WET TROPICS
MANAGEMENT AUTHORITY

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# STATE OF WET TROPICS 2019–2020

*Creating our climate future*

*Creating our climate future*

# State of Wet Tropics 2019–2020

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**Acknowledgement of the Rainforest Aboriginal Peoples of the Wet Tropics**
The Wet Tropics Management Authority acknowledges and recognises Rainforest Aboriginal Peoples as the Traditional Custodians of the Wet Tropics World Heritage Area and recognises their connection to this cultural landscape. We pay respect to Elders past, present and future. We recognise Rainforest Aboriginal Peoples' ongoing and essential connections to the Wet Tropics land, sea and sky country and their rights and responsibilities under customary obligations and Aboriginal lore. The Wet Tropics Management Authority supports the active roles of Rainforest Aboriginal Peoples in the ongoing management and governance of the Wet Tropics World Heritage Area.

Section 28 of the *Queensland Human Rights Act 2019* provides for the protection of cultural rights of Aboriginal peoples and Torres Strait Islander peoples. It is acknowledged that there are scientifically reported effects of climate change which could have the potential to impact on Aboriginal cultural values in the landscape.

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**Further information**
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The Wet Tropics Management Authority is confident that through collaborative action and commitment, our communities can ensure a secure future for the irreplaceable Wet Tropics of Queensland World Heritage Area.

# Message from the Chair

The Wet Tropics of Queensland World Heritage Area (the Area) is an extraordinarily diverse natural asset. It contains the world's oldest continually surviving tropical rainforests, is home to ancient living cultures, and is ranked the second-most irreplaceable World Heritage site on Earth because of its unique concentration of endemic, rare and ancient species.

The presence of these rainforests, clinging to the edge of a dry continent, arises from a rare combination of finely balanced climatic and topographic features. Even small changes in temperature, rainfall or fire regimes could irreversibly transform living conditions for endemic species and forests in the Wet Tropics.

Climate change is happening now. We are already experiencing longer and hotter summers, altered rainfall patterns and more frequent natural disasters from climate change, including an increased risk of wildfires and cyclones. The consequential impacts on the natural values of our World Heritage Area are a threat to our economy, our communities and our way of life, as well as to our environment.

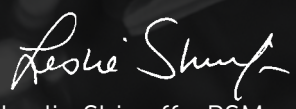
In November 2019, the Wet Tropics Management Authority (the Authority) released its Accept, Act, Adapt: Climate Adaptation Plan for the Wet Tropics 2020–2030, calling for urgent action from governments and communities to limit climate change impacts through delivery of targeted, on-ground priority actions. To realise these priorities and secure the Area's future, the Authority is pursuing multiple avenues of investment and involvement.

We can see that a transition is underway as countries around the world move to adopt low-carbon futures. Reducing greenhouse gas emissions is clearly important at the national and global scale for mitigating climate impacts. At the regional level, emphasis must be on adapting to anticipated changes to the climate and building capacity to respond.

The best way to make the forests of the Area resilient to the emerging 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 impacts of human activity in and around the Wet Tropics.

Ensuring the health of Wet Tropics forests is already a core goal of management. However, the threat of climate change means that we must act strategically, together, and immediately.

**#AcceptActAdapt**



Leslie Shirreffs, PSM

Chair, Wet Tropics Management Authority

# Executive summary

Climate change is the most significant threat to the long-term outlook of the Wet Tropics of Queensland World Heritage Area (the Area). Significant global action to address climate change is critical to slow the deterioration of rainforest ecosystems and their heritage values, and to support recovery. However, at the regional level emphasis must be on adapting to anticipated climate change, such as higher temperatures, the increased prevalence and intensity of extreme weather events, sea level rises and longer, more intense fire seasons.

The Area retains the largest area of tropical rainforests in Australia, and is considered to have outstanding value for the whole world, leading to its World Heritage listing in 1988. Although it represents only a tiny part of Australia, it supports the highest level of biodiversity of any region on the continent. The survival of these species depends on the health of the Area's rainforests and its surrounding landscapes and waterways.

Rainforest Aboriginal Peoples have lived in and managed the Wet Tropics for tens of thousands of years, and their living cultures and customs are formally recognised on Australia's National Heritage List. The health of country is essential to the physical, psychological and spiritual well-being of Rainforest Aboriginal Peoples, and they are already observing impacts on their connections to country due to climate change.

Declines in the distribution and density of endemic and specialised cool-adapted rainforest species have already been recorded in the Wet Tropics—and there are some sobering predictions of modelled impacts, even in the short term. There is a critical need for science-based solutions, advocacy by informed communities, and substantial resources to implement on-ground actions in support of the resilience of the Area.

More extreme and unplanned bushfires will occur in the future. Our warming climate—driven by greenhouse gas emissions—is exacerbating every risk factor for more frequent and intense bushfires. A new approach to fire management, in consideration of both Aboriginal traditional burning practices and emerging science, will be critical.

Invasive species will increasingly impact the Wet Tropics. Existing problems, like feral pigs, and more recent threats, like myrtle rust, will require collaborative effort and resources to manage. Multi-faceted strategies like the Wet Tropics Management Authority's highly effective Yellow Crazy Ant Eradication Program will form the basis of whole-of-community, rapid-response approaches to pest management.

Many livelihoods in the Wet Tropics depend on healthy natural systems. Our reefs and rainforests generate a direct economic contribution to the region of more than $11 billion per annum. As climate change increasingly affects the provision of ecosystem services, Wet Tropics communities will experience changes in economic prosperity, health and well-being.

Regional population growth will put pressure on the natural environment and increase demand for infrastructure like roads, dams and energy supply. On the coast, extreme inundation and erosion events will become more frequent. The cost of insurance may increase as a result.

Tourism already plays an important role in presenting the Area to visitors, and its evolution will bring economic and employment growth, but also increase the need for infrastructure and management of impacts. A strategic, planned approach to responsible tourism across the Wet Tropics will enable the broader community, including Rainforest Aboriginal Peoples, to share in presentation activities and the benefits of tourism.

The Authority is already working alongside stakeholders and communities in the Area to establish region-wide responses to climate change in the Wet Tropics. This report reminds us of the need to accept that biodiversity and ecosystems—and the services they provide—are already changing and will continue to do so. The imperative is that we act strategically, together and immediately, and take steps to empower action that helps Wet Tropics natural systems, cultures, communities and economies to adapt.

