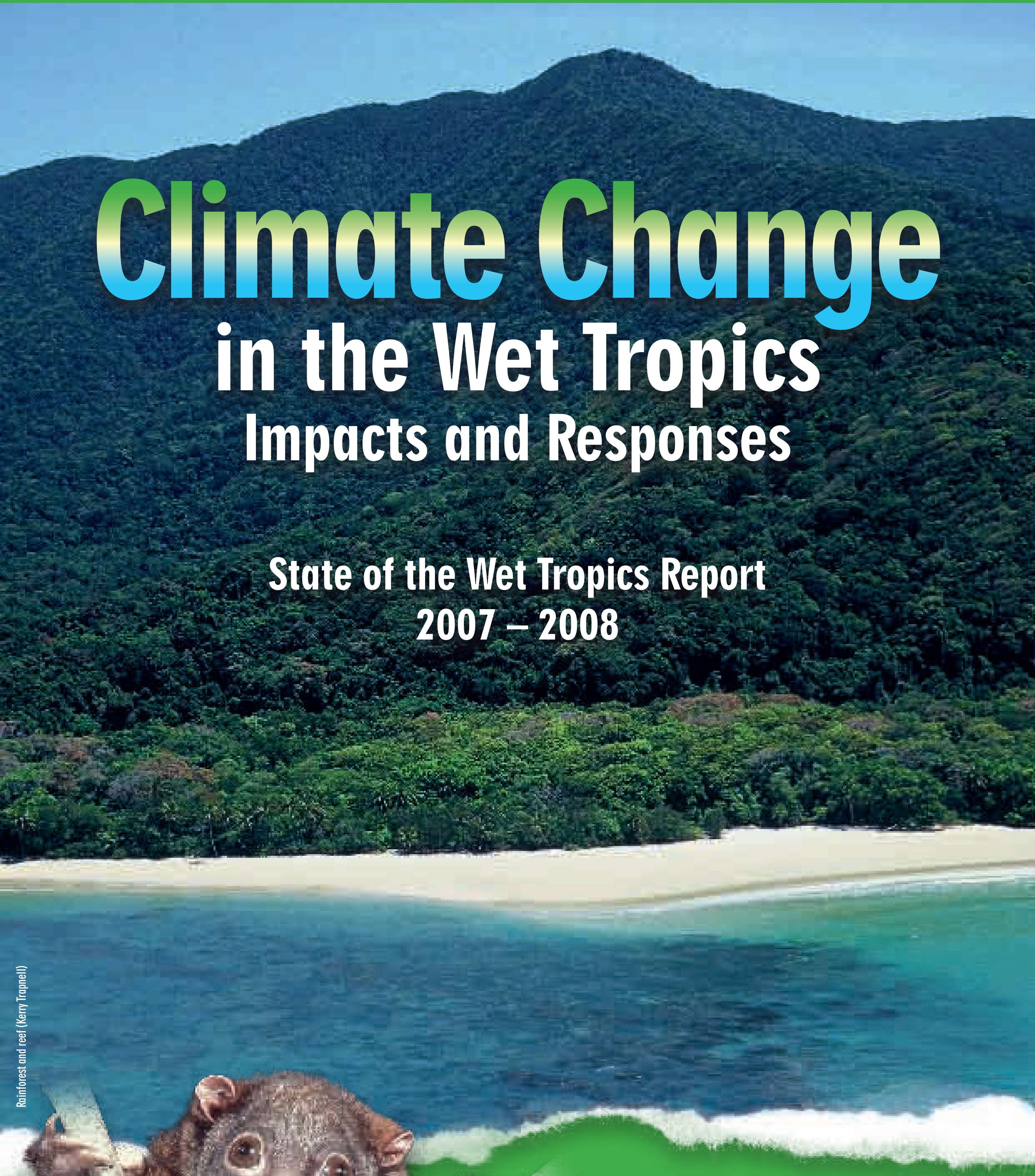

Climate Change in the Wet Tropics

Impacts and Responses

State of the Wet Tropics Report
2007 – 2008

Rainforest and reef (Kerry Trapnell)

Lemuroid ringtail possum (Mike Trenerry)

WET TROPICS
MANAGEMENT AUTHORITY

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Terms and abbreviations

asl	above sea level
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ENSO	El Niño Southern Oscillation
FNQ	Far North Queensland
JCU	James Cook University
MTSRF	Marine and Tropical Sciences Research Facility
RRRC	Reef and Rainforest Research Centre
The Area	The Wet Tropics of Queensland World Heritage Area
The Authority	The Wet Tropics Management Authority
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WTQWHA	Wet Tropics of Queensland World Heritage Area

Foreword

Andrew Maclean, WTMA executive director

Climate change is a major and insidious threat to the ecosystems of the Wet Tropics of Queensland World Heritage Area. Anticipated changes to temperature, rainfall and other climatic conditions will cause major changes to ecosystems and lead to the loss of many plant and animal species for which the Wet Tropics was listed on the World Heritage register.

This State of the Wet Tropics Report focuses on the impacts of climate change on the internationally recognised values of the World Heritage Area. The report summarises the latest available scientific information about expected changes in the forests as they respond to climate change. It identifies current management actions being taken in response to climate change and identifies opportunities for further action at a regional scale.

The Wet Tropics of Queensland is an extraordinarily diverse natural asset. The presence of rainforests at the edge of a dry continent arises from a rare combination of finely balanced climatic and topographic features. Even small changes in climate are likely to have significant adverse impacts on the World Heritage values of these forests.

Australia's international reputation for sustainable management of its natural heritage flows from its performance in managing World Heritage properties such as the Wet Tropics. In joining the World Heritage Convention, Australia accepted that it has a duty to ensure protection, conservation, presentation and transmission to future generations of its World Heritage listed properties. Australia also

View from Lambs's Head

Photo: TQ

Nature based tourism

undertook to 'do all it can to this end, to the utmost of its own resources' (World Heritage Convention, Article 4).

Effective responses to climate change impacts in the Wet Tropics have real economic benefits. Tropical North Queensland receives over 2 million international and domestic visitors each year. These visitors are primarily drawn to the region because of its outstanding natural features, in particular, the World Heritage rainforests and reefs. International visitors return to their home country having made judgements about Australia's environmental management. The environmental reputation of tourist destinations is an increasingly important factor in tourist destination planning and spending.

Both the Australian and Queensland Governments have recognised the threat of climate change and both governments are mobilising resources to combat it. The current focus of climate change policy at the national and state level is largely on mitigation. The Australian and Queensland Governments are leading the search for ways to reduce emissions of greenhouse gases through measures such as emissions trading, support for development of alternative energy sources and encouraging energy conservation in homes and businesses. All of these measures are important to reduce the global extent of climate change.

While reducing greenhouse gas emissions is clearly important at the national and global scale, at a regional level the emphasis must be on *adapting* to anticipated climate changes, in addition to sharing responsibility for reducing emissions. This requires changes in the way we manage our World Heritage forests to make them more resilient to the threat of elevated temperatures, changing rainfall patterns and greater climatic variability. In addressing the threat of climate change on World Heritage properties, UNESCO has recommended that World Heritage properties serve as laboratories where monitoring, mitigation and adaptation processes can be applied, tested and improved.

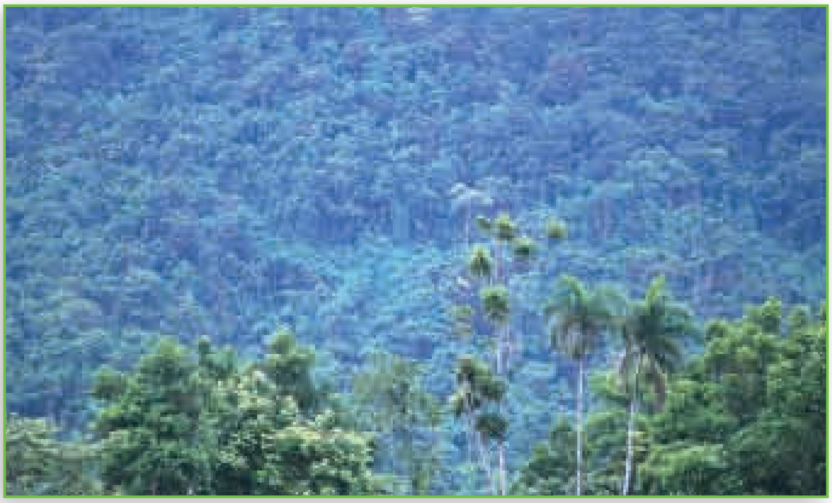
Put simply, the best way to make the forests of the Wet Tropics resilient to the anticipated adverse impacts of climate change is to ensure that they are healthy. This means reducing or eliminating other threats to forest health such as weeds, feral animals and disease; fragmentation and isolation; inappropriate fire regimes; and other impacts of human use in and around the World Heritage Area.

Ensuring the Wet Tropics forests are healthy is already a core goal of management. However, the threat of climate change means that we must accelerate our progress and ensure we consider the response of forest ecosystems to future as well as current climatic conditions. Through the Wet Tropics Management Authority and its partner agencies, and with the support of community, industry and regional landowners, the institutions and processes required to implement change are already mostly in place. With appropriate investment, rapid and effective action is possible.

Making the Wet Tropics resilient to the anticipated effects of climate change requires work in four key areas: on-ground works to improve forest health; improving and communicating our knowledge of the effects of climate change; increasing community awareness and mobilising behavioural change; and regional planning, coordination and leadership.

This report highlights the magnitude of the climate change risk for the World Heritage Area. It establishes a framework that, with appropriate government and community support, will give us the best chance of maintaining the outstanding universal values of the Area for Australia and the world.

