependency:**
  1. No prerequisite required
  2. Prerequisite required, but can do without (but will be sub-optimal)
  3. Prerequisite required

Strategy 1—Improve knowledge and understanding

There is a need for better knowledge of the responses of species and ecosystems to past and current climate change. Increasing that knowledge requires three elements: identification of key information requirements, identification of biodiversity that is most vulnerable to climate change, and development of a programme of climate change biodiversity research and monitoring.

1.1 Carry out research and monitoring to better understand the impacts of climate change on native biodiversity and to measure the success of adaptation techniques.

ACTION 1.1: Science and Capability Group, DOC			
Develop and implement a programme of climate change biodiversity research and monitoring that utilises links and/or identifies synergies with other related projects	E.g. direct, indirect and adaptation impacts of climate change on native biodiversity	Not yet started	A1

1.2 Identify which native species, ecosystems, ecosystem processes and services are likely to be most vulnerable to climate change and to climate change-induced changes in invasive pests and land use.

ACTION 1.2: Science and Capability Group, DOC; Landcare Research			
a. Identify species and ecosystems, ecosystem processes and services that are:			
• Most vulnerable to climate change (tuatara), threatened ecosystems (dryland, freshwater, coastal)	E.g. highly specialised species	Underway and ongoing	A1
• Suitable indicators sensitive to climate change	E.g. species measures such as timing of breeding	Underway and ongoing	A1
b. Identify climate change-induced changes in invasive pests and land use	E.g. wider rat distribution in beech forest, increased numbers of rabbits indryland ecosystems, increased irrigation, increased Douglas fir (*Pseudotsuga menziesii*) plantations	Not yet started	A1