The Authority is confident that through collaborative action and commitment, our communities can ensure a secure future for the irreplaceable Wet Tropics World Heritage Area.

# Introduction

The Authority's annual State of Wet Tropics report updates stakeholders and community members on the integrity and state of the Wet Tropics of Queensland World Heritage Area (the Area).

This report examines the current impact and ongoing threat of climate change to the Outstanding Universal Value of the Area and the actions required to ensure its long term health. In concert with the recent release of the Authority's Accept, Act, Adapt: Climate Adaptation Plan for the Wet Tropics 2020–2030, this report emphasises and examines:

- the need to **accept** that biodiversity and ecosystems—and the services they provide—are already changing and will continue to change
- the imperative to **act** strategically, together and immediately
- tangible steps to empower action that helps Wet Tropics natural systems, cultures, communities and economies to **adapt**.

## Accept, Act, Adapt

Released in November 2019, the Authority's Accept, Act, Adapt: Climate Adaptation Plan for the Wet Tropics 2020–2030 [1] calls for urgent action from governments and communities to limit climate change impacts. It states that effective action must be taken now to build ecological resilience in Wet Tropics landscapes through:

- improving landscape resilience that promotes or restores the potential for adaptive change in biodiversity and ecosystems by managing for diversity in the structure, composition, processes and functions in Wet Tropics landscapes
- establishing inclusive regional adaptation planning and coordination frameworks that increase the efficiency of planning processes for adaptation in the Wet Tropics region and establish mechanisms that enable cross-sectoral planning
- facilitating transition to adaptive communities and industries by implementing transformative actions in the management of natural systems and actively supporting decisions that achieve transition to ecologically, culturally, socially and financially sustainable systems under new and uncertain climatic conditions.

## Outstanding Universal Value under threat

The rainforests of the Area were forged in ancient and long-term cycles of change in climate dating back to the time of the supercontinent Gondwana. It is no small irony, then, that human-induced climate change is now regarded as the fastest growing threat to the Outstanding Universal Value (OUV) and integrity for which the Area was inscribed onto the UNESCO World Heritage List in 1988 [2, 3].

The climate change threat to biodiversity in the Wet Tropics is well documented. The IUCN (International Union for the Conservation of Nature) World Heritage Outlook 2 [4] states that 'the insidious and damaging threat posed by invasive plants, animals and diseases, and the high risk posed by the predicted impacts of climate change present real danger to the continuing integrity of the site's biodiversity and associated endemic species'.

## Wider climate impacts: cultural and economic

Along with high biodiversity, there are numerous and substantial economic and cultural values associated with the rainforests of the Wet Tropics, including agriculture and tourism. Outside of the protected area estate there are multiple, and sometimes conflicting, demands for use of natural resources. Climate change is likely to exacerbate these issues and challenges.

Rainforest Aboriginal Peoples are important inhabitants and land managers across the Wet Tropics who will be directly and indirectly affected by climate change [5]. Rainforest Aboriginal Peoples are aware of climate change-induced ecosystem change because of the close associations between healthy country, physical and mental well-being and cultural practices. Rainforest Aboriginal Peoples' traditional knowledge about land and sea will be a valuable resource in adapting to, and dealing with, climate change in the Wet Tropics [6,7].

Agriculture in the Wet Tropics region is likely to be challenged by climate change, requiring adaptations in where, what and how food is produced in the region. This sector's responses will flow on to other sectors.

Tourism associated with the natural assets of the Great Barrier Reef and the Wet Tropics World Heritage Area brings in more than $11 billion per annum to the region [8]. We have already seen the response of the tourism sector to perceived declines in the health of the Reef; climate change impacts could, therefore, have ongoing and long-term consequences for the region's economy and communities.

The Wet Tropics alone provides more than $5 billion of total economic value, including ecosystem services, to the communities of the region [9], clean water, aesthetic and cultural values. These are also at risk as the climate changes and our relationship with the rainforest shifts.

## Why is the Wet Tropics irreplaceable?

The unique biodiversity and its significance in understanding evolutionary history makes the Area one of the most important and irreplaceable regions in the world [10]. The Wet Tropics retains the largest area of tropical rainforests in Australia, supports the highest level of biodiversity of any region in Australia and fulfills all four natural criteria for World Heritage listing. Covering just 0.12% of Australia, the Area is home to an exceptionally high proportion of the nation's biodiversity including:

**3,300+** plant species including **700+** endemic species

**700+** vertebrate species including **88** endemic species

**30%** of Australia's marsupial species and **48%** of bat species

**45%** of Australia's bird species and **60%** of Australia's butterfly species

**25%** of Australia's frog species

**41%** of Australia's freshwater fish species

**65%** of Australia's fern species and **30%** of Australia's orchids

**16%** of Queensland's Critically Endangered plant species

**15** of the world's **26** ancient linages of flowering plants, the highest concentration in a single protected area on Earth.

"Our Wet Tropics lifestyle as we know it will change substantially."

# Wet Tropics regional climate projections

The Intergovernmental Panel on Climate Change (IPCC) [11] is now over 95% confident that human activities are changing Earth's climate, even with allowances made for natural variability. Climate change projections for the Wet Tropics are well documented [12], while historic changes also give us an eye into the future climate of the region. Without strong intervention, this future is not one that bodes well for the rainforests of the Wet Tropics. These climate change projections [13, 14], are highlighted below.

At a glance:

- More hot days and fewer cold days will occur.
- Extreme weather conditions such as heat waves, floods and droughts will increase in frequency and severity.
- Tropical cyclone intensity is likely to increase, while overall frequency may decrease.
- Fire seasons may lengthen and intensify.
- Rising sea levels are expected to increase the area of lowlands affected by storm surge and saltwater intrusion and inundation.

## Higher temperatures

Maximum, minimum and average temperatures are projected to continue rising:

- 0.5 to 1.4°C over 1986 to 2005 levels by 2030
- 1.0 to 3.2°C by 2070.

Average summer temperature could rise from 27°C:

- to over 28°C by 2030
- to over 30°C by 2070.

## More extreme temperature spells

There is likely to be a substantial increase in the temperature reached on the hottest days, and an increase in the frequency of hot days.

## More intense downpours

Rainfall predictions to 2070 continue to show a large amount of variability. There may be slight declines in spring rainfall by the end of the century.