Andrew Maclean
Executive Director
Wet Tropics Management Authority



Rainforest at Cow Bay

Executive summary

Climate change creates major risks for the Wet Tropics of Queensland World Heritage Area (WTQWHA, the Area). This report identifies the key values of the Area that are vulnerable to climate change and explains how predicted changes in rainfall, temperature and other climatic variables will affect these. It identifies a series of actions that, with sufficient public and private investment, may increase the resilience of the region to the anticipated impacts of climate change.

The World Heritage Committee of UNESCO identified the WTQWHA as having outstanding universal value and integrity. The Area's diverse landforms support an extraordinary assemblage of plants and animals. Despite comprising only a very small proportion of the Australian continent. The Area supports a high proportion of Australian flora and fauna, reflecting the diversity and biological productivity of its ecosystems.

Photo: Kerry Trapnell

Rainforest, Mount Lewis

The distinctive and diverse assemblages of plants and animals in the Wet Tropics are the result of finely balanced climatic conditions that, in turn, are due to the latitude and topography of the region and its proximity to easterly winds carrying moisture from the Pacific Ocean. Climate change threatens to disrupt these climatic conditions and may result in rapid and catastrophic changes to the regional environment that will limit the extent of rainforests and lead to the extinction of many of the region's fauna and flora.

The vulnerability of the Wet Tropics to climate change has been widely recognised. The World Heritage Centre, which administers the World Heritage Convention, has identified the WTQWHA as a site at particular risk from even small changes in temperature. UNESCO has proposed that World Heritage sites such as the Wet Tropics could serve as valuable laboratories to study the impacts of climate change and the effectiveness of management responses. The

Australian Government, in the recently completed Carbon Pollution Reduction Scheme Green Paper [52], acknowledged the particular threat climate change poses for the Wet Tropics. The Queensland Government has also acknowledged the threat to the Wet Tropics and has established climate change as a key policy driver in the recently released Far North Queensland Draft Regional Plan 2025 [11]. This level of recognition provides a good basis for investment in the measures required to effectively respond to the identified risks.

Impacts of Cyclone Larry at Bicton Hill

Climate projections for the Wet Tropics indicate the magnitude of change that the region's ecosystems may encounter. Temperature may increase by 1.4ºC by 2030 and 4.2ºC by 2070 under high emission scenarios. Rainfall is predicted to become more seasonal with a wetter wet season and a longer, drier dry season. Cyclone intensity is predicted to be greater, creating risks of more frequent major ecosystem disruption as witnessed after Cyclone Larry. The El Niño phenomenon is predicted to occur more frequently, causing more frequent droughts and increasing the risk of bushfire, with consequent damage to rainforests.

Climate changes of this magnitude will have severe and interacting effects on the values of the WTQWHA. We can anticipate changes in the abundance and distribution of flora and fauna. Interactions between organisms, such as predator prey relationships and insect pollination, are likely to be disrupted, creating consequent changes in ecosystem composition, structure and function.

Many of the highly valued endemic species of the Area are confined to the higher, cooler parts of the region. Modelling indicates that with 2ºC warming the proportion of the Area with a mean annual temperature of 22ºC or less will markedly reduce, diminishing the proportion suitable for these thermally sensitive fauna. This will substantially increase the risk of extinction for several high elevation endemic wildlife species.

Disruption of ecosystems and changed climatic conditions will make the Area more vulnerable to weed, feral animal and disease invasion. Weed species that may not be able to invade native ecosystems at present may gain a competitive advantage under the warmer drier conditions that are expected. The risk of new vertebrate and insect pests and plant and animal diseases is also likely to increase.

Photo: Kerry Trapnell

Daintree rainforests

Cloud stripping is a significant source of fresh water in the region. Temperature increases are likely to cause a rise in the altitude of the cloud layer, reducing the area where cloud stripping can occur and diminishing catchment runoff. Reduced stream flows will have ecological impacts and will also reduce the amount of water available for irrigation and urban water supply.

Climate change will also compromise other environmental goods and services. For example, if the loss of rainforest values becomes obvious, the Area may become less attractive for tourists, creating significant economic impacts in the region.

While the outlook for the WTQWHA is a cause for great concern, much can be done at a regional level to adapt to the anticipated changes. The most important management interventions will be those that build ecological resilience in and around the Area. The following four broad areas of activity are proposed:

- **On-ground works to improve forest health** – The principal means of achieving ecosystem resilience is to build and maintain ecosystem health. Measures such as wildlife corridors, limiting further clearing, rehabilitation of previously cleared areas, protecting important habitat refuges and managing the threat of environmental pests will all assist to strengthen Wet Tropics ecosystems against climate change.
- **Improving and communicating our knowledge of the effects of climate change** – Regional research institutions such as CSIRO and James Cook University (JCU) with support from the Marine and Tropical Sciences Research Facility (MTSRF), have made good progress in understanding the

impact of climate change in the Area. More work is needed to improve, refine and communicate current knowledge. There are opportunities to capitalise on regional research capability through establishment of a Centre for Climate Change Adaptation at JCU that would deliver information to managers and policy makers to improve adaptation responses.

Tree planting in the Daintree

- **Increasing community awareness and mobilising behavioural change** – Private land managers can make a major contribution to the adaptation work in the Wet Tropics. Land and environment agencies need to provide leadership by increasing community awareness of the risks of climate change and helping communities to find regionally relevant ways of adapting. Improved land management practices should be supported through technical advice, incentives and appropriate land and resource management policies. Communities must be appropriately engaged in decision-making affecting their own land or public lands such as those in the WTQWHA.
- **Regional planning, coordination and leadership** – This work aims to coordinate and align the efforts of regional land and environment agencies and private land managers to ensure resources are well targeted and effort is appropriately aligned with agreed priorities. Regional institutions and communities already have the underlying capability to take action against climate change if supported with adequate resources.

Promoting cassowary habitat with Cassowary Country signs

1. Introduction

Climate change presents an immediate and urgent challenge for biodiversity conservation in the Wet Tropics region. The transformation of much of the environment by agriculture, urbanisation and industry has created, and continues to create, a wide range of unintentional experiments in which the region's wildlife are exposed to severe and novel pressures to which they will either have to adapt or cease to exist. The greatest of these experiments is now under way – the alteration of the atmosphere and climate of the earth, with consequences for every living thing. In this report we attempt to sketch out the main tasks that the Authority considers the region needs to undertake to respond to this challenge.

The forests of the Wet Tropics of Queensland World Heritage Area (WTQWHA, the Area) owe their genesis to long-term cycles of change in climate. It may seem ironic then, that climate change is now regarded as the single biggest threat to the future of the outstanding universal values and integrity for which the Area was inscribed onto the World Heritage list in 1988 [1].

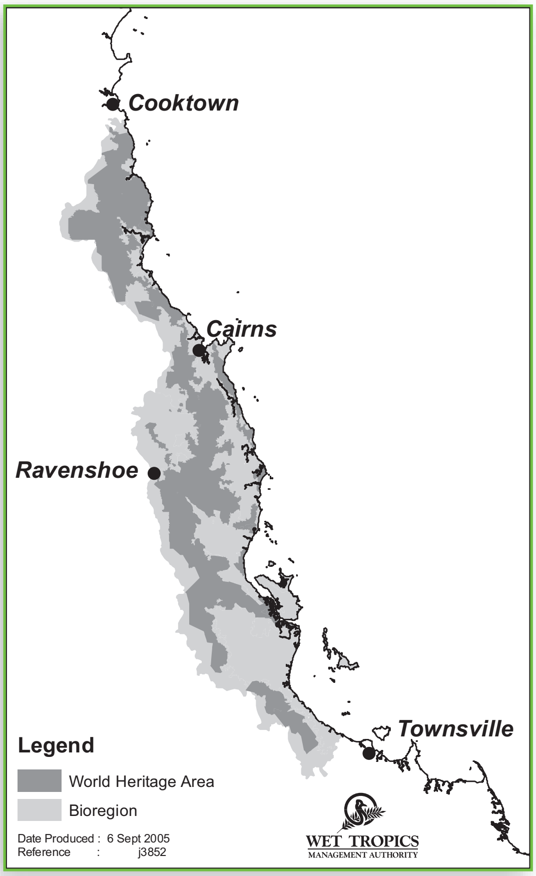
The Area is a large (894,420ha), rugged, central spine of the 1,976,000ha Wet Tropics bioregion which extends from near Cooktown in the north to near Townsville in the south and borders the Great Barrier Reef World Heritage Area along a considerable part of the coastline. The region's economy depends largely on tourism generated from the attraction of its two World Heritage Areas.

In the past few years there has been a remarkable increase in the level of awareness of climate change worldwide. Concerns about causes and effects have moved beyond the realm of scientific debate to the living rooms of people everywhere. As evidence accumulates

Photo: Kerry Trapnell

Reef and rainforest - two World Heritage Areas that a warming planet will cause widespread and mostly harmful effects, scientists and policy makers have proposed various mitigation strategies that might reduce the rate of climate change – a national and international response for those officials in government who must plan now for an uncertain future. However, strategies for adapting to climate change at a regional level are equally important.

Although the options available for taking adaptive action have become better defined over time, adaptation planning continues to involve many uncertainties. Nevertheless, it is imperative that, in a region as internationally important as the Wet Tropics, we take immediate proactive steps to increase the probability of our biodiversity surviving. We cannot be complacent, we have too much to lose.