A

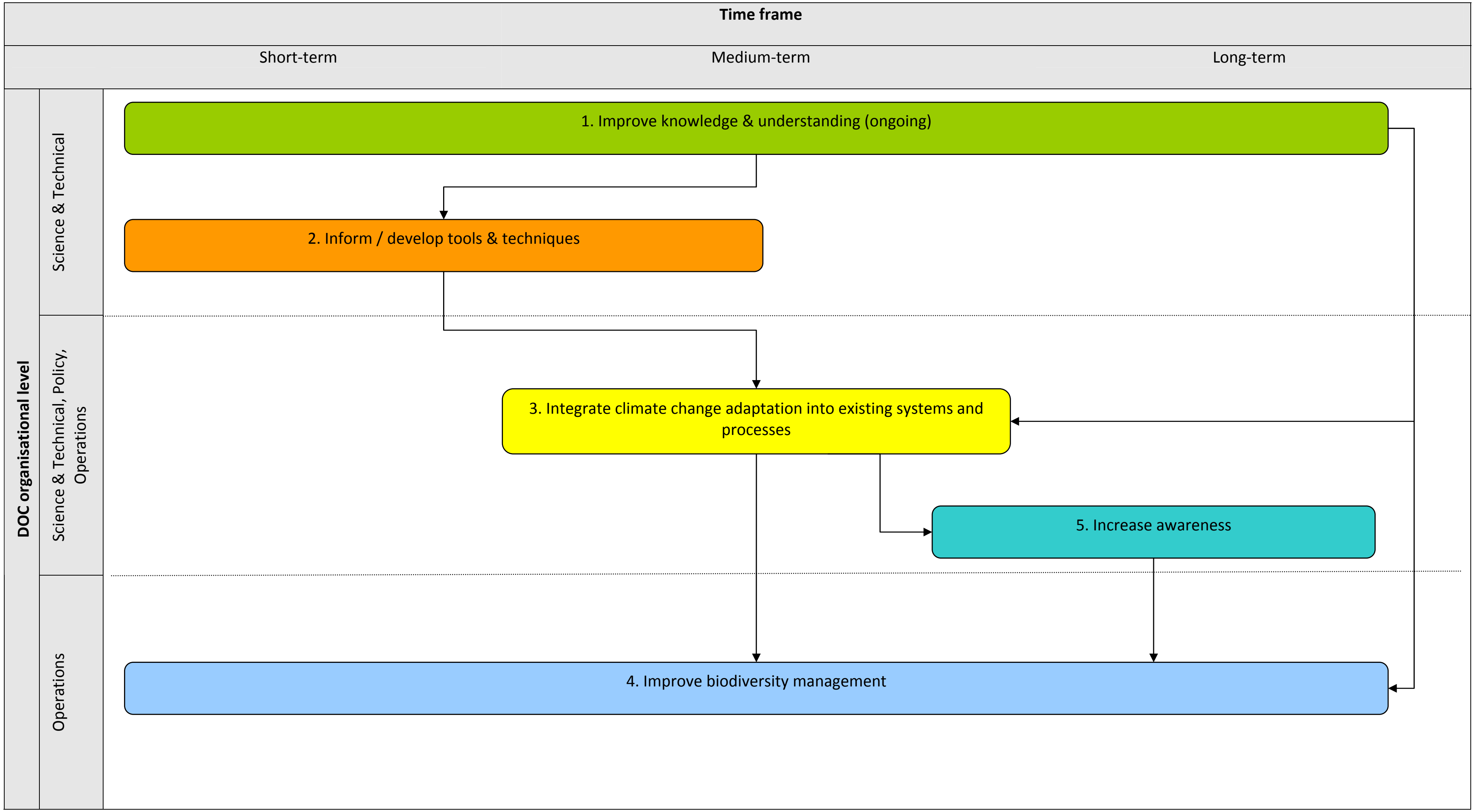
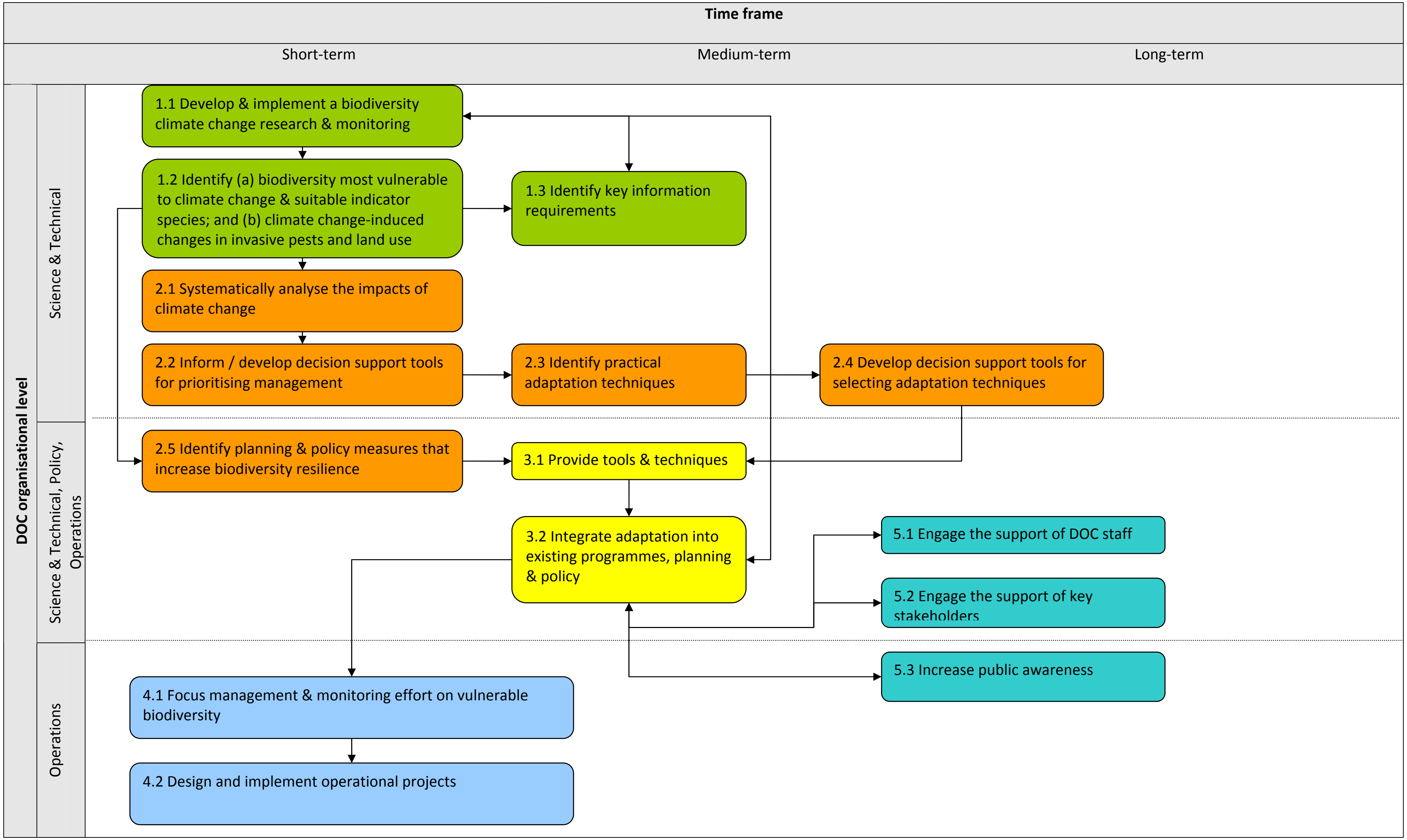