The intensity of heavy rainfall events is likely to increase.

### Fewer but more intense tropical cyclones

Tropical cyclones are projected to become less frequent, but with increases in the proportion of the most intense storms.

### Uncertain changes to fire frequency

Fire weather conditions are expected to worsen.

More extreme fire events and impacts when they occur.

### Sea levels will continue to rise

Sea levels are projected to rise by 0.8m above present day levels by 2100.

Higher sea levels will increase the risks of coastal hazards such as storm tide inundation.

20% to 30% increase in storm surge height.

### Reduced cloud stripping

A rise in the altitude of the cloud base is predicted, reducing the total effective transfer of water from the atmosphere to the region's terrestrial systems (cloud stripping).

### Wind

Wind speeds are expected to increase across eastern Australia.

A changing climate is already impacting the Area, and without intervention will continue to do so with increasing severity and implications for the Area's ecological, social and cultural values.



"Climate change is expected to not only result in severe adverse impacts on habitats and wildlife within the Area, but also impact upon the ecosystem goods and services the Area provides..."

# Current and future impacts of climate change on Wet Tropics values

Research shows that the Outstanding Universal Value (OUV) of the Area is highly sensitive to climate change [15,16]. This OUV is associated with the natural assets of the Area that in turn provide ecosystem services such as flood mitigation, leisure activities or educational opportunities to Wet Tropics communities.

Climate change is, therefore, the major threat to not only the ecosystems and biodiversity of the Wet Tropics, but to our economy and community health and well-being. The Wet Tropics lifestyle as we know it will change substantially.

While some regional climate projections discussed in this document are dealing with scenarios up to 50 years into the future, there is evidence that climate change is already affecting the Area.

For example, long-term monitoring in the Wet Tropics has already highlighted declines in the distribution and populations of many rainforest species due to climate change [17, 18], and only last year (2019) record temperatures at the Area's mountain peaks were recorded years earlier than climate models anticipated [19].

Large-scale changes in the distribution of species and complete turnover of future ecosystems are predicted as responses to climate change.

At a glance:

- Rainforest Aboriginal Peoples are already observing loss of cultural heritage sites.
- Fifty upland species could become globally extinct from the Wet Tropics World Heritage Area with only a moderate average temperature increase.
- Invasive species will increasingly impact native species with no natural defences.
- Bushfire risk will increase, changing fire regimes.
- Some ecosystems of the Wet Tropics will disappear entirely.
- Many species, especially cool-adapted mountaintop endemics, will be displaced.

## Indigenous knowledge and climate change

There are at least 20 Rainforest Aboriginal tribal groups, made up of 120 clans and 8 language groups—over 20,000 people—with ongoing traditional connections to the landscapes of the Area. Across these groups there is a huge body of rich and diverse traditional knowledge about the Wet Tropics environment.

Rainforest Aboriginal Peoples' unique cultural connection to and successful management of land and sea country, and associated systems of kinship and customary law underpinned by biocultural knowledge systems, result in simultaneous high resilience and high vulnerability to climate change impacts [20].

Rainforest Aboriginal Peoples are already experiencing the impacts of climate change, including:

- loss of community, environmental and cultural heritage sites
- loss of land and hunting ground
- longer drought periods and greater bushfire risk
- increased risks of flood events and more frequent coastal flooding and associated impacts such as coastal erosion [21, 22].

Rainforest Aboriginal Peoples' exposure to such climate impacts is compounded by existing socio-economic disadvantages such as chronic poor health, limited employment and the burdens of the colonial history of dispossession and hostile policy settings [23, 24].





## Climate memory

by Frank Royee, Malanbarra Elder, Gordonvale

"The river is our lifeblood. It provides our food, our drinking water, everything we need is in the river and the land. Indicators on the river tell us how healthy our sites are. We look for clean water, little crustaceans, water plants. When we walk along the river, we see little plants underwater, we call them water filters. They collect all the silt and dirt and we know the water is clean to drink where they grow. We are losing crustaceans. There used to be one breed of freshwater prawns, now we are getting a different breed with a red tail instead. These are things you notice when you walk on country. You see things, you see the rainforest dry in summer, you see the old people's fruit trees dying.

We use the 'poison vine' to hunt fish. We crush it up and filter the milky sap into the rapids. It takes the oxygen out of the water and stuns the fish. We scoop them up when they rise the surface. It is the easy way to fish! But things are starting to flower at the wrong time. We have to look harder for the poison vine and it is not flowering when we expect it. We can't hunt how we want to, how we were taught."

# Message from the Rainforest Aboriginal Peoples of the Wet Tropics World Heritage Area and biocultural region (abridged) [25]

A forum of Rainforest Aboriginal Peoples from across the Wet Tropics sent a strong resolution to the First Nations Climate Summit, held in Brisbane on 4 June 2019 [26].

"Our traditional country is the world's oldest continually surviving rainforests and home to our peoples for more than 65,000 years. Our lands, seas and waters are under imminent threat from climate change, with escalating decline of our plants and animals already being observed due to increasing temperatures, changed fire patterns and extreme weather events. We express our support to consider the threats posed by a changing climate to our natural and cultural values and to the spiritual, material, intellectual and emotional features of our landscapes and seascapes, our seasonal indicators and our areas of customary responsibilities.

Our ambition is that traditional knowledges and western science is brought together to identify ways forward to address those threats and impacts, and influence action to improve the resilience of our lands, seas and waters. Climate change will, and already is, further disconnecting our people from the lands, seas and waters and from our ancestral spirits connected to Country. We call on the Australian, Queensland and local governments to take strong action on climate change."

## Opportunities for invasive species

Although many species are likely to be negatively affected by climate change, the greatest community and ecosystem impacts may come from native and/or exotic plant or animal species that are favoured by changed conditions [27, 28].

Climate change will likely increase the number and intensity of disturbance events—fires, drought or cyclones—in the Wet Tropics [29], placing greater stresses on native species and ecosystems. Weeds, which often outcompete native species, are already one of the most serious threats to Australian biodiversity [30, 31].

A shift of suitable habitat for existing species creates the opportunity for new and as yet unidentified invasive threats. For example, species already present in Australia in low abundance may thrive in the Wet Tropics under more favourable conditions brought on by climate change.





