Recent trends in and preparedness for extreme weather events

A submission calling for national action to co-0rdinate the conservation of certain Australian plants ex-situ.

Terms of Reference addressed

(b) based on global warming scenarios outlined by the Intergovernmental Panel on Climate Change and the Commonwealth Scientific and Industrial Research Organisation of 1 to 5 degrees by 2070:

(ii) the costs of extreme weather events and impacts on natural ecosystems, social and economic infrastructure,

The Tasmanian Arboretum Inc. [TAI]

Is a not for profit membership based organization operating a landscape arboretum on 66ha at Eugenana, some 10km south of Devonport, Tasmania.

Our collections of temperate climate woody plants currently hold some 4,600 taxa, mainly in geographic collections. They included some plants naturally found in warmer and colder climates than pertaining in Eugenana.

TAI is working on a strategy for its operations in a changing climate, recognizing that some of the plants in our collections may not tolerate the future climate and that, given the longer life of woody plants, the collections development should where possible have a focus on the predicted climate now we have entered a period of change.

The strategy also addresses how TAI can reduce its demands on energy and sequester carbon and some other associayed impacts such as changes in visitor behaviour.

The Draft Strategy is Appendix 1.

TAI is a member of the following organizations; the Australian Network for Plant Conservation, the Botanic Gardens of Australia and New Zealand and the Botanic Gardens Congress International. I am a member of the International Dendrology Society.

All the organizations TAI is a member of represent institutions that understand the intrinsic value of plants, recognize the contribution they make to economies and their other benefits to humans.

BGCI has publications on plant conservation that recognize the need for increased conservation efforts in a warming world.

Outline of Risk

The degree of risk to the survival of plant species, and perhaps the associated animals [especially those that have evolved specialist relationships, is dependent on a number of factors.

The rate of warming is faster than the generally recognized rate that allows for natural evolution, as that rate is currently understood [+- 0.06d per century].

Plants may relocate as environmental factors they have evolved to tolerate change. This relocation is relative to their means and rate of seed dispersal, their maturation period and whether there is a suitable location to relocate to.

For woody plants a number of years may be required before the alternation of generations commences. That seed production may continue for many years.

Plants dependent on low temperatures may move poleward to higher latitudes or to higher altitudes in a warming world and the opposite in a cooling one. Paleological evidence supports this.

Of course these ancient movements of plant species occurred before 7 billion people had organized their activities in a way that creates barriers to the natural movement of plants across latitudes.

Plants with a limited distribution, such as those isolated on mountains, and unable to survive in a changing climate, are at risk of extinction. The closer that distribution to the peak of a mountain the less area they have to occupy.

Plant communities already on the top of the mountain they inhabit are at the greatest risk. They are also the plants living with the lowest local temperatures.

Other factors associated with the climate that influence local environments may also change. For cloud dependant forests changes in the patterns of cloud formation on mountains and thus moisture availability may be affected by warming. It is an additional risk factor.

Some warmer climate plants at the Tasmanian Arboretum

Some Australian plants with a limited higher altitude distribution in other states are already held in our collections at the Tasmanian Arboretum.

Eucryphia wilkesii, related to the Tasmanian leatherwood, is naturally distributed among boulders on Mt Bartle Frere in northern Queensland. It is the only wet tropic rainforest plant we currently have held for multiple years in the in-ground collections.

In the time we have held this species it has not suffered from cold temperature damage even though it is in a south facing position close to the valley floor. This demonstrates it tolerance of and probably, because of its pattern of natural distribution, need for low temperatures.

Nothofagus mooreii, related to the myrtle beech of Tasmania and Victoria, Is naturally distributed from Lamington Tops in Queensland to Barrington Tops in

NSW. Its distribution is not continuous but is restricted to above 600 metres where rainfall is high and mists are common within that range.

In the 23 years we have held this species its growth rate has increased. This may not be directly related to changes in the local climate but to the plant growing away from the lower temperatures found closer to ground level during frosts.