Figure 2. A conceptual diagram of the relationships between A. strategies and B. actions (next page) within the climate change framework, showing both the organisational level and estimated timeframe at which a particular strategy will occur. Actions and strategies are colour coded to match each other.

Figure 2—continued

B



1.3 Identify the gaps and limitations in our current understanding of the impacts of climate change on species, ecosystems and natural processes.

ACTION 1.3: Science and Capability Group, DOC			
Identify key information requirements necessary for refining impact scenarios, developing practical adaptation responses and designing a monitoringprogramme to measure success	E.g. periodicity of annual events such as mast seeding	Not yet started	B2

Strategy 2—Develop decision-support tools and adaptation techniques

Developing decision-support tools is vital for deciding which impacts are manageable and for assessing which impacts have a high priority. This style of approach should create opportunities to manage impacts before they become critical and make effective management difficult, costly or impossible. Furthermore, identification of practical adaptation techniques, as well as planning and policy measures, should enable the effects of some climate change impacts on native biodiversity to be managed and reduced.

2.1 Prioritise which climate change impacts on biodiversity are management priorities.

ACTION 2.1: Science and Capability Group, DOC			
Inform existing or develop new decision-support tools for prioritising management of climate change impacts	E.g. inform current species and ecosystems optimisation and/ or develop decision-support tools specific for climate change (Appendix 2)	Underway and ongoing	B2

2.2 Identify practical conservation management techniques that can be adjusted for climate change adaptation to protect native biodiversity.

ACTION 2.2: Science and Capability Group, DOC			
Identify conservation management techniques that can be adjusted for use as practical adaptation methods	E.g. native planting of riparian zones to increase shading of streams (decreases water temperatures and rates of evapotranspiration)	Not yet started	A2

2.3 Identify which practical adaptation techniques should be used to manage the impacts of climate change on biodiversity.

ACTION 2.3: Science and Capability Group, DOC			
Develop decision-support tools for selecting the appropriate practical adaptation technique	E.g. dichotomous key for selecting the appropriate operational management action (Appendix 3)	Not yet started	B2

2.4 Identify planning and policy measures that would increase native biodiversity resilience to the impacts of climate change.

ACTION 2.4: Science and Capability Group, Policy and Regulatory Services Group, DOC			
Identify planning and policy measures that increase biodiversity resilience to the impacts of climate change	E.g. water extraction rules, limits to locations of pine plantations, coastal development rules	Not yet started	A2

Strategy 3—Incorporate adaptation strategies into existing management

The need for the integration of climate change priorities into existing programmes, planning and policy is evident. Current conservation management plans (e.g. recovery plans, planning documents, standard operating procedures) and programmes fail to specifically address the impacts of climate change on biodiversity. The integration of climate change adaptation into DOC planning and management processes should both create efficiencies in terms of time and money, and provide a mechanism for implementing management strategies for adapting to climate change. This requires two elements: firstly, the transfer of decision-support tools, adaptation techniques and policy and planning measures to decision makers, conservation managers, researchers etc. is needed; and secondly, uptake of these tools and techniques into existing programmes, planning and policy documents by the aforementioned conservation managers, etc. must occur.