# Invasive species threaten the Outstanding Universal Value of the Wet Tropics World Heritage Area

With increased tropical cyclone intensity we expect to see significant structural and compositional changes to tropical landscapes from weed invasion. When native vegetation is stressed or destroyed by droughts, fires, floods or severe storms, weeds gain new opportunities to replace native species. There is a huge pool of invasive plants available to colonise bare spaces. Vines and woody invasive species that are shade-tolerant and recruit from the seedling layer may constitute the greatest threat to the Wet Tropics following severe storms.

Some weeds—like *Miconia calvescens* (Miconia), the 'purple plague'—establish after disturbances like cyclones but persist as the canopy closes again, growing and producing seeds. After the next major cyclone disturbance, they are ready to germinate in far greater numbers, dominating areas and excluding all native species, as they have done in areas of Hawai'i [32].

Other weed species, such as *Chromolaena odorata* (Siam weed) are extremely fast growing with the capacity to scramble over existing vegetation, displacing native vegetation and increasing the fire hazard. Currently, most of these potential 'ecosystem engineers' are managed, but significant resources will be needed for ongoing and coordinated intensive management to maintain vigilance and take swift action to eradicate or contain emerging threats.


## Changed fire regimes

Evidence suggests that climate change is causing, and will continue to cause, increases in the severity and duration of fire weather [33]. In fact, 2019 was Australia's hottest and driest year on record [34]. This is likely to lead to significant changes in fire regimes in the Wet Tropics, but there are not yet any specific projections due to the complexity of climate-fire-vegetation interactions. Such forecasts are urgently needed so that we can plan and secure the capability to manage this threat to natural ecosystems and communities.

More extreme fire weather, and changes in the timing and or quantity of rainfall, will affect fuel load and combustibility, and will likely alter fire regimes. Rainforest, previously considered a natural fire barrier, is now vulnerable to fire. The Wet Tropics region can expect more frequent and more intense fires due to hotter temperatures, more droughts, longer periods of low humidity, carbon dioxide-induced increases in vegetation biomass and smaller windows of opportunity for prescribed burns. Increased threats from invasive weeds as a result of climate change will also alter fire regimes in the Wet Tropics.

# Does it matter if rainforest burns?

During the 2019 summer, 80% of the Blue Mountains World Heritage Area and more than 50% of the Gondwana Rainforests World Heritage Area burned [35].

The scale of the disaster could affect the values for which both these World Heritage Areas are internationally recognised, not to mention the threat to lives and property. The catastrophic event was described as "climate change in its most fundamental form" and "totally, totally unique and unprecedented" [36].

However, 12 months before in the Wet Tropics World Heritage Area—after a dry season that had been unusually long, coupled with extremely high temperatures—a wildfire burned for 10 days, destroying mature trees across about 300 hectares. Here, the forest canopy had been previously damaged by severe tropical cyclones Larry and Yasi. Vines that had grown into the disturbed canopy carried the fire from the forest floor and into the tops of the trees [37].

Whilst rainforest species are typically considered fire sensitive, rainforests rarely burn. Typically, due to decomposition, rainforests have a very low amount of surface fuel (mostly made up of dead, moist leaf litter and twigs). These naturally high levels of moisture result in rapid breakdown of leaves so that these areas have much lower fuel loads compared to adjacent wet and dry eucalypt forests. In addition, moisture in the soil and vegetation slows or stops the fire.

Because the Wet Tropics is expected to become more susceptible to extreme weather events due to climate change, wildfire risk is expected to rise. A regime of increased fire, even low-intensity fire, will likely impact on these communities by changing the species composition and, potentially, the flammability of the systems. The promotion of drier, more flammable (often invasive) species in the rainforest, is also likely to promote fire.

At present, scientists are unable to definitively say how old-growth rainforests will respond to fire damage. There are worrying observations that Siam weed, an invasive plant, has begun growing in the burnt area at Japoon National Park.

While a single fire may not be cause for concern, the frequency of fires is. Fires that occur too closely together will not allow sufficient time for plant or animal populations to recover enough to respond. A high-intensity fire which kills all of the trees, such as those that occurred in the southern rainforests, will result in ecosystem change that may take centuries to recover, if it recovers at all.

## Abundance and distribution of key species

Climate change is likely to impact on ecosystem processes such as dispersal, pollination and migration. Already there is evidence of species movement, particularly in mountaintops where cool-adapted species are moving to higher altitudes. Habitat connectivity will be important for species needing to move, meaning some species will fall under threat of climate change when this connectivity does not exist due to forest fragmentation [38].

Climate change is leading to changes in the distribution of suitable climate space for many species, and these species will either have to acclimatise or move if they are to persist [39]. Different species perform different roles in ecosystem processes, which will dramatically impact our lives and interactions with the Wet Tropics.