We also hold, in partnership with the Royal Tasmanian Botanical Gardens, a collection of Southern Hemisphere Conifers. Some of those plants in the in ground collection naturally occur found above 900metres asl in New Caledonia.

Some examples of what is happening to plants in other locations in the changing climate.

The longest measured example for Botanical Gardens available to me is from the IDS Yearbook for 2012. It discusses warming at the St Petersburg Botanical Gardens since 1742 and the changes in the habits of the plants tended in that garden such as earlier flowering.

The article states that in the 1780-1789 period the mean annual air temperature was 2.8dC. In the 1999 to 2008 period that mean had changed to 6.3dC.

The sum of winter temperatures has fallen from a total of minus 1050dC in 1752 – 1761 to +- minus 600dC in 1998 to 2007.

The number of growing days from the beginning of flowering of Alnus incana L. and the change of colour of the leaves of Betula pendula Roth has gone from +- 153 days in 1841-1850 to +- 180 days in 1997-2006.

The study of the timing of plant behaviour [phenology] shows plants are acting earlier in flowering, bud burst. Leaf development and fruiting earlier. Washington DC in the eastern region of North America is known for its flowering cherries. They are now flowering 2 weeks earlier.

Pinus species in North America are affected by pine bark beetle outbreaks, many trees affected being killed. These have been worse in warmer years, They are now affecting larger areas than ever before and the altitude at which the beetle are active has increased.

Because the Pinus species at higher altitudes have not evolved natural defence mechanisms the impacts of the beetles is greater on those plants.

The Sundabaran forest is drowning as sea level rises. The world’s largest mangrove forest provides habitat for endangered animals including the iconic Bengal Tiger.
It is also an important local resource, providing a fishing ground and protecting the coastline from the impacts of storms and tsunamis. It also acts to sequester carbon.

Such changes could impact on littoral rainforests in Australia.

Plants will react differently, depending on their inherent range of tolerance as well as where they are in their distributional range, and the changes in their particular environment.

Unknown value of some Plant Genetic Resources

Although it may seem esoteric to be concerned about plants but, beyond their intrinsic value, we cannot be sure what other uses the mixtures of genes developed over the ages will provide for us.

One thing is certain, extinction is forever.

No hybridizing the dodo with domestic pigeons to increase size or growth rates.

Currently, under the EPBC Act 1999, 52 plants are listed as extinct. State jurisdictions have a number of plants listed under their legislation. Some of these are not listed federally.

Seed Banks and Recalcitrant Species

As part of the Millennium Seed Bank Project managed by the Royal Botanic Gardens Kew, England and several Australian botanical Gardens have established Seed Banks.

Keeping viable genetic material is important in conserving species for their intrinsic value as much as for the value of the genetic combinations.

One project run by the RBG Sydney is the Australian Rainforest Seed Bank Project, a 3 year study to determine how seed from species occurring in ‘rainforests’ NSW may be stored.

Orthodox seed can be stored using long standing techniques, such as low temperature storage, and remain viable for a period. However, some seed cannot be stored for long periods. It is described as recalcitrant. Some Australian plants appear to fit this category and may be resistant to current storage techniques.

In any case all seed has a storage life, that time dependent on the species and the technique used.

Conservation of species in situ is the best method but, if the climate changes certain habitats will become unavailable to plants no longer able to relocate altitudinally or longitudinally.

A rapid rate of change will deny plants time to naturally re-establish and reproduce in new locations.

According to the latest research published by the Tasmanian government on the future climate in Devonport area of north-western Tasmania by 2070 the climate is predicted to have shifted up 400 metres in altitude, the equivalent of about 4d in Latitude.

Already, the response of a limited range of Australian ‘ráinforest’ plants being grown at the Tasmanian Arboretum has shown a change in the last 10 years. 25 years ago low temperatures made Agathis robusta [kauri pine] from Queensland difficult to establish in the ground. Recent plantings has shown this is not the case now. Syzygium australis [lilypilly] from the east coast is no longer cut completely to the ground.