The WTQWHA and the Wet Tropics bioregion

The WTQWHA is a living museum containing one of the most complete and diverse living records of the major stages in the evolution of land plants in the world. It conserves a largely intact flora and fauna with hundreds of locally endemic species restricted within its boundaries. It also provides the only habitat for more rare or threatened species and primitive plants and animals than anywhere else in Queensland. The Wet Tropics region, as a whole, conserves 41% of all Queensland's vascular plant species in slightly over 1% of the State's land area. Within the Australian context, the Wet Tropics region is a very distinctive bioclimatic and landform unit with exceptionally steep and diverse environmental gradients and contains the country's greatest variation in topographical relief. Some appreciation of the importance and species richness of the Wet Tropics bioregion can be gained from the contribution it makes to Australia's overall biodiversity.

Photo: Mike Trenerry

Blue ghost moth

Although the Wet Tropics comprises only 0.26% of the total area of the Australian continent its biodiversity significance is enormous, being home for the following percentages of Australia's species [2]:

- vascular plants (26%)
  - fern species (65%)
  - cycad species (21%)
  - conifer species (37%)
  - orchid species (30%)
- bird species (40%)
- frog species (29%)
- mammals (35%)
  - marsupial species (30%)
  - bat species (58%)
  - rodent species (25%)
- reptile species (20%)
- freshwater fish species (42%)
- butterfly species (58%).

The Wet Tropics is also characterised by a very large number of restricted endemic species whose total world-wide distribution is confined to the region – in some instances to a single location within the region such as a mountain summit or a small sub-catchment.

Photo: Jason McCall

Bowenia spectabilis

1.1 International perspective

The issue of the impacts of climate change on World Heritage properties was brought to the attention of the World Heritage Committee in 2005 by a group of concerned organisations and individuals. Troubled about the potential for climate change to adversely affect and threaten the outstanding universal values and integrity of World Heritage properties, the World Heritage Committee tasked the World Heritage Centre of UNESCO and its advisory bodies, to undertake further investigation of the issue. The Committee endorsed the resulting reports, Predicting and Managing the Effects of Climate Change on World Heritage [3] and Strategy to Assist States Parties to Implement Appropriate Management Responses [4], as official documents in 2006.

The Committee subsequently requested the World Heritage Centre to develop a policy document on the impacts of climate change on World Heritage properties. The policy document was adopted by the General Assembly of States Parties in 2007 [5, 6]. The policy document encourages managers of World Heritage properties to include climate change messages in their communication, education and interpretation activities as appropriate; and to build public awareness and knowledge of climate change, its potential impacts on World Heritage properties

Selaginella species

and their values, and activities or available options for adaptation and mitigation. This report has been prepared to provide such a message about the impacts of climate change on the WTQWHA and options for adaptation.

The policy document [6] reiterated that the primary objective of World Heritage management is to safeguard the outstanding universal values and integrity of World Heritage properties. The document also recommended that World Heritage properties serve as laboratories where monitoring, mitigation and adaptation processes can be applied, tested and improved, since actions taken at these iconic properties attract world-wide attention and can influence the adoption of good management practices elsewhere.

In 2007 the World Heritage Centre published a number of case studies on climate change [7]. The WTQWHA was identified as one of the sites at particular risk from even a small increase in temperature. This was primarily due to the very large predicted declines in range size for almost every endemic vertebrate faunal species found in the Area.

1.2 National perspective

Queensland's Wet Tropics, along with the Great Barrier Reef, the Australian Alps, and Southwest Western Australia, have consistently been identified in several national and state reports as being at particular risk of biodiversity loss from climate change [8, 9, 10]. Research commissioned by the recent Garnaut Climate Change Review [51] noted that the Wet Tropics was among a number of World Heritage properties in Australia under threat. The Australian Government's recent Carbon Pollution Reduction Scheme Green Paper [52] also acknowledged the serious impact that climate change is likely to have on the WTQWHA. Concern about the impacts of climate change in the Wet Tropics on the nation's biodiversity is highlighted in many sections of the recent Office of Climate Change report, Climate Change in Queensland: what the science is telling us [50].

1.3 Regional perspective

Protection of the region's natural values depends not only on effectively adapting to the impacts of climate change, but also on the type of regional development path that is pursued. The Wet Tropics region has experienced a steady increase in population growth over recent decades, averaging higher than the national growth rate [11]. Impacts on the natural environment are likely to continue increasing along with population growth. It will, therefore, be necessary for climate change adaptation responses to be viewed in the wider context of regional sustainable development efforts such as espoused in the Far North Queensland Draft Regional Plan 2025 [11]. Any proposed regional responses aimed at reducing the vulnerability of the values and integrity of the Area must be designed and implemented in this larger regional landscape context. The Area should be considered as the core focal area within a functioning regional network of natural and semi-natural areas. The protection and management of the Area must be approached from a whole-of-region landscape perspective.

Urban development, Mission Beach

2. Wet Tropics regional climate projections

Summary

1. The Wet Tropics can expect a warmer, drier future.
2. Although wet season rainfall is likely to increase for most years, this will be countered by an increase in the frequency of El Niño drought years, resulting in reduced wet season rainfall during these El Niño periods.
3. More intense rainfall events including higher intensity cyclones are likely.
4. Increased temperatures will result in corresponding increases in evaporation and transpiration.
5. Sea levels are rising and an increase in the area of lowlands affected by storm surge and saltwater intrusion and inundation is expected.

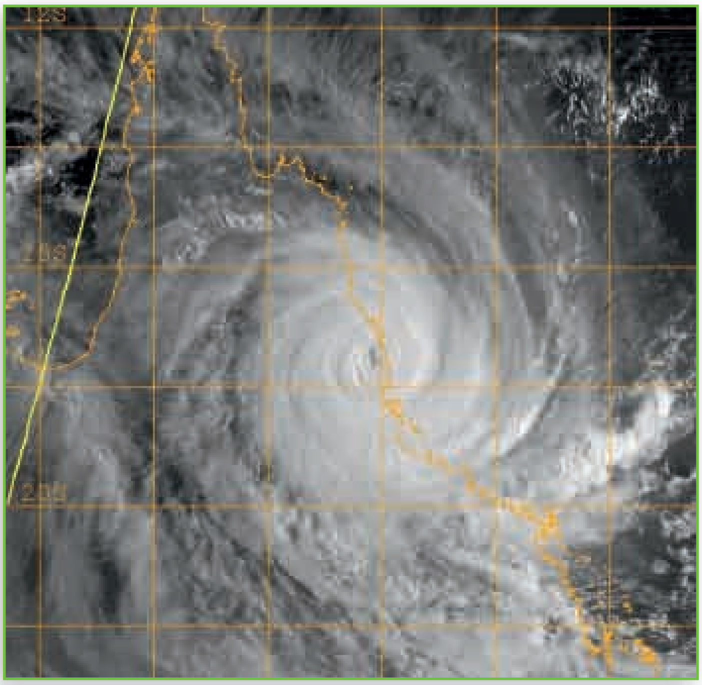


Photo: Bureau of Meteorology

Cyclone Larry

CSIRO has been developing tools and methods to predict climate change trends at a scale relevant for the Wet Tropics and the Great Barrier Reef regions. This is being undertaken through a program of research linked to the Marine and Tropical Sciences Research Facility (MTSRF) [12] administered in North Queensland by the Reef and Rainforest Research Centre (RRRC) [13]. CSIRO has identified a number of possible outcomes based on the results of 15 different global climate models [14]. Predicting the magnitude, rate and spatial pattern of climate change is very complex and scenarios for areas as small as the Wet Tropics region contain a degree of uncertainty. These models, therefore, should not be regarded as forecasts but, rather, as indications of the likely directions and magnitude of change based on the best current information. The wisest approach is to use these projections to assess the additional risk that changes on this scale could pose.

Some of the projections for the Wet Tropics based on the results of these models are listed below [14].

Temperature (compared to 1990 temperatures)

2030

- An increase of 0.5ºC for low emission scenario
- An increase of 1.4ºC for high emission scenario

2070

- An increase of 1.0ºC for low emission scenario
- An increase of 4.2ºC for high emission scenario
- An increase in the frequency of extreme temperature periods (days above 35ºC) from the current annual average of three days to up to 41 days by 2070.

Rainfall

- Regional rainfall shows a decreasing trend over the last century and this trend is stronger after 1950
- Overall drier and more seasonal conditions for the region are likely, characterised by a longer and drier dry season
- Rainfall variability is expected to be higher from year to year, especially for the wet seasons
- Rainfall is expected to increase slightly in the wet season, depending on the state and frequency of the El Niño Southern Oscillation (ENSO)
- Rainfall is expected to decrease markedly in the late dry season
- There will be an increase in the frequency of El Niño events resulting in lower rainfall and longer dry seasons [15].

2030

- Changes in rainfall of -6% to +5% annually
- -5% to +4% wet season (January – March)
- -16% to +2% dry season (August – October)

2070

- Changes in rainfall of -19% to +14% annually
- -16% to +13% wet season (January – March)
- -50% to +7% dry season (August – October).

Josephine Falls

Climatic events

- Models indicate an increase in the frequency and severity of extreme weather conditions such as heat waves, floods, droughts and destructive storms [15]
- Tropical cyclones are projected to increase in maximum intensity (+5% to +10% in maximum wind speed and +20% to +30% increase in maximum precipitation by 2030), but show little change in their region of formation or number (which is highly dependant upon changes to ENSO) [14]
- A rise in the altitude of the cloud base is predicted, resulting in a retarding of the cloud stripping ability of the region's upland rainforests. These upland rainforests currently derive up to 30% of their total annual precipitation from intercepting the cloud layer [16]. A rise in the cloud base would

thereby reduce the total effective transfer of water from the atmosphere to the region's terrestrial systems with serious impacts on hydrology, ecosystem processes and biodiversity [17].