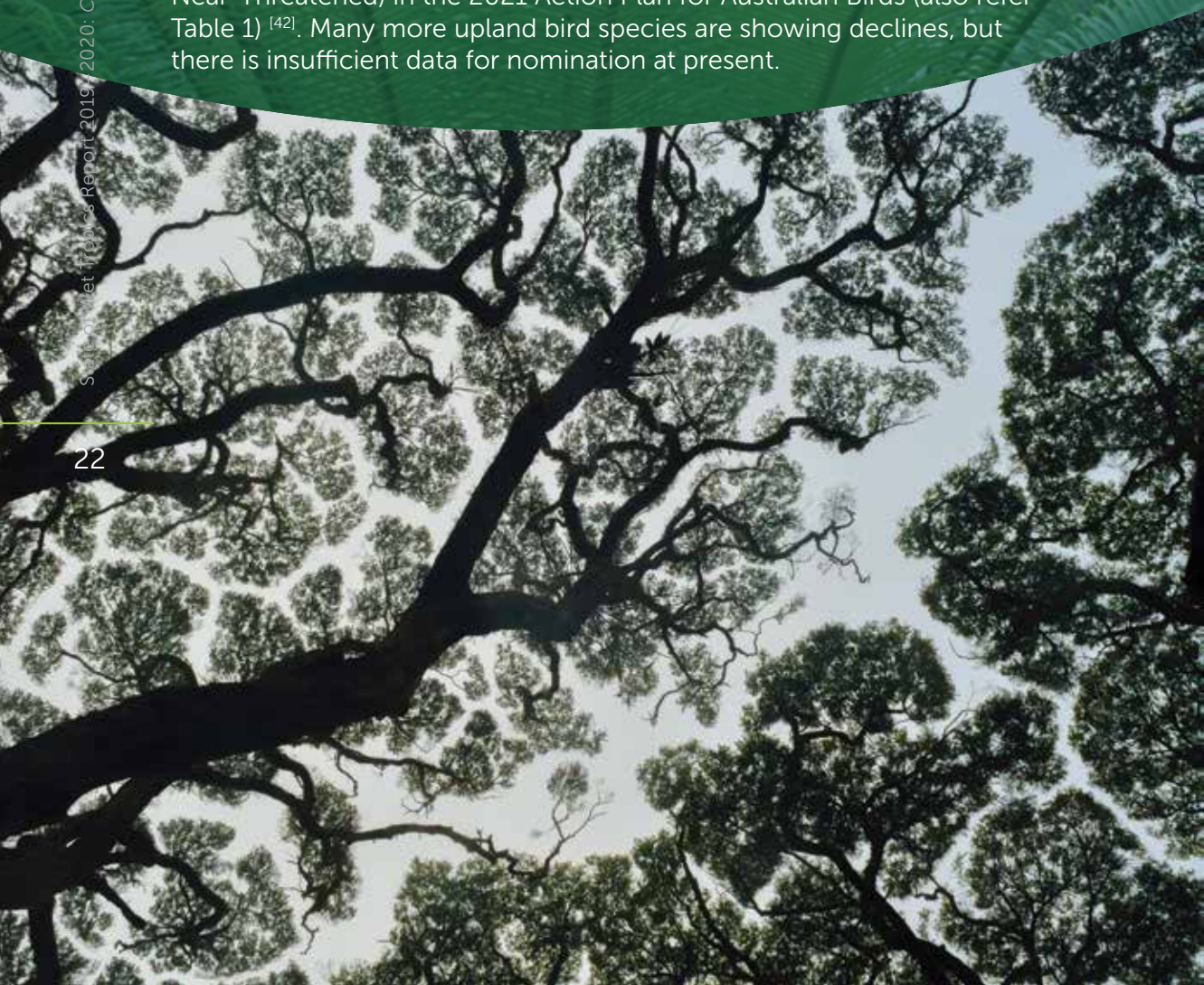
# Rainforest birds are feeling the heat

by Stephen E. Williams and Alejandro dela Fuente

Wet Tropics rainforest birds, particularly endemic species, are suffering serious declines. Two decades of research is demonstrating declines in abundance and shifts in species consistent with a warming climate [40]. Bird species that are rainforest specialists have declined by an average of 20% and endemic species by 34%. In contrast, the local abundance of habitat generalists, mostly widespread species, have increased.

These trends are associated with upward shifts to the cooler, higher elevation of lowland species, and a decline of 44% in upland rainforest specialists and regional endemics. The spatial pattern of the declines provides additional support for the hypothesis that increasing temperature, particularly heat waves, is the primary driver [41].

These documented population declines are supported by a number of other bird monitoring projects in the region and have recently resulted in 14 regionally-endemic bird species being newly nominated for threatened status (three Endangered, seven Vulnerable and three Near-Threatened) in the 2021 Action Plan for Australian Birds (also refer Table 1) [42]. Many more upland bird species are showing declines, but there is insufficient data for nomination at present.



## Wet Tropics upland flora and fauna

Many Wet Tropics endemic species are only found in the cooler, higher altitude parts of the region [43, 44]. It is these species that played a key role in the World Heritage listing for the Wet Tropics, but they are also the most vulnerable to climate change impacts.

By 2070, under a high greenhouse gas emissions scenario, the climates that currently characterise some upland environments may disappear entirely, leading to a substantial loss of biodiversity.

### Upland flora

Recent modelling of habitat suitability for 19 Wet Tropics endemic plants, has made predictions of a decline in suitable habitat for each of the 19 species by a minimum of 63% by 2040 [45].

The plants listed in Table 1 are those that will lose more than 90% of their core climate habitat by 2085.

More species are showing declines but there is insufficient data for robust analysis.

The potential resilience of the ancient lineage species to climate change cannot be determined due to a lack of detailed knowledge about their distributions, life history characteristics, physiology, ecological tolerances and relative competitive abilities. Lowland species could migrate with the projected shift in tropical and subtropical environments, but their capacity to respond in this way will be severely constrained by habitat fragmentation.

### Upland vertebrate fauna

James Cook University and CSIRO bioclimatic models suggest that climate change will also have catastrophic effects on many of the region's endemic vertebrate species.

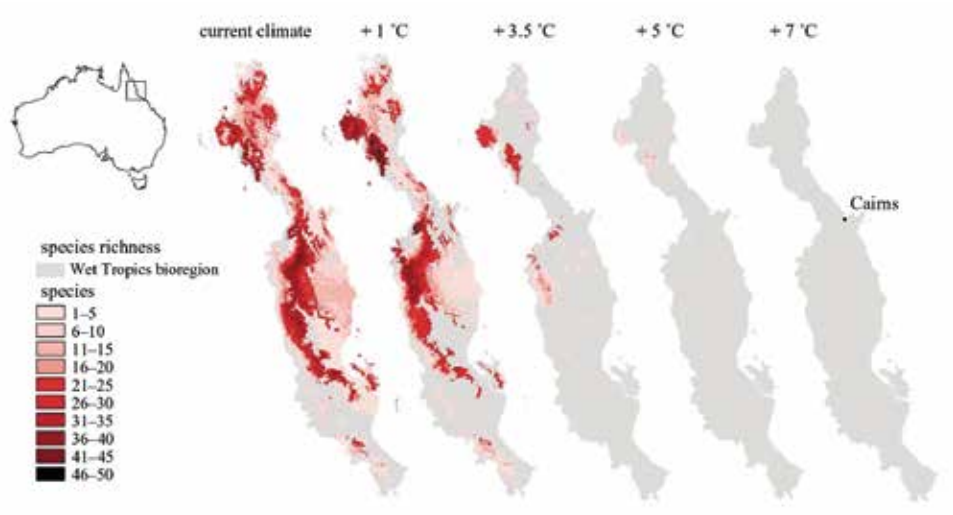
Based on current distributional range limits, an increase in regional average temperature of 1.0°C could decrease distributional range of the region's endemic vertebrate species by 60% [46].

An increase in regional average temperature of 3.5°C could reduce the distributional range of these species by around 95% of their current range.