I only comment on these two species because, although we have a wider range of Australian east coast species in our collection, some are clearly hardy to our degree of cold and others we have only held in ground for a season.

Some plants may adjust to some changes to the climate within their range in situ, but, as yet, which species will adapt is an unknown. It is not something the nation can afford to experiment with.

Recommended Actions

It is most likely necessary that some species will need to be held in ex-situ collections and perhaps whole communities will have to be translocated. These may be later seed sources for further storage or provide material to re-establish habitats if the climate returns to the values they evolved in.

Current State boundaries appear to bee determining project priorities and efforts. This needs to change to a co-ordinated national effort, especially where recalcitrant and high altitude species are concerned.

Zoo’s have, through necessity, learnt to manage their genetic resources to maintain viable collections and to assist in re-establishing species in the wild.

With the range of predictions given by the IPCC of increases in global temperature from 1.1 up to 6.4dC and with a potential that the threshold for some plant communities will be passed this century.

Early action should be taken to allow for the time necessary for understanding plant requirements and establishing ex-situ collections in suitable multiple locations to provide a secure collection of the genetic material with the greatest difficulty of naturally relocating to a suitable new environment.

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Australian National Botanic Gardens Climate Strategy link
http://www.environment.gov.au/parks/publications/climate/anbgclimatechangestrategy.pdf

Appendix 1.

Draft Only

The Tasmanian Arboretum Inc - Climate Change Strategy 2013-2028

Background

The Intergovernmental Panel on Climate Change Fourth Assessment Report concluded that human induced climate change is expected to have a discernable influence on many physical and biological systems. The resilience of many ecosystems is likely to be exceeded over the course of the twenty first century and approximately a quarter of all plant and animal species are likely to be at increased risk of extinction if increases in global average temperature continue to match current projections (IPCC 2007).

Botanic gardens, in partnership with herbaria, will play an increasingly critical role in ex situ plant conservation as climate change impacts on natural populations of plant species. The key focus of botanic gardens in addressing climate change includes:

- providing a safety net for plant species through living plant collections and seedbanks
- providing knowledge and expertise to support climate change research through horticultural and field-based research, plant species distribution and plant taxonomy
- providing opportunities for increasing community awareness and education about climate change (CHABG 2008).

The Tasmanian Arboretum occupies a 66 hectare site on the at 30m to 70m above sea level 7km from the Bass Strait coast on the banks of the Don River connected to a public reserve of equal size. The dry sclerophyll vegetation of the neighbouring forest extends into the TAI site.

The Arboretum also contains the vegetation of limestone outcrops and a collection of exotic temperate woody flora.

The strategy identifies the preliminary adaptation, mitigation and communication actions that TAI needs to implement to manage the consequences of climate change and reduce the carbon footprint of the site.

The strategy should be considered as a 'first step' and an adaptive tool subject to ongoing review. This allows for management responses to be amended to take account of improvements in the understanding of the implications of climate change on TAI

This strategy is consistent with the *National Strategy and Action Plan for the Role of Australia's Botanic Gardens in Adapting to Climate Change* (CHABG 2008). The strategy also aims to complement the policies and actions outlined in the Operational Plans.

Regional climate change projections

The predicted effects of climate change in the Devonport region include a rise in temperature, more bushfire events and an increase in the frequency and intensity of droughts and severe storm activity (CSIRO 2007).

Past and current climate:

- The Devonport City municipality has a temperate climate with a moderate temperature range (average daily maximum temperature is 21.5 °C in February, and 12.7 °C in July).
- Average annual rainfall is around 750 to 1000 mm per year with a distinct seasonal cycle. For example, Devonport Airport receives an average of 778 mm per year (37 mm in January, 96 mm in July), and Forthside Research Station receives an average of 967 mm per year (45 mm in February and 121 mm in July).
- Rainfall in the Devonport City area can come from the regular westerly frontal rain systems that cross Tasmania, however an important fraction of the rainfall comes from episodic systems from the north and east, including cutoff lows.
- Year-to-year rainfall variability is partly correlated with the El Niño Southern Oscillation in autumn, winter and spring (where El Niño winters are generally drier than average, La Niña winters are generally wetter than average). There is also some correlation with the Indian Ocean Dipole in winter and spring.
- Average temperatures have risen in the decades since the 1950s, at a rate similar to the rest of Tasmania (up to 0.15 °C per decade). Daily minimum temperatures have risen slightly more than daily maximum temperatures.
- There has been a decline in average rainfall and a lack of very wet years in the Devonport City municipality since the mid 1970s, and this decline has been strongest in autumn. This decline was exacerbated by the ‘big dry’ drought of 1995-2009. The recent two years have seen generally above average rainfalls.

Future scenarios - from the Climate Futures for Tasmania project

Fine-scale model projections of Tasmanian climate were made for two hypothetical but plausible scenarios of human emissions for the 21st Century (taken from the special report on emissions scenarios (SRES) from the Intergovernmental Panel on Climate Change (IPCC)). The scenarios are of ongoing high emissions, A2, and one where emissions plateau and fall, B1. The climate response under the two scenarios is similar through the first half of the century, but the changes under the higher emissions scenario become much stronger than the lower scenario in the later half of the 21st Century.

1. Temperature

 Under the higher emissions scenario (A2), the municipality is projected to experience a rise in average temperatures of 2.6 to 3.3 °C over the entire 21st Century. The rise in daily minimum temperature is expected to be slightly greater than daily maximum temperature, and fairly similar in the different seasons. Under the lower emissions scenario (B1), the projected change over the entire century is 1.3 to 2.0 °C. A time series of projected mean Tasmanian temperature is shown in Figure 1.

 The projected change in average temperatures is similar to the rest of Tasmania, but less than the global average and significantly less than northern Australia and many regions around the world, especially the large northern hemisphere continents and the Arctic.

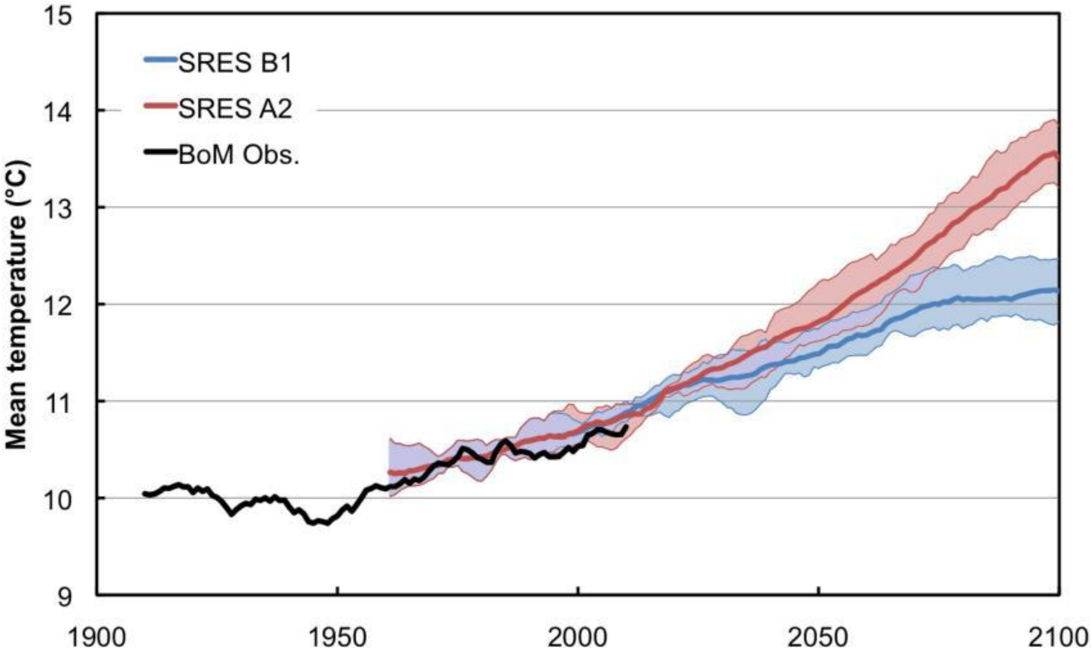

Figure 1. Tasmanian average temperature in observations (black) and model projections for the A2 scenario (red) and the B1 scenario (blue), all series are smoothed (11-year running average), shading shows the range of model projections. Changes under the higher scenario by the very end of the century are discussed in the examples below