3.1 Transfer climate change adaptation tools and techniques to conservation managers and decision makers.

ACTION 3.1: Science and Capability Group, Policy and Regulatory Services Group, Conservation Services Group, DOC			
Provide decision-support tools, practical adaptation methods, and planning and policy measures to managers, planners and policy makers	E.g. Intranet site, national training workshops, internal presentations	Not yet started	C3

3.2 Integrate climate change adaptation tools and techniques into existing programmes, planning and policy.

ACTION 3.2: Science and Capability Group, Policy and Regulatory Services Group, Conservation Services Group, DOC			
Integrate climate change priorities into existing monitoring, research and management programmes, and planning and policy	E.g. Species and ecosystems optimisation, national monitoring and reporting systems, CMS* planning, recovery plans	Not yet started	C3

* Conservation management strategy.

Strategy 4—Improve management and restoration of existing biodiversity

Existing management of species and ecosystems needs to improve in order to enhance their resilience to the impacts of climate change. Climate change is just one of the many threats to be considered when managing biodiversity (see Fig. 1 and section 2.2 in particular for a discussion of these threats). Reducing pressure on native biodiversity from sources other than direct climate change may give some species and ecosystems the extra resilience they need to adapt to climate change.

4.1 Prioritise protecting the most vulnerable species and ecosystems from the impacts of climate change.

ACTION 4.1: Conservation Services Group, DOC			
Focus management and monitoring effort on species and ecosystems that are most vulnerable to the direct and indirect impacts of climate change	E.g. ephemeral freshwater fish species, coastal wetlands	Not yet started	D2

4.2 Identify what management is required to improve ecosystem representation and replication, biodiversity resilience, and ecosystem services.

ACTION 4.2: Conservation Services Group, DOC			
Design and implement operational projects that aim to improve: • Ecosystem representation and replication within the protected areas network • Species and ecosystem resilience • Ecosystem services	E.g. projects that decrease invasivespecies pressure (rats, wilding pines), minimise the impacts of climate change-induced land-use changes [need to identify key performance indicators]	Not yet started	D2

Strategy 5—Raise awareness and understanding

Increased public awareness and understanding of the impacts of climate change on native biodiversity are important, because DOC is unlikely to be able to respond to all the problems for biodiversity created by climate change. Therefore, raising awareness and providing information and support to other sectors and to the public should enable more 'across the board' management of climate change impacts on biodiversity.

5.1 Engage the support of DOC staff for implementing climate change adaptation measures.

ACTION 5.1: Science and Capability Group, Policy and Regulatory Services Group, Conservation Services Group, DOC			
Engage the support of DOC staff for measures of biodiversity adaptation to climate change	E.g. regular electronic newsletter, Intranet page, climate change email distribution list	Not yet started	B2

5.2 Engage the support of key stakeholders in the environment to protect native biodiversity from the impacts of climate change and climate change adaptation by other land-use sectors.

ACTION 5.2: Science and Capability Group, Policy and Regulatory Services Group, Conservation Services Group, DOC			
Engage the support of key external stakeholders for measures of biodiversity adaptation to climate change	E.g. Internet page, publications, key relationships	Not yet started	B2

5.3 Increase public awareness of the negative impacts of climate change on New Zealand's species and ecosystems.

ACTION 5.3: Science and Capability Group, Conservation Services Group, DOC			
Increase public awareness and understanding of the impacts of climate change on native biodiversity	E.g. Internet page, publications, displays at public events, summer visitor programmes	Not yet started	B2

4. Conclusions

The general conclusions and broad recommendations arising from research supporting the development of a framework for the conservation of terrestrial native biodiversity in New Zealand are as follows:

- Climate change is one of many threats to native biodiversity in New Zealand, but is different in that it is all-pervasive because it has both direct and indirect (through its impact on other existing human and biological threats) impacts on native biodiversity.
- DOC management actions pertaining to adaptation to climate change will mainly use current conservation management tools and techniques. However, some tools and techniques may need to be used more intensively, and some types and locations of certain practices may change.
- Application of this framework of climate change adaptation will mainly require the updating of relevant management systems that already exist, and the inclusion of its strategies and actions in some systems that are currently under development. This will help to ensure that the most cost-effective and appropriate response to climate change is achieved.
- Some new decision-support tools may need to be developed. Development of these tools would be best achieved under the ongoing natural heritage improvement work programme as part of tools and technologies. This would avoid unnecessary duplication of processes and ensure that synergies between similar systems are realised.
- The Department's work programme needs to explicitly include climate change as a threat, to ensure that climate change is assessed alongside other threats to species and ecosystems. Climate change needs to be included as a threat in the ecosystems and species prescriptions, so that it can be factored into operations through the DOC business planning process.
- The National Biodiversity Monitoring and Reporting System needs to explicitly include indicators for measuring the impacts of climate change on native biodiversity in its suite of indicators. This long-term monitoring will ensure that DOC is better able to assess the actual impacts of climate change on native biodiversity in order to better plan its response(s).
- Undertaking research on climate change impacts and adaptation in response to them is necessary to establish the links between climate, native species, pest species, ecosystems and ecosystem processes. This research should encompass both analysis of historic data and collection of new information. Collaboration with both internal and external research providers would be beneficial.
- Because of the likely long timeframe of climate change and the need for long-term monitoring and response planning, climate change research needs to continue to be included in DOC's long-term business planning for research and development.
- Planning and policy measures that increase biodiversity resilience to the impacts of climate change need to be identified, and should be built into both existing and future DOC policy decisions and directions.
- Raising awareness and providing information and support to other sectors, including the public, is needed to ensure that the best possible climate change adaptation measures can be undertaken.
- This framework needs to be reviewed and updated at regular intervals (i.e. every 3–5 years) to ensure that it stays relevant and continues to link into other DOC systems and processes.

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Appendix 1

Proposed systematic method of appraisal

Inventory of climate change impacts

The assembly of an inventory of the likely impacts of climate change on native biodiversity would involve reviewing literature that describes the response of native ecosystems and species to climate change. It is expected that the recent reviews by McGlone et al. (2010) and McGlone & Walker (2011), which summarise climate change impacts on native biodiversity, will inform the core of this inventory. Other sources would likely include peer-reviewed journals, unpublished reports, magazine articles, conference papers, websites, and literature from government and non-government organisations. Where literature is absent or unavailable, scientific experts should also be contacted for relevant information and opinions.

Structure of classification system

The production of a classification system would involve summarising and tabulating the climate change inventory into a spreadsheet format. Using an ecosystem-based approach, climate changes could be classified into ecosystem type (based on underlying vegetation community), region, climate drivers, natural and/or anthropogenic driver, climate change impact for management, and outcome for native biodiversity (Fig. A1.1). Within these groups, each climate change impact could also be classified into sub-categories. By nesting ecosystem types and species (outcome for native biodiversity), it would be possible to either break groups up for more specific analyses or aggregate groups for broader analyses. Ecosystem type classifications could be based on vegetation groupings sourced from spatially explicit databases, so that they can also be used to estimate the size of the area affected. Likewise, species distributions could be classified where possible using digitised species distribution maps (Table A1.1). However, the

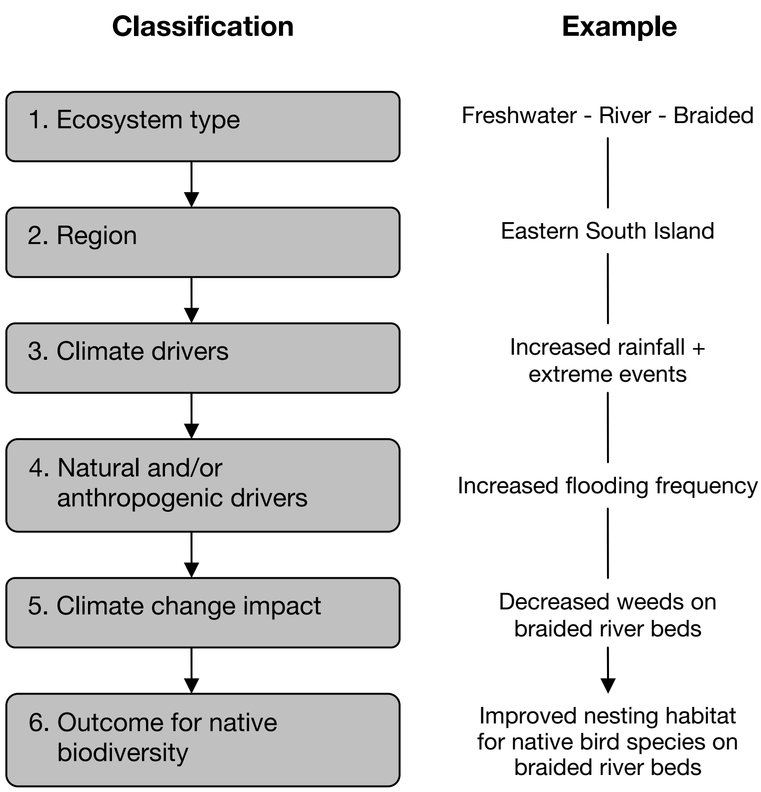

Figure A1.1. The structure and process used to identify the outcome of a climate change impact on a specific component of native biodiversity, with a worked example on the right.