Projected warming of this magnitude also predicted a loss of approximately 65% of these Wet Tropics endemic vertebrates. This implies a strong likelihood of approximately 50 species becoming globally extinct from the Area with only a moderate average temperature increase.

Most upland endemic vertebrate species will disappear under the worst-case scenarios with temperature increases of 5.0°C or more [47].

Figure 1. Geographical pattern of species richness of regionally endemic rainforest vertebrates at each temperature scenario. Species richness is produced by overlaying all species-distribution models at each temperature scenario.




With each modelled increase in temperature, it is evident that patches of climatically suitable habitat become smaller, fragmented and more isolated. Any of the described temperature increase scenarios would be catastrophic to the values for which the Area was listed.

"...a strong likelihood of approximately 50 species becoming globally extinct from the Area with only a moderate average temperature increase."

# Possums in peril

The iconic, endemic rainforest ringtail possums of the Wet Tropics World Heritage Area are in trouble. Primarily restricted to higher elevations across the Wet Tropics, their plight under climate change was raised more than 17 years ago, with models suggesting they could face extinction by the end of this century. Since then, long-term monitoring, combined with improved distribution modelling and physiological research, has supported these concerns: declines in ringtail populations in the region are consistent with the impacts of a warming climate.

Possum populations have declined in the lower, warmer parts of their range and initially increased in the upper elevations. The most sensitive species appears to be the lemuroid ringtail possum (*Hemibelideus lemuroides*). In the northern population (Mount Lewis) the number of individuals crashed after a heat wave in 2005 and no individuals were seen for a number of years, followed by a slow recovery.

In the southern population centred on the Atherton Tableland, lemuroid possums started disappearing at lower elevations, and while initially abundance increased at 800m and 1000m until about 2010, it has been in decline ever since. The core population at the 800m long-term monitoring site has now declined to approximately 25–30% of pre-2008 numbers.

Additional monitoring sites in this area have recently been established in collaboration with Queensland Parks and Wildlife rangers, however, the possum numbers at these new sites matches the trends in the longer-term sites. At the current rate of decline, the lemuroid population, at 800m elevation, will disappear within the next two to five years. These observed declines are graver than even the most severe future predictions under the IPCC RCP8.5 scenario that predict a 50% decline by 2035-2045 [48].

Herbert River ringtail possums (*Pseudochirulus herbertensis*) have disappeared from 600m elevation since 2008, declined by more than 50% at 700m and have been relatively stable, or even increasing slightly, thus far at 800m and higher; although there are signs of a declining trend in recent data.

Green ringtail possums (*Pseudochirops archeri*) increased in abundance at higher elevations above 800m from 1992–2008, although numbers have declined over the last two years. The data available on Daintree River ringtail possums (*Pseudochirulus cinereus*) is insufficient for robust statistical analysis at this stage.

Increasing our knowledge of these declines and exploring mechanisms to inform potential management options is critical to protecting these iconic species that are so important to the Outstanding Universal Value of the Wet Tropics World Heritage Area.

Table 1. Wet Tropics endemic vertebrate fauna and flora predicted to be most at risk from climate change [49].

| Frogs | |
|---|---|
| *Cophixalus concinnus* | Thornton Peak nurseryfrog |
| *Cophixalus exiguus* | Dainty nurseryfrog |
| *Cophixalus hosmeri* | Rattling nurseryfrog |
| *Cophixalus monticola* | Mountain nurseryfrog |
| *Cophixalus neglectus* | Bellenden Ker nurseryfrog |
| *Mixophyes carbinensis* | Carbine barred frog |
| *Pseudophryne covacevichae* | Magnificent broodfrog |
| *Taudactylus rheophilus* | Northern tinkerfrog |

| Mammals | |
|---|---|
| *Antechinus godmani* | Atherton antechinus |
| *Dasyurus maculatus gracilis* | Spotted-tailed quoll (northern sub-species) |
| *Hemibelideus lemuroides* | Lemuroid ringtail possum |
| *Petaurus gracilis* | Mahogany glider |
| *Pseudochirulus cinereus* | Daintree River ringtail possum |
| *Pseudochirulus herbertensis* | Herbert River ringtail possum |

| Birds | |
|---|---|
| *Acanthiza katherina* | Mountain thornbill |
| *Alisterus scapularis minor* | Wet Tropics Australian king-parrot |
| *Colluricincla boweri* | Bower's shrike-thrush |
| *Cormobates leucophaea minor* | White-throated treecreeper |
| *Gerygone mouki mouki* | Wet Tropics brown gerygone |
| *Heteromyias cinereifrons* | Grey-headed robin |
| *Lophorina victoriae* | Victoria's riflebird |
| *Oreoscopus gutturalis* | Fernwren |
| *Prionodura newtoniana* | Golden bowerbird |
| *Psophodes olivaceus lateralis* | Wet Tropics eastern whipbird |
| *Scenopoeetes dentirostris* | Tooth-billed bowerbird |
| *Sericornis keri* | Atherton scrubwren |
| *Sericornis magnirostra viridior* | Wet Tropics large-billed scrubwren |

| Skinks | |
|---|---|
| *Calyptotis thorntonensis* | Thornton Peak skink |
| *Eulamprus frerei* | Bartle Frere bar-sided skink |
| *Glaphyromorphus mjobergi* | Atherton Tableland mulch-skink |
| *Lampropholis robertsi* | Grey-bellied sun skink |
| *Saproscincus czechurai* | Wedge-snouted shadeskink |
| *Saproscincus lewisi* | Cooktown shadeskink |
| *Techmarscincus jigurru* | Bartle Frere cool-skink |

| Flowering plants | |
|---|---|
| *Acrotriche baileyana* | Northern ground berry |
| *Austromuellera valida* | |
| *Bulbophyllum lilianae* | Warty strand orchid |
| *Cinnamomum propinquum* | Pepperwood |
| *Dracophyllum sayeri* | |
| *Elaeocarpus hylobroma* | Quandong |
| *Elaeocarpus linsmithii* | Quandong |
| *Flindersia oppositifolia* | Mountain silkwood |
| *Garcinia brassii* | Mountain mangosteen |
| *Gynochthodes constipata* | |
| *Gynochthodes podistra* | |
| *Leptospermum wooroonooran* | Wurununu ti-tree, mountain teatree |
| *Leucopogon malayanus subsp. novoguineensis* | |
| *Litsea granitica* | Bollywood |
| *Octarrhena pusilla* | Wispy grub orchid |
| *Parsonsia bartlensis* | |
| *Pleioluma singuliflora* | Lewis coondoo |
| *Polyscias bellendenkerensis* | |
| *Symplocos wooroonooran* | Small-leaved hazelwood |
| *Syzygium fratris* | |
| *Tasmannia sp. (Mt Bellenden Ker J.R.Clarkson 6571)* | |
| *Trachymene geraniifolia* | Geranium-leaved trachymene |
| *Zieria madida* | Thornton Peak stink bush |
| **Conifers** | |
| *Agathis atropurpurea* | Black kauri or purple kauri |
| **Ferns** | |
| *Hymenophyllum whitei* | Filmy fern |





"The river is our lifeblood. It provides our food, our drinking water, everything we need is in the river and the land."