 The projected change in average temperature is accompanied by a change in the frequency, intensity and duration of hot and cold extremes of temperature. For Devonport under the A2 (higher) scenario by the end of the century the projections indicate:

o The number of Summer Days (>25 °C) increases from around 10 days per year, to 40 or more days per year, with night time minimum temperatures over 20 °C occurring a few times every year.

o The temperature of very hot days increases more than the change in average temperature (by 3-4 °C in some locations in some seasons).

o A reduction in frost-risk days at the coast from up around 6 per year to around 1 per year.

o Warm spells (days in a row where temperatures are in the top 5% of baseline levels) currently last around 6 days, are projected to last up to 19 days longer.

2. Rainfall, runoff and rivers

- The projected pattern of change to rainfall and runoff is similar in nature between the two scenarios, but stronger by the end of the century under the A2 scenario. The model projections indicate that the general long-term influence of climate warming by the end of the century is for a very slight increase in annual average rainfall.

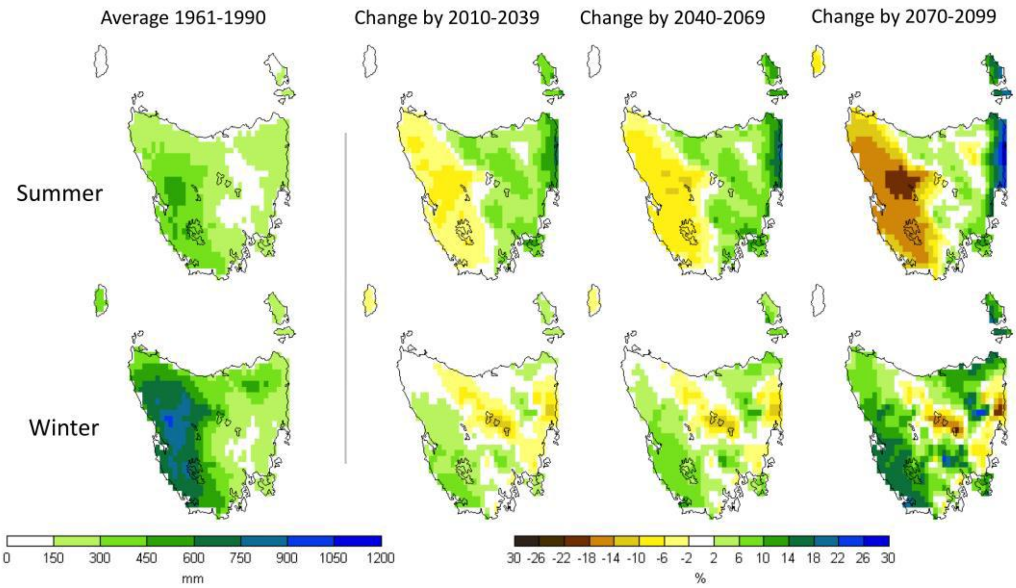

Figure 2. Average rainfall in summer and winter – the left hand side plots show the average rainfall in the baseline period (1961-1990), the plots to the right show the proportional change (%) from that amount in various periods in the 21st century in the average of six climate model projections under the A2 (higher) emissions scenario.

- The central estimate of the projections indicates a slight increase to the annual average rainfall under the A2 scenario or B1 scenario by the end of the century (model mean is for less than 5% change.)

- The model mean shows that rainfall is projected to slightly increase in winter and summer by the end of the century, with little change in spring and autumn (see Fig 2 for summer and winter).