Photo: EPA

Cloud forest

Coastal areas

- A rise in sea levels of 3cm to 17cm by 2030 is predicted, increasing to 18cm to 59cm by 2100 depending upon the nature of local coastal relief [15]
- An increase in the intensity of oceanic storm surges caused by both a rising sea level and more severe cyclones resulting in a 20% to 30% increase in storm surge height [18].

Cape Tribulation

3. Impacts of climate change on the WTQWHA

Summary

1. Climate change will have severe adverse impacts on wildlife and their habitats as well as on ecosystems and the goods and services they provide society.
2. In general, all native species will be more vulnerable, even those able to tolerate climatic changes *per se*, as they will all have to deal with a variety of new competitors, predators, diseases and introduced species for which they may have no natural defence.
3. It is predicted that existing ecosystems will undergo major changes. Some are likely to disappear entirely; some totally new or novel ecosystems may appear; and others will experience dramatic changes in species composition and geographic extent.
4. While rainfall totals may not vary by much under climate change, there could be significant changes to the variability and seasonality of rainfall.
5. Climate change will adversely affect a range of environmental goods and services provided by the WTQWHA. For instance, a rise in cloud levels would cause a significant decline in catchment water yield sourced from cloud stripping, an important source during the dry season.

Photo: EPA

Copperlode Dam

Research shows that the biodiversity of the Area is highly sensitive to climate change [19, 20, 21]. The location and extent of rainforests in particular are largely determined by rainfall and its seasonality, while the type of rainforest and many of the organisms found within a rainforest depend upon narrow temperature ranges. Climate change impacts upon biodiversity at all its levels of organisation, ranging from biological, ecosystem and ecological impacts through to population level impacts.

These impacts result either directly from climate change *per se* or indirectly through interactions with other species that are affected by climate change, leading to changes in competition, food, habitat and predation patterns and processes. For some species these indirect impacts may be stronger than direct impacts. This cascade of climate change impacts also interacts with other human pressures on biodiversity such as habitat degradation and loss, water extraction and regulation of flow regimes, pollution and introduction and spread of pest species. Not only do climate change impacts add to these other pressures, they also interact, altering the way species and ecosystems would otherwise respond and adapt.

Biological impacts include direct changes to organisms such as physiological and behavioural changes, including:

- differential responses by different species in both magnitude and type to changing conditions
- changes in timing of species' life-cycles such as flowering and fruiting (phenology).

Photo: Martin Cohen

Bumpy satinash flowers

Changes will also occur to the composition, structure, function and services of ecosystems including:

- changes in nutrient cycling and natural resource supply such water cycles

- changes in predator-prey, parasite-host, plant-pollinator and plant-disperser relationships
- changes in ecosystem services such as water supply, pest control and pollination.

Ecological impacts include those that result from changed interactions between organisms and their environment, thereby affecting community composition and configuration. They include:

- changes in breeding, establishment, growth, competition and mortality
- changes in the location of species' habitats resulting in range shifts and/or losses due to range expansions, contractions and eliminations
- increased opportunity for range expansion of invasive pest species including weeds, feral animals, pathogens and parasites
- increased opportunity for range expansion of native species with extensive, non-patchy ranges, long-range dispersal mechanisms, large populations and high genetic diversity
- changes in the structure and composition of ecological communities
- formation of novel communities based on new species assemblages.

Population impacts refer to the ultimate impact on species in terms of changes in their abundance and distribution. They include:

- changes in presence/absence and relative/absolute abundances
- differential individual species' responses to warmer and drier/moister conditions
- increases in the risk of extinction for species that are already vulnerable due to limited climatic ranges, limited dispersal ability, specialised habitat requirements, small populations and/or low genetic diversity.

Interactions with other natural and artificial factors include:

- changes in the intensity, frequency and seasonality of extreme events such as cyclones, floods, droughts and fires
- changes in human land use pressures (synergies with changes to land use and other population pressures on the environment).

Pandanus on fire

3.1 Ecological and biological implications of projected climate change

Individual species can exhibit two basic responses (in many combinations) to climate change. They can adapt to new conditions within their existing range or they can migrate to locations where suitable climatic conditions persist. The capacity of individual species to adopt either of these strategies will vary.

Species responses likely to be observed

- shifts in species' ranges - both latitudinal and altitudinal [20, 21]
- changes in species' abundances (including local extinctions) [22]
- changes in the length of a plant species' growing season
- earlier flowering in plants, earlier emergence in insects and earlier egg laying in birds [23, 24]
- changes to the timing and sequencing of flowering, fruiting and leaf flush of plants causing many flow-on impacts to species dependent upon these plants.

Photo: Mike Trenerry

Lemuroid ringtail possum

Ecological responses likely to be observed

- A reduction in the nutritional value and an increase in the toughness of most foliage due to increased CO_2 levels. This will have significant detrimental effects on the abundance of folivores (leaf-eaters) such as endemic ringtail possums and many insects [25].
- Changes in the climate-controlled distribution patterns of arboreal folivores will 'push' species off nutrient-rich, basaltic soils at mid altitudes and onto increasingly poorer granitic soils at cooler, higher elevations [25].

- Raised cloud bases will affect species requiring high and consistent moisture levels [19], directly affecting suspended mosses and epiphytes, microhylid frogs, litter skinks, soil invertebrates and soil microbes.

Photo: Jim Mitchell

Feral pigs

Plant and animal invasions

There is a risk of focusing too much on what will be lost and not enough on what will be gained because of climate change. Although many species are likely to be negatively affected by climate change, the greatest community and ecosystem impacts may come from those native or exotic species that are favoured by changed conditions and interact with other species (for instance, competitors, predators and invasive weeds) [26]. Climate change is predicted to significantly increase the vulnerability of ecosystems to invasion by feral animals, weeds and pathogens [27, 28] and some native colonist species.

Photo: NRW

Miconia calvescens

Changes in fire regimes [28, 32]

Fire controls much of the boundary between rainforest and sclerophyll forests [33]. During the El Niño event of 2002 and 2003, fires encroached into rainforest areas. Increases in the frequency of droughts associated with El Niño events will increase the frequency and severity of unusual fire years and may lead to large changes in the distribution of rainforest and sclerophyll communities. The Wet Tropics region can expect more frequent and more intense fires due to:

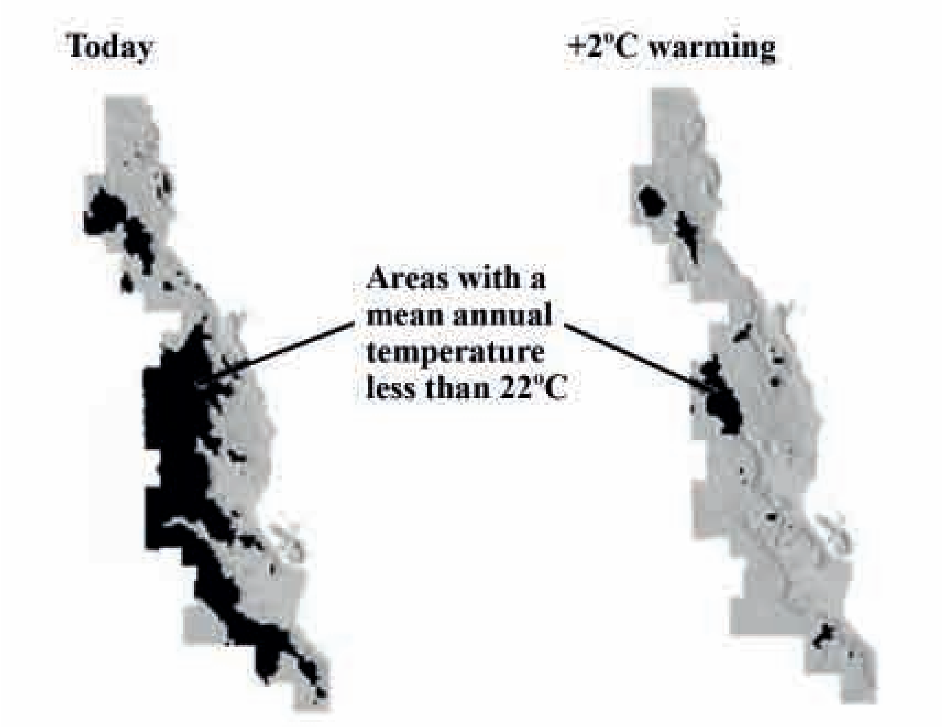
- hotter temperatures
- more droughts
- less rainfall in winter/spring
- longer periods of low humidity
- CO_2 induced increases in biomass
- smaller windows of opportunity for prescribed burns.

Hot fire

3.2 Effects of warming on higher altitude habitats in the Wet Tropics

Many Wet Tropics endemic species live only in the cooler, higher altitude parts of the region [30]. **Figure 1** models how climate change may affect the spatial extent and pattern of cool habitats where the average temperature is less than 22ºC. This approximates the temperature threshold for most arboreal leaf-eating mammals such as possums in the Wet Tropics [31].

Figure 1. Areas in the Wet Tropics with mean annual temperatures less than 22.0ºC (black) in today's climate (left) and after 2.0ºC warming [31].



3.3 Effects of warming on Wet Tropics higher altitude vertebrate fauna

Bioclimatic models developed by researchers from James Cook University and CSIRO suggest that climate change is likely to have catastrophic effects on many of the region's endemic vertebrate species.