## Ecosystem goods and services

Climate change is expected to not only result in severe adverse impacts on habitats and wildlife within the Area, but also impact upon the ecosystem goods and services the Area provides, many of which support economic activities (see Table 2). 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 [50, 51].

The collective worth of the region's natural values has been determined to exceed $5 billion annually. This includes the $2.6 billion associated with the tourism industry [52], plus at least an additional $2.6 billion generated by non-market values associated with the worth the community places on the natural values [53].

Table 2. Examples of ecosystem goods and services provided by the Area [54].

| | |
|---|---|
| **Regulating services**<br>Benefits obtained from regulation of ecosystem processes | • carbon cycles • water purifications<br>• water quality • flood mitigation<br>• regional climates and microclimate<br>• groundwater recharge<br>• pollination • disease regulation<br>• habitat • refugia • water regulation<br>• waste breakdown |
| **Provisioning services**<br>Products obtained from the ecosystems | • food • water supply • tourism<br>• genetic resources • scientific discovery<br>• horticulture • pharmaceutical products |
| **Personal and cultural services**<br>Non-material benefits obtained from ecosystems | • country and homelands • education<br>• enjoyment • spiritual • aesthetic pleasure<br>• inspiration • serenity • leisure activities<br>• lifestyle • sense of place<br>• national identity • mental well-being<br>• recreation |
| **Supporting services**<br>Necessary for the production of all other ecosystem services | • soil formation • nutrient cycling<br>• primary production |

## 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—a process known as cloud stripping. Wet Tropics 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 important in maintaining stream flows throughout the dry season and is considered significant to the overall water budget of the region, especially in terms of water recharge during the dry season.

Studies [55] have revealed that cloud forests contribute much more moisture to waterways than lower-altitude forests because trees at higher altitudes grow more slowly and, therefore, use less of the harvested water. As a result, the excess water finds its way into creeks and rivers, hence the year-round flow.

Under current climate conditions, cloud stripping occurs in rainforests more than 600 metres above sea level. With every degree of warming the base of the cloud condensation layer is predicted to rise by 100 metres. By 2050, we expect a temperature rise of up to 3.0°C, equating to a rise in the effective cloud stripping condensation layer from 600 metres to 900 metres above sea level. In this scenario, the effective cloud stripping area in the Wet Tropics will decrease by as much as 40% [56, 57], meaning significantly reduced water yields for Wet Tropics waterways, especially in the dry season.

## Tourism, agriculture, and horticulture

Tourism is an economic driver across the Wet Tropics region and there are more than 230 managed and unmanaged visitor sites within the Area [58-61]. These sites range from easily accessed sites to more remote locations including waterfalls, lookouts and waterholes. All are vital to the eco-tourism values and appeal of the region. Many of these sites are threatened in some way by climate change including:

- reduced access due to flooding and high sea levels
- deteriorating aesthetic value
- reduced visitor comfort with rising temperatures and unpredictable weather patterns
- increased perceived risk of visiting destination due to extreme weather events [62, 63].

Agriculture (mainly sugar cane and horticulture) generates $1.62 billion annually from the region [64]. Both sugar cane and horticulture are heavily dependent on natural resources and the ecosystem services these natural resources provide.

There are also likely to be extreme event impacts, such as the devastation of the banana industry post Cyclone Larry [65]. Recognising the short- and long-term impacts on tourism and agriculture is a start, but support will need to be provided to build the resilience of individuals and industries in the face of climate change in the region.

The relationship between the Wet Tropics and the Great Barrier Reef means that coordination of approaches will be important for the tourism industry and wider regional economy—as shown with the July 2020 proposal of the TNQ Green and Blue Economic Stimulus Package [66].

"...effective cloud stripping area in the Wet Tropics will decrease by as much as 40%."

## TNQ Green and Blue Economic Stimulus Package: boots on the ground

The TNQ Green and Blue Economic Stimulus Package (the Package) was launched in July 2020 by a broad range of stakeholders across the Wet Tropics region to leverage practical land and sea management and restoration activities that create employment and increase the regional economy's resilience. This will ensure that we can better weather future economic, health and natural crises, including climate change.

The package proposes three programs to be delivered over an initial three-year funding request of $180 million for practical land and conservation programs. These aim to boost economic activity and set a longer term ambition to transform the region to become the smart green capital of Australia.

The Package is an example of regional, cross-industry collaboration to address immediate economic and employment challenges while enacting strategies to protect the region's two key natural assets: the Great Barrier Reef and Wet Tropics World Heritage areas.

# Management responses

The Authority's Accept, Act, Adapt: Climate Adaptation Plan for the Wet Tropics 2020–2030 was developed in consultation with the Wet Tropics community [67], and outlined a strategic framework to guide its vision of "...successful adaptive management of World Heritage in response to climate change":

1 Improve landscape resilience.

2 Establish inclusive regional adaptation planning frameworks.

3 Facilitate transition to adaptive communities and industries.

Following this framework, the following practical steps aim to reduce the impacts of climate change on the region's biodiversity, primarily through adaptive responses. This will be principally achieved through in situ conservation of species and ecological communities, facilitating their natural adaptation by means of improving the Area's overall ecological resilience.

## Improve landscape resilience

Many management responses to climate change, such as pest and weed 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 and socioeconomic benefits. Our response needs, therefore, to be placed within an adaptive management framework: plan, act, monitor, review.

What can be done?