- The long-term effect of greenhouse warming is on top of the usual cycles of rainfall, including droughts, termed ‘natural variability’. The model projections indicate that the recent dry conditions of the ‘big dry’ drought is not a new ongoing climate average state. These projections indicate that in the long term, drought frequency and severity may stay similar what was experienced in the twentieth century.

- The projected increase in rainfall is driven by changes to the average circulation of the region, including the average strength of the westerlies, as well as the incidence of the main rain-bearing weather systems from the east and north, including a change in atmospheric blocking and cutoff lows.

- A major influence of greenhouse warming on rainfall is the tendency for heavier rainfalls interspersed by longer dry periods, and for greater extremes. However, this varies in different areas. For the Devonport City municipality under the A2 (higher) scenario by the end of the century there is projected to be:

o Up to 7 fewer days with >1 mm rain per year on average, but significantly more rain per rain day (a 12% increase or more).

o Around 2 more very wet days each year (where rainfall exceeds the baseline 95th percentile), and the possibility of 2 more days per year that exceed 20 mm.

o An increase in the maximum instantaneous rainfall rate of over 30% in some seasons, and an increase of 9 mm of rainfall on the wettest day of the year (a 20% increase).

o Rainfall brought by rare extreme events will increase: a 200-year average recurrence interval (ARI) event for daily rainfall at is projected to increase by more than 35 mm (a 35% increase). More common ARI events (ARI-10, ARI-50) are projected to increase by a similar proportion.

 Pan evaporation is projected to increase, by up to 19% under the A2 scenario by the end of the century, driven by the increases in temperature but also changes to relative humidity, wind speeds, cloudiness and radiation.

 Changes to rainfall and evaporation lead to changes in water runoff and river flows. This in turn has impacts on the inflows into dams and water storages. Under the A2 scenario by the end of the century:

o Average runoff is projected to increase slightly in most seasons.

o There is a projected increase in runoff amounts during high events but little change in the runoff during low rainfall events.

o Decreased rainfall in the inland areas is projected to lead to slightly reduced average flows in the Forth River (central estimate is -7%) and the Mersey River (-7%), but the Don River is projected to show little change (1%).

3. Agricultural impacts

 As the climate warms, there is a tendency for biological niches to move upward in elevation. This means that there would be increased opportunities for agriculture and increased land-use pressure in the areas up the slope from the coast that are currently limited by temperature.

 There is a projected increase in Growing Degree Days (GDD, a measure of the heat to grow and ripen crops). This will affect where crops are grown, reduce the time to harvest of many crops, and affect many aspects of crop management. At Kindred, the annual count of GDD is projected to increase from less than 1000 to around 1750 by the end of the century under the higher emissions scenario. Higher altitude sites are projected to experience an even larger proportional (%) increase. This means that the temperature environment currently present at 300 m would be present at above 700 m at the end of the century under the higher emissions scenario.

 Pasture growth for dairying is projected to increase through the century due to a combination of effects (including a reduction in temperature limitation and increased carbon dioxide fertilization).

 Frost risk days are projected to become much less frequent with a warming climate. Damaging spring frosts may still occur rarely.

 Chilling affects the growth and flowering of berries, fruits and nuts. Accumulated chill hours decrease given the warming under the two future climate scenarios.

 For more information on agricultural impacts, including a detailed case study of changes along the altitudinal gradient from the coast up the slope, see Holz et al. (2011).

4. Extreme sea level events

High water events causing coastal inundation comes from a combination of sea level, tide, storm surge and wind waves. Sea level has been rising at a rate of 3.3 ±0.4 mm/year in the recent period, and is expected to continue rising with further climate warming. The last IPCC assessment report gave a central estimate of a rise of 0.82 m global average sea level by 2100 under a high emissions scenario. The sea level rise varies in different locations, and for the coasts of Tasmania the sea level rise for this scenario is close to the global average.