Table A1.1. Data sources for species and land cover classes used in classification and for producing measures of climate change outcomes.

VARIABLE	DATA SOURCE*	MEASURE	LOCATION†
Alpine	LCDB2 alpine cover classes	Area	Thompson et al. (2004)
Alpine shrubland	New Zealand forest and shrubland classification	Area	Wiser & Hurst (2008)
Native forest	New Zealand forest and shrubland classification	Area	Wiser & Hurst (2008)
Lowland shrubland	New Zealand forest and shrubland classification	Area	Wiser & Hurst (2008)
Inland wetlands	LCDB2 and WONI wetlands	Area	Thompson et al. (2004) & DOC/Landcare Research
Rivers	FWENZ	Area	DOC/NIWA
Lakes	Lake classification	Area	DOC/NIWA
Coastal/estuarine	LCDB2 coastal/estuarine cover classes	Area	Thompson et al. (2004) & NIWA
Rare ecosystems	Partial rare ecosystems	Area	DOC/Landcare Research
Birds	NZ Bird Atlas 2004 and selected threatened bird species distribution maps	Presence/absence (NZ bird atlas) Abundance (threatened species)	NZ Ornithological Society (Robertson et al. 2007) and S&C DOC
Reptiles	Herpetofauna database records and selected species in detail	Presence/absence	Bioweb & S&C DOC
Frogs	Herpetofauna database records	Presence/absence	Bioweb, DOC
Bats	Bat distribution database records	Presence/absence	S&C DOC
Snails	Snail distribution database records	Presence/absence	S&C DOC
Freshwater fish	NZ freshwater fish distribution database	Presence/absence Abundance	NIWA
Threatened plants	Threatened plant database records and selected threatened species in detail	Presence/absence	Bioweb & S&C DOC
Exotic fauna	Selected pest animal species distributions	Presence/absence	BDI, DOC
Exotic flora	Selected pest plant species distributions	Presence/absence	BDI, DOC

* LCDB2 = Land Cover Database version 2; WONI = Waters of National Importance; FWENZ = Freshwater Environments New Zealand River Classification Database.

† DOC = Department of Conservation; S&C = Science and Capability Group; BDI = Biological Diversity Index.

development of an overarching ecosystems classification system for the ecosystem optimisation project may supersede these databases. If this is the case, this new ecosystem classification could be used to ensure consistency with the species and ecosystems optimisation projects. Sorted lists of climate change impacts on biodiversity, such as the one described here, should help to identify the most urgent conservation management needs.

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Appendix 2

Assessing the size of climate change impacts

There are many ways in which impacts and management needs can be ranked. The following text outlines a function-based approach, in which the size of a particular climate change impact on native biodiversity is assessed using a multiplicative function. The advantage of this approach is that it is transparent, explicit, repeatable and auditable, which in turn enables exploration of alternative approaches, learning and ongoing improvement. This approach also has the added bonus of being used by other Department of Conservation (DOC) internal biodiversity planning and management frameworks, so it could be integrated into these programmes. These DOC programmes include: Waters of National Importance (WONI; Chadderton et al. 2004), Measuring Conservation Achievement (MCA; Stephens et al. 2002) and, more recently, the Species and Ecosystems Optimisation Programmes (Joseph et al. 2008).

The climate change impact equation is as follows:

$$\text{Impact} = \text{Likelihood} \times (\Delta\text{Area} + \Delta\text{Biodiversity})$$

Whereby:

- **Likelihood** is an expert-based estimate of the probability of the impact actually happening, which is informed by the IPCC (Parry et al. 2007) probability classifications (Table A2.1).
- **Change in area (Δ Area)** is the percentage of the total area (km^2) of the species or ecosystem that is affected by the impact. This is calculated by assessing the difference in the size of the area occupied by a particular species or ecosystem before (Time_1) and after (Time_2) the climate change impact occurs (i.e. 2090s), or:

$$\frac{(\text{Area occupied}_{\text{Time1}} - \text{Area occupied}_{\text{Time2}})}{\text{Area occupied}_{\text{Time1}}} \times 100\%$$

  Area occupied $_{\text{Time1}}$ is derived from actual ecosystem distribution data of current species using the spatial databases listed in Table A1.1 (Appendix 1), while area occupied $_{\text{Time2}}$ will need to be estimated using some yet to be invented function.