An increase in regional average temperature of 1.0ºC could potentially produce a decrease of 60% in the distributional range of the region's endemic vertebrate species [21] based on these species' current distributional range limits. A mid-range climate change prediction of 3.5ºC could further reduce the distribution of endemic vertebrates to approximately 5% of their current range. Projected warming of this magnitude also simulated a loss of approximately 65% of the endemic vertebrates currently found in the region. This would imply a strong likelihood of approximately 50 species becoming globally extinct from the WTQWHA with only a moderate average temperature increase. Most upland endemic vertebrate species will disappear under the worst-case scenarios with temperature increases of 5.0ºC or more [21]. With each modelled increase in temperature, it is also evident that patches of climatically suitable habitat become smaller, fragmented and more isolated. Any of the described scenarios would be catastrophic with respect to the conservation of the values for which the Area was listed.

Table 1 lists those Wet Tropics endemic vertebrate species predicted to lose greater than 50% of their current area of core climatic environment with only a 1.0ºC increase in temperature. **Figure 2** illustrates the sequential decline in distribution of species richness of Wet Tropics endemic terrestrial vertebrates as the climate gets progressively warmer.


Photo: EPA

Northern barred frog


Photo: Mike Trenerry

Daintree ringtail possum

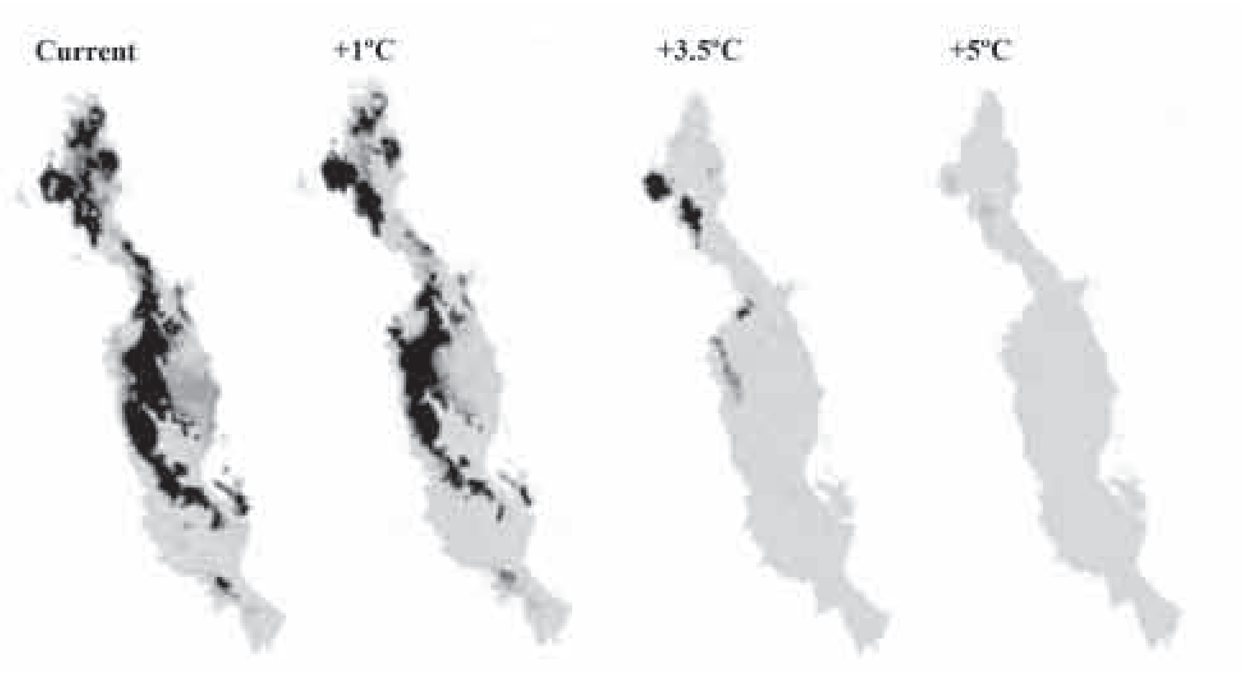
Table 1. Wet Tropics endemic vertebrate fauna predicted to be most at risk from climate change [19, 21].

Frogs	
Thornton Peak nursery-frog	*Cophixalus concinnus*
Magnificent broodfrog	*Pseudophryne covacevichae*
Pipping nursery-frog	*Cophixalus hosmeri*
Northern barred frog	*Mixophyes carbinensis*
Tangerine nursery-frog	*Cophixalus neglectus*
Bloomfield nursery-frog	*Cophixalus exiguus*
Mountain top nursery-frog	*Cophixalus rheophilus*
Northern tinker-frog	*Taudactylus rheophilus*
Mammals	
Atherton antechinus	*Antechinus godmani*
Mahogany glider	*Petaurus gracilis*
Daintree River ringtail possum	*Pseudochirulus cinereus*
Lemuroid ringtail possum	*Hemibelideus lemuroides*
Herbert River ringtail possum	*Pseudochirulus herbertensis*
Spotted-tailed quoll	*Dasyurus maculatus*
Birds	
Golden bowerbird	*Prionodura newtoniana*
Atherton scrubwren	*Sericornis keri*
Mountain thornbill	*Acanthiza katherina*
Skinks	
Thornton Peak skink	*Calyptotis thorntonensis*
Bartle Frere skink	*Techmarscincus jigurru*
Czechura's litter skink	*Saproscincus czechurai*
skink (no common name)	*Saproscincus lewisi*
skink (no common name)	*Lampropholis robertsi*
skink (no common name)	*Eulamprus frerei*
skink (no common name)	*Glaphyromorphus mjobergi*

Golden bowerbird

Mahogany glider

Figure 2. The decline in distribution of species richness of regionally endemic terrestrial vertebrates with increasing temperature (the darker the shade of grey the greater the species richness) [21].



Predicted effects could conceivably have been greater if climate variables other than temperature were considered. Increased CO_2 concentrations, for example, may reduce the nutritional value and increase the lignin component of foliage with detrimental effects on the abundance of leaf-eating fauna. In addition, changes in geographic distribution may push species off nutrient-rich basaltic soils (at mid altitudes) and on to increasingly poorer granitic soils at higher elevations [25]. Forests on these poorer soils generally support lower population densities of leaf-eating fauna [25]. On the other hand, these models are based solely on the degree to which the current macrohabitat of these animals is likely to change (exposure) and ignores possible intrinsic adaptive and behavioural traits of the species, or extrinsic microhabitat factors that may help in countering the extent of the predicted impact. Refinement of these models is a current focus of research efforts.

3.4 Environmental goods and services

Climate change is expected to not only result in severe adverse impacts on habitats and wildlife within the WTQWHA, but also impact upon the environmental goods and services the Area provides (**Table 2**). The region's population receives great value from these ecological goods and services, many of which support economic activities. For example, the supply of a secure and safe water supply supports the quality of life of residents, ensures good public health, and fosters the economic growth and development of the region.

Table 2. Examples of ecosystem goods and services provided by the WTQWHA [29]

Maintenance of the environment	*Utilitarian uses*	*Personal enjoyment*	*Ethics*
• *carbon cycles* • *water cycles* • *water quality* • *regional climates and microclimate* • *flood mitigation* • *groundwater recharge* • *pollination* • *pest control* • *habitat* • *refugia* • *water regulation* • *waste breakdown*	• *water supply* • *tourism* • *recreation* • *genetic resources* • *scientific discovery* • *education* • *horticulture* • *food* • *pharmaceutical products*	• *enjoyment* • *aesthetic pleasure* • *inspiration* • *serenity* • *leisure activities (photography, bushwalking, bird watching, camping)* • *lifestyle* • *sense of place* • *national identity*	• *ethical/moral values* • *intrinsic natural values and importance* • *cultural values* • *historic values* • *existence values*

Rainforest creek

Rainfall and water supply

A reliable water supply is one of the most valued environmental services supplied by the Area. While it is predicted the Wet Tropics region will fare much better than many other regions in Australia with respect to availability of water with the onset of climate change, nevertheless, impacts in this region are expected to occur. These are summarised below:

- An increase in the frequency of El Niño years will reduce summer wet season stream flows.
- Reduced rainfall in the winter dry season as a result of increased evapo-transpiration and decreased cloud stripping will reduce dry season stream flows.
- There will be greater seasonality in stream flows (more variable in the wet season, lower in the dry season).
- There will be greater year to year variability in flows (due to greater frequency of extreme events).
- The combination of low elevation, decreases in freshwater flows and rising sea levels increases the risk of saltwater incursions that may affect the quality of freshwater sources currently tapped for urban and agricultural purposes [18].

Photo: EPA

Mountain stream

Cloud stripping and water supply

High altitude rainforests which are immersed in cloud for a large proportion of the time strip considerable amounts of moisture from passing clouds. Researchers from CSIRO have found that, in some months of the year, up to 40% more water is harvested out of the clouds than is measured as rainfall in a rain gauge. They found that the region's high altitude rainforests behave like giant sponges, capturing large volumes of water directly from clouds, which they then release slowly throughout the year. This process is now believed to be of great importance in maintaining stream flows throughout the dry season.

The process is considered significant to the overall water budget of the region, especially in terms of water recharge during the dry season. For the upland rainforest, cloud-stripping contributes up to 70% of the total water input into the forest system during the drier months. During the wet season, high rainfall masks the importance of cloud stripping which nonetheless still contributes 10-20% of the total water input into the region's upper catchments [16].

Under current climate conditions, cloud stripping occurs in rainforests more than 600m asl (above sea level). With every degree of warming the base of the cloud condensation layer is predicted to rise by an average of 100m. By 2050 we may expect temperatures to be between 1.0ºC to 3.0ºC warmer than at present which equates to a rise in the effective cloud stripping condensation layer from 600m asl to 900m asl. With 3.0ºC of warming, the effective cloud stripping area in the Wet Tropics will decrease by as much as 40% [16]. What this will mean for absolute water yields remains unknown, except to conclude that water yields will be significantly lower, especially in the dry season. The implications of climate change on this process will include:

- reduction in the area suitable for the cloud stripping process
- less cloud stripping in the dry season and generally reduced cloud cover
- changes to vegetation characteristics which may reduce the water stripping capacity of upland rainforest.