- ✓ Develop a Wet Tropics climate vulnerability index aimed at conserving the Outstanding Universal Value and integrity of the Area and the biodiversity of the overall region.
- ✓ Support regional clean and green initiatives by the tourism industry.
- ✓ 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.
- ✓ Maintain and enhance landscape-scale ecological connectivity.
- ✓ Identify, conserve and create wildlife corridors and protect climatically stable refugia.

## Establish inclusive regional adaptation planning frameworks

Responding to climate change is unlikely to succeed if it is done in isolation from other land management agencies and activities. 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 (including the neighbours of the Wet Tropics region). This must involve government agencies, industries, Rainforest Aboriginal Peoples and regional communities.

What can be done?

- ✓ Coordinate with climate change responses in other sectors such as urban and regional planning.
- ✓ Incorporate the implications of climate change into existing regional management plans, strategies, guidelines and policies.
- ✓ Promote the Accept, Act, Adapt: Climate Adaptation Plan for the Wet Tropics 2020–2030 as the source of conservation priorities for regional land and environment decision-makers.
- ✓ Identify social and economic costs of climate change and management response options, including the cost of not taking action.
- ✓ Expand the scope of monitoring to develop methods to assess and monitor species, communities and ecosystems over the long-term.
- ✓ Build regional capability and reduce uncertainty, through knowledge and skills sharing.
- ✓ Promote economic stimulus for regional development that addresses integrated environmental, social, cultural and employment benefits.
- ✓ Strengthen state and national environmental policy and regulations.





"Responding to climate change is unlikely to succeed if it is done in isolation from other land management activities."

## Facilitate transition to adaptive communities and industries

Social and economic trends that affect the region's vulnerability to climate change, as well as the social and economic impacts of climate change on the region, are very poorly understood.

What can be done?

- ✓ Explore the spectrum of carbon trading opportunities, economic incentives and other opportunities which are available to help achieve or fund effective climate adaptation responses.
- ✓ Develop and implement a communications strategy to raise awareness of climate change impacts and the advantages of early attention to adaptation.
- ✓ Collect and analyse social and economic data and trends to assess how these factors are likely to influence vulnerability to climate change.
- ✓ Support the expansion of a regional hub for research into climate change and its impacts on terrestrial, aquatic and estuarine ecosystems and biodiversity.
- ✓ Provide regional leadership in measures to reduce greenhouse gas emissions.
- ✓ Invest in comprehensive monitoring of World Heritage attributes and prioritise science research towards facilitating climate responses.

## Innovating to tackle climate change in the Wet Tropics

Wet Tropics researchers have developed a decision framework aimed at guiding managers and policy makers that considers the various adaptation options, ranging from the least expensive and most likely to have benefits to the more costly and risky actions [68, 69].

It is important to stress that many of the common environmental management practices such as control of invasive species, implementing appropriate fire regimes and minimising fragmentation are all important for maintaining future resilience of the Wet Tropics rainforest. However, new approaches will also need consideration.

### Rainforest refugia

The identification and preservation of refugia areas will be essential in the long-term conservation of species in the region. Climatically buffered microhabitats within pristine rainforests will likely serve as another line of defence against extreme weather events. These small microhabitats remain cool and wet during hot conditions and should provide conditions that species can survive in, at least over short timeframes—for example, a heat wave [70].

## Avoiding the ark of last resort

The mountaintop cloud forests of the Wet Tropics World Heritage Area harbour more than 100 species of plants that are found nowhere else on Earth. Recent modelling studies [71] on a subset of those species showed that for 25 of 37 species analysed, climate-driven habitat loss will exceed 90% by 2085, and seven species will lose their habitat entirely.

As a response, the Wet Tropics Management Authority has partnered with researchers from the Australian Tropical Herbarium, James Cook University, seven botanic gardens and relevant Traditional Owner groups to undertake an ex situ conservation program to 'back up' at-risk wild populations and support research, display and education.

The team is pursuing novel research on seed banking strategies, genetic diversity and plant tolerance of extreme climates to ensure that the reserve germplasm collections—comprising live plants and stored seed distributed across multiple botanic gardens and seed banks along Australia's east coast—incorporate high redundancy (to guard against accidental loss), are genetically and physiologically diverse (to maximise resilience) and climatically matched to wild habitat.

Captive breeding populations could be established for plant and animal species at high risk of extinction. However, a triage review would need to be done to establish species that have a high priority, are suitable for captivity and have future options for release back to the wild.

Large-scale refugial areas will, however, ultimately be required for successful long-term conservation of populations. These areas can be identified using spatially explicit modelling approaches that capitalise on long-term data of species distributions and climate modelling in the region [72].

### Innovative approaches

Intervention may also be needed to support at-risk species using innovative approaches such as creation of artificial habitat, biomimicry, genetic engineering and establishment of ex situ populations.

A last resort is the consideration of assisted colonisation and ex situ conservation. These approaches are likely to be highly expensive, present ethical dilemmas and are not guaranteed to succeed, particularly for fauna. Research is required now on the methodology and efficacy of these more radical actions, in the event in situ conservation options prove ineffective [73, 74].

### Increased monitoring

In order to fully understand the consequences of long-term climate change, and to respond accordingly to population decline, more long-term monitoring of populations will be required. Long-term data are paramount for informing and triggering successful management actions in the region.

### Community collaboration

Climate change-induced ecosystem impacts in the Wet Tropics will inevitably affect human communities and the industries that depend on them. The magnitude of these impacts will largely depend on the willingness and capacity of the local community to collaborate in developing and undertaking management responses. Effective management, therefore, requires the employment of strategies that are socially and economically sustainable, and co-designed with local communities.

## Accept, Act, Adapt

While climate change is a global issue, the Authority is committed to tackling the challenge at a regional, Wet Tropics-focused level, drawing on the myriad research and modelling that has already been undertaken across the Area. By examining local climate projections, their impacts on the Wet Tropics to date, and likely future impacts, it is possible to consider both long-term and more immediate, practical management responses.

The Authority is confident that, through collaborative action and commitment, our communities can ensure a secure future for the Area. One in which we #AcceptActAdapt together.



"Effective management, requires the employment of strategies that are socially and economically sustainable, and co-designed with local communities."

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# Terms and abbreviations

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| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| IPCC | The Intergovernmental Panel on Climate Change |
| IUCN | International Union for Conservation of Nature |
| the Area | The Wet Tropics of Queensland World Heritage Area |
| TNQ | Tropical North Queensland |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |


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