- **Change in biodiversity (Δ Biodiversity)** is the percentage of the taxon or ecosystem of interest that is affected by the climate change impact. It is calculated by assessing the difference in species occupancy, within the defined area, before (Time_1) and after (Time_2) the climate change impact occurs, (i.e. 2090s), or:

$$\frac{(\text{Species occupancy}_{\text{Time1}} - \text{Species occupancy}_{\text{Time2}})}{\text{Species occupancy}_{\text{Time1}}} \times 100\%$$

  Species occupancy $_{\text{Time1}}$ is generated from actual data of current species' distributions and lists (see Appendix 1: Table A1.1), while species occupancy $_{\text{Time2}}$ will need to be estimated using some yet to be invented function.

The score of a climate change impact reflects that impact's effect on native biodiversity, with a large effect earning a high score and therefore being ranked as a higher priority for management or research. In contrast, an impact that will have only a small impact on biodiversity will get a low score and accordingly be ranked as a much lower priority. The following impacts on biodiversity will score high: those with a high likelihood of occurrence; those that will affect a large proportion of the current range of the species and/or ecosystems; and/or those that will affect a large number of species or ecosystems. The reverse will be true for impacts that gain a low score. Examples of species or ecosystems that may earn a high score include threatened species or ecosystems with existing small home ranges (e.g. frog species, chevron skink (*Oligosoma homalonotum*), takahē (*Porphyrio mantelli*)); and impacts with higher immediacy,

Table A2.1. Probability values of likelihood categories and corresponding descriptions for climate change impacts (based on IPCC descriptions and categories, in Parry et al. (2007)).

P VALUE	IPCC *P* RANGE	LIKELIHOOD CATEGORY	DESCRIPTION
0.00	<0.01	Exceptionally unlikely	Likely will never happen
0.05	0.01–0.10	Very unlikely	Highly unlikely, but conceivable
0.22	0.10–0.33	Unlikely	Unlikely to occur, but possible
0.50	0.33–0.66	Medium	Might occur; 50/50 chance
0.78	0.66–0.90	Likely	Will probably happen
0.95	0.90–0.99	Very likely	Is expected to happen, perhaps more than once
1.00	>0.99	Virtually certain	Is happening already

because likelihood estimates will be more accurate and higher (e.g. increases in mast seeding frequency in beech (*Nothofagus*) forest). In contrast, a low score is much more likely when species or ecosystems cover a large geographic range, even if numbers are sparse (e.g. rock wren (*Salpinctes obsoletus*), South Island robin (*Petroica australis australis*)); there is a large number of species and only a proportion of the species group will be affected (e.g. forest birds); and an impact is likely to manifest a long time into the future and so its likelihood is more difficult to predict (e.g. impact of sea level rise and coastal freshwater ecosystems).

There are some impediments to using this multiplicative approach, with regard to the availability and existence of the data needed for the equation. While information on likelihood, current area and current species is generally available, data estimating the proportional change in biodiversity as a result of climate change are either not available or do not exist. This is partly a consequence of a lack of knowledge about the relationships between natural processes, species, ecosystems and climate, but also due to the inherent complexity of this type of data. Thus, better information and, in particular, identification of critical knowledge gaps is needed to underpin both the multiplicative equation and selection of the appropriate adaptive management response.

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Appendix 3

Decision flow-chart for climate change operational management

Conservation managers will need to decide which management actions are most appropriate for managing the particular impacts of climate change on biodiversity. While the use of *in situ* conservation management techniques is the preferred option, this may not be enough to prevent the loss of some species and/or ecosystems, particularly where they are isolated, or exist on offshore islands or on an island of native habitat surrounded by land cleared of native vegetation for farming or development purposes. This lack of habitat connectivity compromises ecosystem resilience by disrupting a species' ability to colonise new locations and thereby adapt to climate change. Therefore, conservation managers may need to consider moving species to sites where they do not currently occur. Fortunately, the transfer of species outside their historic range is already undertaken by the Department of Conservation (DOC), albeit for a range of other reasons (e.g. management of isolated populations, transfer of threatened species to pest-free islands). Therefore, these types of transfers are already covered by DOC's standard operating procedures for translocations. A decision flow-chart has been developed to aid conservation managers in deciding which management action to take once a climate change impact on native biodiversity has been identified (Fig. A3.1).