On the north coast of Tasmania, the very high tide heights contribute more to coastal inundation events than the relatively modest storm surge heights – the current 100-year storm tide event is around 1.9 to 2.0 m above average sea level. Changes to storm surges by the end of the century will not be as large as sea level rise. Accounting for all effects, the current 100-year event in George Town will be exceeded every 10 to 30 years by 2030, and more frequently than once every 4 years in 2090 under the high emissions scenario, and a similar influence can be expected in Devonport.

5. River floods – Mersey-Forth Rivers

Changes to design flood hydrographs were calculated for the 1:10, 1:50, 1:100 and 1:200 annual exceedance probability events for future periods using the climate model outputs and flood hydraulic models by partners at Entura consulting. Short duration high rainfall and runoff events are projected to become more intense, so catchments with a critical duration of less than 72 hours will experience high flood levels and faster response times. The peak discharge of the Mersey and Forth Rivers is projected to increase significantly through the 21st Century under the higher emissions scenario. Additionally, sea level rise will significantly increase coastal inundation events in the estuary of the Mersey (see above point). Please see the full Entura report and accompanying maps for more details.

Produced by Michael Grose, Antarctic Climate and Ecosystems Cooperative Research Centre, using material from the technical reports of the Climate Futures for Tasmania project

From this projection it can be concluded that a similar result is likely for the Don River Catchment which has a less than 72hour critical duration. The Tasmanian Arboretum sits at the confluence of the Don River and Melrose Creek and above a flood flow restricting gorge.

The experience of the 21st January 2010 indicates the potential impact.

Appendix – details of climate projections

Greenhouse gas emissions have an influence on the Earth's climate system, along with other human activities such as the emission of ozone-depleting substances, emission of aerosol (particles) and changing the land cover (e.g. deforestation). Sophisticated model simulations can be used to project the likely effect of these influences into the future given our current state of knowledge. It is impossible to predict exactly what future human emissions will be, so models are run under a set of plausible hypothetical emissions scenarios. A model simulation shows the likely effect if we follow that scenario, so it is not a single 'prediction' of the future. The simulation can't include the effect of things that are impossible to predict (such as major volcanic eruptions).

The Climate Futures for Tasmania project produced a set of climate projections at the regional scale for Tasmania. Two emissions scenarios were considered – one of ongoing high emissions (SRES A2), and one where emissions plateau and fall (SRES B1). The climate response under the two scenarios is similar through the first half of the century, but the changes under the higher emissions scenario become much stronger than the lower scenario in the latter half of the 21st Century.

Climate warming causes many complex changes to the earth's climate system. These changes include alterations to ocean currents, average atmospheric circulation and ocean-atmosphere cycles such as the El Niño Southern Oscillation. Projected effects that are relevant to Tasmania include a continued extension of the East Australia Current bringing warmer waters off the east and northeast coast of Tasmania, a pole-ward shift of the subtropical ridge of high pressure and shifts in the mid-latitude westerlies (the 'Roaring 40s'), and a change in remote climate drivers such as atmospheric blocking, the El Niño Southern Oscillation and the Southern Annular Mode. The position of Tasmania adjacent to the Southern Ocean means that the effect of climate warming is not as severe as other more continental regions.

The results presented in this report were made using established methods, including:

- Extreme value distribution fitting in a generalized Pareto distribution to calculate the average recurrence intervals (ARIs).
- Hydrology runoff models developed and calibrated for the Tasmanian Sustainable Yields project to estimate the runoff, river flows and inflows to storages.
- Standard agricultural indices such as the Utah model to calculate chill hours and standard

equations and a 10 °C threshold to calculate Growing Degree Days.

All information is drawn from the Climate Futures for Tasmania Technical reports please see these reports for more details, and to cite in other written work.

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Impacts of climate change on the Arboretum

There is a degree of uncertainty regarding how some of these projections of climate change will affect the values of TAI. However, based on regional climate change projections the following impacts are expected.