Behana Creek water supply

4. Management responses

Summary

Effective action can be taken now to build resilience in the Wet Tropics landscape to the threat of climate change. The actions needed to combat climate change include:

1. on-ground works to improve forest health
2. increasing community awareness and mobilising behavioural change
3. improving and communicating our knowledge of the effects of climate change
4. improving regional planning and coordination.

Management involves allocating resources amongst competing interests. The relative importance of different issues may change as a result of climate change. Therefore, resource allocations need to be adaptive, actively seeking information where there are data and understanding gaps, and taking account of new information as it becomes available.

Changes to ecosystems will inevitably affect human communities and industries that depend on them. Regional communities are dependent on the WTQWHA as a major source of income and an important determinant of lifestyle. The magnitude of the impacts of climate change on the natural values of the region will depend, in large part, on the willingness and capacity of the local community to modify those practices that reduce the ecological resilience of natural and semi-natural habitats. Effective management, therefore, requires the employment of strategies that are socially and economically sustainable [34, 35, 36].

Although there remain uncertainties about the timing, magnitude and geographic distribution of climate change impacts, it is evident the result will be a warming, drying, more variable climate with more frequent, extreme weather events. These climate changes are likely to interact with a broad range of other pressures on the Area. Two recent climate events can help to illustrate the nature of stresses and disruptions to natural, social and economic systems by a climate driven by warmer temperatures: the severe storms of Cyclone Larry in 2006; and the severe drought conditions which affected the region in 2002 and 2003 and the associated penetration of bushfires into rainforest areas.

While climate change has significantly 'upped the ante' with respect to regional land use planning and management issues, the overlap and close relationship between the application of best practice land management measures and constructive climate change adaptation measures is significant. This provides considerable reassurance and opportunities for the region to take useful, 'no

Drought at Lake Tinaroo in 2003

regrets' climate change response measures – the type of measures that will have complementary benefits for maintaining the health and condition of the Area together with long-term flow-on benefits to the regional economy and quality of life. Much of what needs to be done is already being done – it just needs a commitment to do these things better, more often, over a larger area and in a more coordinated and prioritised way. It will also require a commitment from the regional community to embrace these changes and adaptation initiatives. Living in an internationally recognised biological hotspot entails responsibilities to ensure it is conserved for all people and for future generations.

There are two broad categories of climate change responses: mitigation (avoiding or reducing greenhouse gas emissions and increasing sequestration of greenhouse gases); and adaptation (coping with climate change impacts). The following practical steps are aimed at reducing the impacts of climate change on the region's biodiversity, primarily through adaptive responses. This will be achieved through in situ conservation of species and ecological communities by facilitating their natural adaptation by means of improving the overall ecological resilience of the region.

4.1 Resilience

Ecological resilience can be defined as the capacity of an ecosystem to tolerate or recover from disturbance without collapsing. A resilient ecosystem can withstand shocks and rebuild itself when necessary. For ecosystems to persist in the long-term, successful recovery after disturbance is fundamental. Natural systems are characterised by environmental thresholds that, if crossed, may lead to large-scale and relatively abrupt shifts in state, including changes in ecosystem processes and structure [37, 38]. Once a threshold is crossed and a shift in state or a key process occurs, it may be difficult, or even impossible, to reverse the shift.

A major benefit of managing natural systems for overall resilience is that it provides the best general insurance against current and emerging threats [38, 39]. It is inevitable that currently unrecognised threats will emerge within the region, so the best long-term management strategy is to aim for a system with the resilience to recover from as wide a range of anticipated challenges as possible. Factors contributing to ecological resilience include:

- **Biological diversity** – Ecological systems with high biological diversity will generally have greater inherent resilience, largely because they will have more diverse responses and capacities available to them, which can provide the basis for adaptation [40]. Diversity of habitats also increases the likelihood of some habitats being more resilient to impacts from particular stresses or disturbances [40].

Wet sclerophyll forest

- **Connectivity** – Connectivity refers to the extent of the connections between populations. The capacity of natural systems to recover after a disturbance, or to reorganise in the face of new or intensified pressures, depends to a large extent on the ability of plant and animal populations and ecological processes to disperse or move across the landscape.

Photo: Lars Kazmeier

Donaghy's corridor, Atherton Tableland

- **Refugia** – Refugia are areas within the landscape where ecosystems are buffered from pressures or disturbances that would otherwise result in reduced resilience elsewhere. Refugia serve as secure source areas which are important for the replenishment of disturbed populations and serve as stepping stones for maintaining population connectivity across larger scales. Important features of refugia include adequate extent to provide sufficient source populations and inclusion of a diverse and comprehensive sample of many different habitat types.

Photo: EPA

Mountain refuge

Conserving or creating greater landscape connectivity between areas rich in biodiversity, in conjunction with refugia, provides greater opportunities for species and ecological processes to recover, re-establish and relocate or to adapt and evolve. The following four sections outline a range of practical steps that the region can take to help achieve a more resilient natural environment.

4.2 Regional planning, coordination and leadership

4.2.1 Integrating climate change into management

Responding to climate change is unlikely to succeed if it is done in isolation from other land management activities and other agencies involved in land management. The climate change challenge is occurring at all scales, from species to catchment to landscape scales, and across industries, property boundaries and land tenures. For a regional response to be meaningful, all those affected need to be brought together to deliver integrated approaches to natural resource and land management problems. This must involve government agencies, industries and regional communities.

Many management responses to climate change, such as pest management and creating wildlife corridors, are already being undertaken to enhance Wet Tropics conservation. Such conservation activities will become more urgent and priorities may alter in the light of climate change to ensure additional environmental or socioeconomic benefits.

Wet Tropics coastline

What can be done?

- Develop a Wet Tropics Bioregional Climate Change Action Plan aimed at conserving the outstanding universal values and integrity of the Area and the biodiversity of the overall region.
- Coordinate with climate change responses in other sectors such as urban and regional planning, water use, coastal management and Great Barrier Reef planning and management.
- Develop and implement a communications strategy to raise awareness of climate change impacts and the advantages of early attention to adaptation.

WTMA, Main Roads and Terrain NRM brochure

4.2.2 Coordination and alignment

Climate change threats will introduce a range of social and ethical issues that will need to be addressed. A common approach by regional land management organisations and the research community will have benefits.

What can be done?

- Continue to develop the North Queensland Climate Alliance as a network of climate change interest groups at a regional level.
- Support the bid by James Cook University's Centre for Tropical Biodiversity and Climate Change to host the National Climate Change Adaptation Research Facility - Terrestrial Biodiversity Hub in Townsville. This facility would establish a national/international network of climate change interest groups.

- Promote the Wet Tropics Conservation Strategy [49] as the source of conservation priorities for regional land and environment decision-makers.

4.2.3 Reducing emissions

An audit of greenhouse gas emissions commissioned by the Authority in 2007 [48] showed that per capita emissions in the Wet Tropics (23.6 tonnes CO_2 or equivalent) in 2005 were significantly lower than average emissions for Queensland and Australia. However, they remained 70% greater than average emissions for industrialised countries subject to emission targets under the Kyoto Protocol. Low stationary energy emissions in the Wet Tropics were due primarily to hydro, wind and bagasse power and the absence of energy intensive industries. Higher than average transport emissions were partly due to use of aviation fuel. As in many other areas of Australia, local residents are increasingly aware of the need to conserve resources and use less energy. There are ecological and socioeconomic benefits from wise and sparing use of energy and our natural assets such as water and forests.

What can be done?

- Use the regional greenhouse gas audit as a baseline for future monitoring of emissions.
- Provide regional leadership in measures to reduce greenhouse gas emissions.
- Promote the Cities for Climate Protection program in regional councils.

Wind farm at Ravenshoe

Launch of the Wet Tropics greenhouse gas emissions audit

4.2.4 Planning and development

The Far North Queensland Draft Regional Plan 2025 [11] promotes a stronger, more liveable and sustainable community. It acknowledges that the likely impacts of climate change are significant for the region's environment, economy and communities. There has been strong community support for biodiversity conservation in the region and the need for wildlife corridors that will help to build resilience in the Wet Tropics landscape.

Clearing for development, Mission Beach

What can be done?

- Support implementation of policies in the FNQ Draft Regional Plan 2025 [11] that will help to mitigate greenhouse emissions and support measures to build environmental and community resilience.
- Ensure that climate change impacts are considered in all major planning and development decisions.

4.2.5 Wet Tropics tourism

The region's economy relies heavily on a sustainable nature based tourism industry. The principal natural resources on which this industry depends are the WTQWHA and the Great Barrier Reef World Heritage Area. The impact of climate change on these two World Heritage Areas as tourist attractions has the potential to significantly affect the tourism industry, with consequential social and economic impacts.

What can be done?

- Support regional clean and green initiatives by the tourism industry.
- Support moves by the tourism industry to build rainforest resilience and promote green tourism through the use of regional biodiversity offsets.

- Develop regional adaptation strategies for nature based tourism.
- Continue to assess the impacts of climate change on tourism and tourism values (physical, social and economic) and on the relative impact of climate change on the different forms of tourism.

Photo: TQ

Daintree River cruise

4.2.6 Maximising carbon market opportunities

With carbon trading proposed nationally for Australia, significant opportunities exist for biodiversity conservation to be jointly planned for as part of proposals for the biosequestration of carbon. Opportunities for combining greenhouse and biodiversity objectives range from the selection of native species mixes for forest plantation establishment to the creation of strategic corridors, the restoration of landscape connectivity and the buffering of intact natural areas. These multiple environmental benefits could have additional corporate appeal in terms of displaying a company's commitment to broader environmental protection.