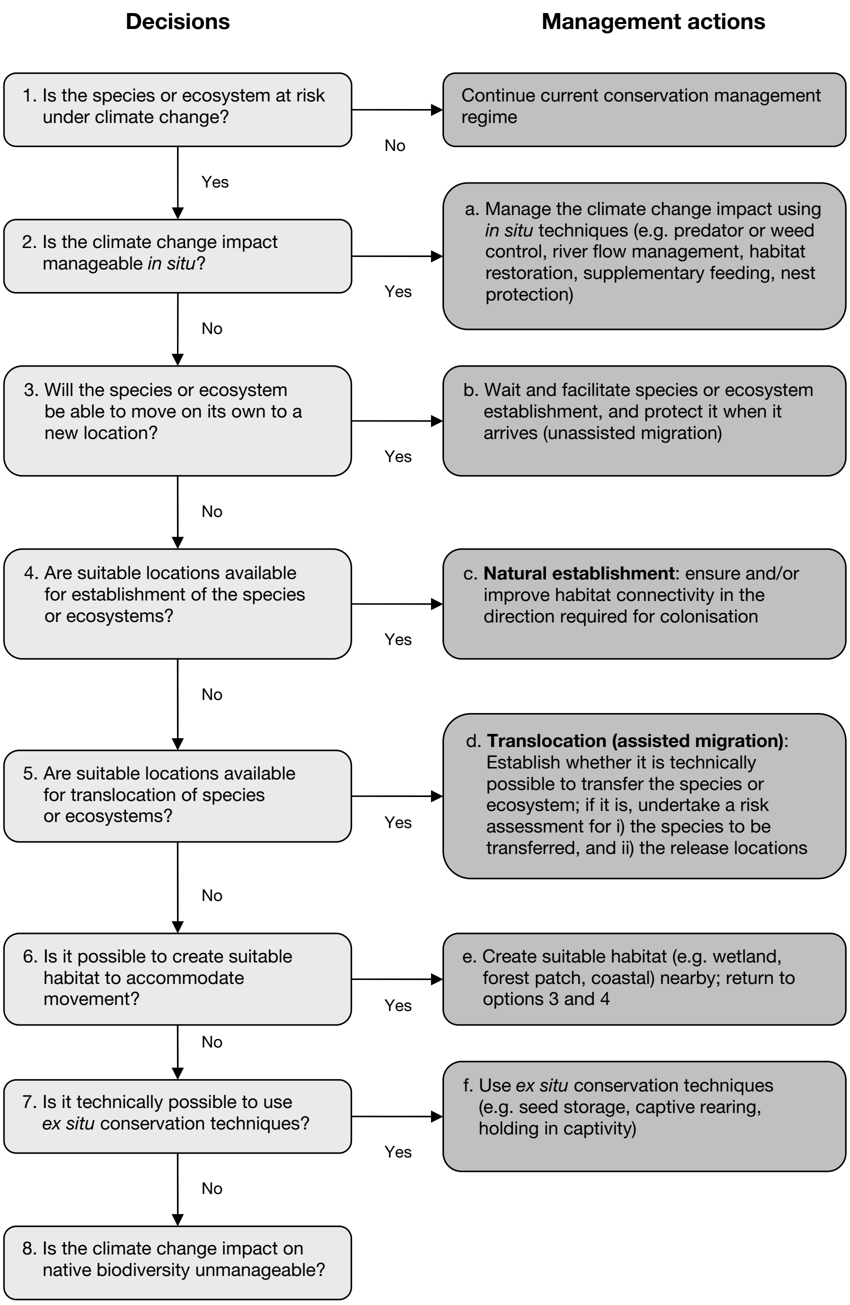

Figure A3.1. A decision flow-chart for selecting the appropriate management action. Actions denote increasing levels of intervention and complexity proceeding from a to g.