What can be done?

- Explore the spectrum of carbon trading and other economic incentives which are available to help achieve or fund effective climate adaptation responses to build resilience for the WTQWHA.

Photo: Barbara Maslen

Daintree Cassowary Care Group

4.3 Improving and communicating our knowledge of the effects of climate change

4.3.1 Building regional capability and reducing uncertainty

While the Wet Tropics region is recognised as being a leader in climate change research for the two World Heritage Areas, there remain substantial gaps in our knowledge of climate change, its impacts and appropriate responses to these impacts. There is also a need to improve the synthesis and dissemination of information so that it is more relevant and understandable to decision-makers and the general community. Key components of adaptive capacity include the ability to generate, access and interpret information about climate change and its likely impacts; suitable methods for identifying and assessing potential adaptation strategies; adequate financial and other resources; and a willingness to adapt.

The region's scientists have generated an impressive base of information about how the climate is changing and the broad physical impacts these changes may have. However, the Authority, other government agencies and the community require improved information about the projections of climate change, particularly of extreme events and their impact upon the Area's values and integrity.

What can be done?

- Support research and educational institutions which place rainforest and reef World Heritage management issues and concerns high on their research and teaching agendas.
- Support the CSIRO and James Cook University projects funded through MTSRF which are starting to provide climate change projections and regional scenarios at scales relevant to decision-makers.
- Increase and promote postgraduate research on the thermal tolerances of threatened species and on possible mitigation measures.
- Develop improved regional climate change projections, extreme climate event projections and improved regional climate modelling and downscaling techniques.

Researcher at work

4.3.2 Understanding social resilience

Social and economic trends that affect the region's vulnerability to climate change and the social and economic impacts of climate change on the region are very poorly understood. It is important for facilitating social and economic resilience that the region supports more social research.

What can be done?

- Collect and analyse social and economic data and trends to assess how these factors are likely to influence vulnerability to climate change.
- Identify social and economic costs of climate change and management response options, including the cost of not taking adaptation action.

Sunbird, an energy efficient house, Cairns

4.3.3 Establishment of climate change research centres

Universities and research institutions have a special role to play in educating and building regional capacity through establishing centres for climate research, fostering international networks of collaborating scientists and institutions, and providing training and career development opportunities for young scientists.

The research capability of the region has increased significantly in the last decade, especially with respect to research on the impacts of climate change on biodiversity and ecosystem processes. However, there is still a need for further research on climate change impacts in the Wet Tropics and how to integrate this research into the management of threatening processes such as fragmentation, pests and fire. This includes the need to identify critical thresholds for natural ecosystems and approaches to increasing their resilience to the impacts of climate change.

A recent bid by James Cook University to establish a national 'Centre for Climate Change Adaptation' would provide a broader examination of the social, economic, agricultural and environmental impacts of climate change and how best to manage them. This would coordinate and integrate research and decision-making about climate change impacts on various community sectors. The centre may also become a funding body to broker research partnerships and develop new research.

Photo: Earthwatch Expeditions

Setting up data loggers in boulder fields

What can be done?

- Support an expansion of the established regional research base into an international hub for research into climate change and its impacts on terrestrial, aquatic and estuarine ecosystems and biodiversity.
- Support the bid to establish a Centre for Climate Change Adaptation in the Wet Tropics.
- Incorporate the implications of climate change into existing regional management plans, strategies, guidelines and policies.

4.3.4 Monitoring

Monitoring climate, climate impacts and management responses is critical given climate change entails so many uncertainties. Monitoring is necessary to detect population changes and species declines or increases. Monitoring should focus on species at special risk, but be flexible enough to detect other changes.

The climate change/biodiversity monitoring plots which have been established in the Wet Tropics by James Cook University and CSIRO researchers, with funding from MTSRF, Smart State and other sources, has provided Australia with an opportunity to join a worldwide network of rainforest monitoring plots. The Wet Tropics plot network has the potential to provide the most comprehensive study of biological communities ever undertaken in Australia. They not only provide the baseline for long-term monitoring for a very large proportion of all the species and bioclimates in the Wet Tropics, but also a large proportion of Queensland’s and Australia’s total biodiversity.

The Wet Tropics has the potential to become a central hub of a global network of biodiversity/climate change monitoring sites. From a topographical and climatic basis, Queensland’s Wet Tropics has affinities with upland tropical forest localities in the upper reaches of the Amazon and Congo basins and in the uplands of the east coast of Madagascar, Brazil and New Guinea [2, 41]. Together, these forests contain a very large proportion of the world's total biodiversity. However, what sets the Wet Tropics apart is that it contains tropical rainforests at their latitudinal and climatic limits. This potentially makes the Area an early warning site for alerting other vulnerable tropical forest hotspots to the emerging effects of climate change.

Photo: Earthwatch Expeditions

Downloading data in the field

What can be done?

- Support the established regional climate change/biodiversity monitoring programs being undertaken by James Cook University and CSIRO.
- Expand the scope of this monitoring to further develop methods to assess and monitor species, communities and ecosystems over the long-term; monitor ecosystem response to help develop and verify predictive models; measure responses to management actions; and assess whether the strategies are effective in protecting biodiversity and ecosystem function.
- Advocate for the increased use and development of remote sensing methods for monitoring such as the use of satellite technology, non-destructive techniques and the use of simulation tools to predict the impact of climate change.

4.4 On-ground works to improve forest health

The following outlines a range of actions that can be implemented to increase the ecological resilience of the region's natural systems. Many are relevant for implementation at both large and small scales, but their efficacy will be increased if they are part of a coordinated effort by all land and natural resource managers.

4.4.1 Managing environmental stress created by climate change

Existing threats

Climate change will interact with many existing threats to the outstanding universal values and integrity of the WTQWHA and other natural and semi-natural areas of the region, resulting in even greater negative impacts on the environment. Reducing other existing threats or pressures to biodiversity will help build resilience into natural systems and species. Natural systems that are already stressed or suffering from multiple pressures are more likely to succumb to the additional stresses of impacts by climate change.

Invasive species

Invasive pest species are generally expected to be climate change winners because they tend to be colonisers or adaptable opportunists and are among the first to occupy new or expanding environmental niches after disturbance or within stressed ecosystems. A particular challenge in this area is the potential for 'sleeper' weeds and feral animals to begin to expand their range suddenly and dramatically in response to even moderate shifts in climate or in response to changes in the frequency of extreme events such as fires or cyclones.

Priority targets for eradication efforts should be those species that have a high potential to invade the Area and those that are currently rare in cultivation and rare in the wild. Invasive introduced grasses are another group of weeds that justify special attention. Introduced flammable grasses are already a serious environmental threat even without considering climate change. Guinea grass and molasses grass, for example, grow taller than native grasses and also grow in much thicker stands preventing native tree recruitment, both by shading out their seedlings and fuelling hot fires that destroy them.

Pond apple

Fire

Land managers will need to accept that a new climate regime may bring a permanent change to fire regimes for various native ecosystems throughout the non-rainforested parts of the region. Regional land managers will need to consider investing more in fire management to reflect any increased fire risk and identify and protect fire refugia where natural fire regimes can feasibly be retained.

Photo: EPA

Controlled burn

What can be done?

- Reduce other (non-climate) environmental pressures.
- Eradicate newly emerging invasive pest species and control or contain more widespread invasive plant, animal and disease outbreaks.
- Assess and model the implications and synergies between climate change, fire management and ecosystem alterations.

4.4.2 Managing landscape health in the face of climate change

Landscape connectivity

Connectivity refers to the maintenance or restoration of key, large-scale ecological phenomena, flows, and processes critical to the long-term conservation of biodiversity [42]. This may range from large-scale ecological processes such as water cycles and flow regimes to the transfer of genes from lowland areas to upland areas. An important connectivity process with respect to climate change is the role of dispersive species. Dispersive species are those species that are capable of travelling large distances and may be important in moving pollen and seed over large distances. While the capacity of dispersive species for long distance travel will be advantageous in the face of climate change, habitat fragmentation and degradation may present significant barriers to species that may need to move to new habitats and refugia.

Ecological corridors

A wildlife corridor refers to a swath of land or a watercourse intended to allow passage by identified wildlife species between two or more forested areas. Wildlife corridors are generally considered at a local scale and for individual species. Their primary purpose is to link otherwise separated populations and for mitigating other impacts of habitat fragmentation on wildlife populations [43, 44]. Designing a corridor network involves identifying specific lands that will best maintain the ability of wildlife to move between forested blocks, even if the remaining land becomes inhospitable to wildlife movement. Climate change adds greatly to the rationale for conserving or creating ecological corridors. Although the most important corridors are those that run long distances or which capture an altitudinal gradient [45], all corridors promote genetic exchange and link populations, which in turn fosters adaptation to climate change. Strengthening and extending networks of corridors by planting trees will also provide a carbon sink. A regional corridor network will benefit and increase the resilience of many species of wildlife and vegetation communities by mitigating some of the detrimental ecological impacts arising from surrounding land uses and by providing conduits through which:

- wildlife can disperse from areas which have reached maximum carrying capacity and/or competition, and recolonise other favourable habitats, potentially improving the resilience of a population to stress
- wildlife can follow or escape local or longer-term seasonal changes in environmental conditions
- wildlife can access previously separated populations with which breeding may take place, better maintaining and possibly improving genetic variability.

Cassowary

Refugia

In evolutionary terms, refugia are parts of the landscape in which certain types or suites of organisms are able to persist during periods in which most of their original geographic range becomes uninhabitable because of climatic change. The resulting refugia contain high frequencies of endemic species because the species in them tend to respond to the contraction of range by evolving differences from their original, widespread stock [46].

Refugia, therefore, are important as they represent those areas where favourable habitat will persist or develop as the climate changes. As conditions outside refugia become hostile with changing climate, a species will be lost from the wider range and persist largely in the refugia. Locations that have served as refugia during past climate changes may serve as refugia for the present period of climate change. However, refugia may also develop outside of the current range of a species as climate zones shift and ecosystems shift with them. In this case, it will be crucial to also identify and protect these new refugia and migration corridors to them.

Bellenden Ker mountaintop vegetation

Habitat replication

Replicate, secure habitats are a vital form of insurance as they protect multiple source populations, climate refugia and migration corridors. The smaller and more isolated a habitat, the more likely it is to lose species over time and the more vulnerable it is to stressful events such as cyclones, droughts, fires or floods. With sufficient habitat replication, a species has a greater likelihood of remaining viable with a greater capacity to adapt to environmental change. Although the WTQWHA captures a great diversity of habitats, refugia and migration corridors due to its possession of significant environmental gradients, there are many lowland and tableland habitats that are poorly represented within the Area.

What can be done?

- Maintain and enhance landscape-scale ecological connectivity.
- Identify, conserve and create wildlife corridors.
- Identify and protect climatically stable refugia.
- Ensure habitats, species and other environmental values are replicated in the protected area estate wherever feasible.
- Increase landscape and habitat heterogeneity within protected areas, including altitudinal, latitudinal, topographic and vegetation diversity.

4.4.3 Ecological site management

Tree plantings

One of the biggest opportunities to improve landscape condition and connectivity is through programs of strategic tree plantings and habitat restoration. From both a biodiversity and natural resource management perspective, riparian revegetation is a high priority as it has multiple environmental and economic benefits such as stabilising stream banks, filtering runoff, shading streams (thus keeping water temperatures within their natural range), and contributing to the food web for in-stream biota. Replanting schemes also offer opportunities for reintroducing genes to isolated populations, increasing the population size of threatened species and providing keystone resources to increase the ecological functionality of wildlife corridors.

Revegetation

Thermal refuge sites

Ecologists use the term 'refuge' to mean a location in which a species or suite of species can persist for short periods when large parts of their preferred habitats become uninhabitable because of unsuitable climatic or ecological conditions.

Deep gullies, rock outcrops and south-facing slopes are landscape features that are generally cooler than their surroundings, thereby providing sites that offer thermal relief. Special consideration and priority should be given to these and other landscape features that create a mild microclimate. Habitats can also be enhanced to increase cool microclimates. For example, riparian vegetation can be restored to shade watercourses, logs and rocks installed as part of revegetation projects or in semi-natural areas to provide cool sites to assist native species. In general, tree plantings significantly cool and insulate sites. The loss of shady riparian vegetation, silting up of deep pools and the lowering of water levels all lead to higher stream temperatures that may be intolerable for some aquatic wildlife. Improving stream habitat quality might include the maintenance of cooling features such as the restoration of riparian cover or restrictions on water extraction.

Photo: Kerry Trapnell

Thornton Peak

What can be done?

- Revegetate cleared and degraded areas.
- Identify, conserve, create and enhance cool climate refuges/sites within the landscape.
- Identify, conserve and create aquatic refuges.

4.4.4 Species management

Species at risk

A large proportion of the species identified in the listing of the WTQWHA as having outstanding and universal value have one or more of a range of characteristics. They are:

- restricted to high-altitude environments
- have small and/or isolated or bounded distributions
- have small restricted ranges
- have poor dispersal capabilities
- are physiologically susceptible to extreme temperatures
- are considered to possess extreme habitat/niche specialisation
- show close, co-evolved, or synchronous relationships with other species
- display inflexible physiological responses to climatic variables
- are at the limits of their latitudinal or altitudinal range.

In some cases it is likely that climate refugia or core habitats cannot be maintained, are unlikely to persist, or migration may not be possible.

Spotted-tailed quoll

Key functional groups

Recovery processes are frequently highly sensitive to disturbance, highlighting the importance of identifying and protecting the functions that are essential for recovery. One function of central importance to the resilience of rainforest ecosystems is dispersal, particularly seed and pollen dispersal.

The conservation of long-range seed dispersal and pollinator fauna is important to promote genetic adaptation. Some trees have highly mobile pollinators and the transfer of pollen from warmer adapted and/or more stress tolerant populations of a species to less well adapted or tolerant individuals will help them produce offspring better adapted for a warmer or more environmentally stressful future.

Photo: Mike Trenerry

Spectacled flying fox

While the importance of dispersal to the functioning of Wet Tropics rainforest ecosystems has been a focus of research in recent years, many other species groups are also likely to play an important role in resilience. Although less studied, higher trophic species such as predators exert important top-down controls on trophic systems. These predators, which generally require large territories for survival, selectively remove individuals from prey populations that are less well adapted to their environment. Without this selective pressure, it is possible that many lower-trophic species will take longer to adapt to changes in conditions associated with climate change.

Translocations

Translocation of species outside their natural range entails risks. The Intergovernmental Panel on Climate Change [47] warns that 'moving species to adapt to the changing climate zones is fraught with scientific uncertainties. The consequences of invasive organisms cannot be predicted; many surprises would be expected.' Because of the inherent risks, translocation is identified here as a policy of last resort, as something to address in the future, except perhaps with the selection of provenances of trees for replanting projects. Translocation assumes that:

- appropriate host habitats are available, correctly identified and will not be disrupted
- ecological relationships are fully understood and can be catered for
- resources will be available for all individuals of the translocated and resident species.

Mass plantings based on climatic predictions assume complete climatic and biological knowledge, which is usually lacking. Plantings should focus on key areas such as riparian strips where natural resilience has been lost. Elsewhere, natural regeneration, perhaps in conjunction with weed control, is likely to be a more effective approach to recovering resilience over large areas. In contrast to plantings, natural regrowth can be achieved over large areas, is less costly, and selects for genotypes adapted to the prevailing climate trends.

Captive breeding and cultivation

Captive breeding populations could be established for species at high risk of extinction. Botanic gardens and herbaria could play a role in the preservation of species and genetic material over time and could play an important role in educating the public about climate change impacts.

What can be done?

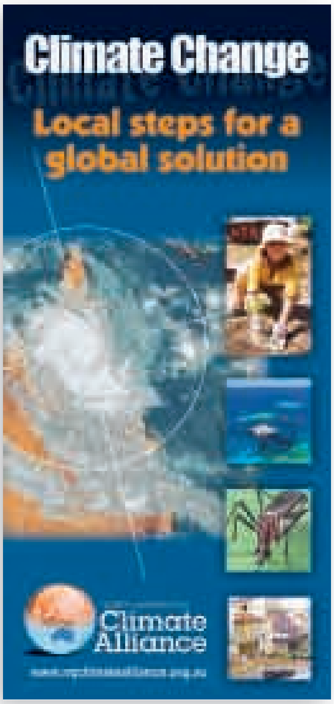
- Identify significant species at risk and plan their recovery and research needs.
- Identify, conserve and encourage key functional groups such as long-range animal dispersal vectors (seed and pollen).
- Develop policies and guidelines regarding the translocation of species (as a last resort).

4.5 Increasing community awareness and mobilising behavioural change

Community involvement will be vital to ameliorate climate change impacts and reduce greenhouse gas emissions in the Wet Tropics [49]. While the potential impacts may be severe, the Wet Tropics is also fortunate to have significant capacity to reduce emissions and create a healthy and resilient landscape. The region is also well placed to potentially benefit ecologically and economically from carbon offsets through tree planting programs with exceptionally high biodiversity value.

Tree planters from TREAT

Community awareness



Climate Alliance brochure

The Authority and a range of other government agencies and community groups actively promote public education about climate change and how its impacts may be addressed. Community education promotes the benefits of biodiversity conservation for the community's quality of life. It ranges from general public awareness about the need to reduce energy and resource use to the need to incorporate biodiversity conservation into a sustainable regional community. For instance, many schools have adopted programs to minimise electricity use at the school and are also planting trees or building wetlands in the grounds to attract wildlife. Landholders are also targeted for education about how to control weeds and feral animals, fence animals out of areas rich in biodiversity or plant trees to prevent erosion and promote habitat for wildlife.

Community engagement

The Wet Tropics Conservation Strategy [49] advocates cooperative management and community engagement to address pressures on the WTQWHA. There is already a strong local culture of conservation and support for the Wet Tropics and Great Barrier Reef World Heritage Areas. Large sectors of the community are already actively engaged in conservation measures such as planting wildlife corridors, wildlife care and weed control. Such activities are not restricted to conservationists and now include such diverse groups as primary producers, the tourism industry, infrastructure providers, Rainforest Aboriginal people and local businesses [49]. For instance, the creation of the Barron River Green Corridor

Media relations

Project has been funded and implemented by all levels of government and a range of businesses, landholders and volunteers. Increasingly, local residents are seeing the social and economic benefits that flow from community conservation. The majority of these measures are also vital to help address climate change impacts.

What can be done?

- Continue to raise awareness of climate change and adaptation options.
- Develop and distribute educational material specifically about climate change and its impacts on the Wet Tropics.
- Enhance existing community capacity to undertake conservation works to reconnect habitat and control weeds and feral animals.
- Ensure community involvement in regional planning.
- Provide incentives for landholders to engage in biodiversity conservation on private lands.
- Facilitate, support and champion coordinated action on adaptation involving land managers, communities and government agencies.
- Support and champion initiatives to increase regional capacity to deal with the challenge.
- Promote community involvement in climate change and conservation research.

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