Heat stress and reduced water availability
An increase in the incidence of hot days [greater than 25°C], events which have already resulted in heat stress presenting in the plants displayed at the TAI affecting the living collections. Heat stress in plants is likely to be exacerbated by reduced water availability (through more prolonged drought conditions) and increased potential evaporation. Also of impact can be hot drying winds from the North, a result of hot days in Victoria combined with certain pressure system configurations. Unless this is offset by increased watering of the living collection there is an increased risk of plant mortality. Extended drought conditions may also lead to an increase in grazing and trampling pressure from both native animals (e.g. possums) and feral animals (e.g. rabbits) that may take refuge on the site for food and water. Increased costs has already placed a financial restriction on water use and increased drought may also restrict water availability for TAI.

Increased fire risk and storm damage
The expected increase in the number of hot days [greater than 25°C] and the number of days with very high or greater forest fire danger is likely to increase the risk of fire in forests to our northwest and north, e.g. on Kelcey Tier. Fire is most likely to threaten the northern and western boundary of the site. An increase in the frequency and intensity of storm events is likely to increase damage to the living collection through increased erosion and direct plant damage. Some erosion impacts have already been experienced

Reduced frost damage
A reduction in the number of nights below 0°C is expected to lead to less frost damage to plants in the living collection and a reduction in the demand for protection of frost sensitive plants. It is also possible that a greater range of species may be able to be grown in the living collection with milder minimum temperatures. This appears to be the case as plants damaged by frost are less so and one reduced by cold temperatures to epicormic buds until 2009 is now carrying multi-years growth.

Visitor impacts
An increase in the annual average temperature and the number of hot days [greater than 25°C] is likely to impact on visitor comfort and satisfaction. More extreme weather events such as high winds or intense storm activity will increase the risk of tree and branch damage which increases the risk of injury to both TAI visitors and volunteers. TAI may restrict visitor access on days of extreme fire danger and intense storm activity. Any changes in visitation patterns may impact on income.

Buildings and infrastructure
More extreme climatic conditions are likely to place increased pressure on garden infrastructure which may lead to an increase in infrastructure maintenance costs. Increased erosion caused by more intense storm activity may impact on infrastructure such as garden paths and roads. An increase in the number of very high or greater forest fire danger days may result in an increased fire risk to buildings which may necessitate the need to redesign the existing landscaping around structures and an increase in insurance premiums.

Recommended management actions

The recommended management actions align with the five objectives of the Parks Australia Climate Change Strategic Overview 2009-2014 outlined below.

1. To understand the implications of climate change.
2. To implement adaptation measures to maximise the resilience of our reserves.
3. To reduce the carbon footprint of our reserves.
4. To work with communities, industries and stakeholders to mitigate and adapt to climate change.
5. To communicate the implications of, and our management response to, climate change.

4.1 Understand the implications of climate change
Plant flowering times and seasonality of natural populations of plant species is a key indicator of the response of an ecosystem to the effects of climate change. Botanic gardens have significant expertise and knowledge in the area of seasonality which can significantly contribute to our understanding of the implications of climate change on natural systems and assist managers to prepare and implement effective response options. TAI is positioned to provide some local leadership in climate change research and education and with strategic partnerships and unique collection of resources.

Recommended Management Actions		Timeframe
4.1.1	Secure resources to conduct a program of long-term monitoring of plant phenology.	Ongoing
4.1.2	Work with all researchers into climate change.	Ongoing
4.1.3	Select an area threatened by climate change and research the establishment of an ex-situ representative collection in partnership with another botanical garden.	
4.1.4	Follow climate change and horticultural research to better understand the implications of climate change on the living collections.	Ongoing

4.2 Implement adaptation measures to maximise the resilience of our reserves
The future condition of the TAI in the face of climate change will depend on a range of factors such as the rate and associated impacts of climate change itself, the resilience of the living collections to cope with environmental change and the level of

resources allocated to manage the site. The resilience of the TAI is ultimately dependent on the availability and affordability of a long term water supply and the selection of appropriate species to be displayed in the living collection.

Recommended Management Actions		**Timeframe**
4.2.1	Undertake a consultation process to review the living collection and set broad future directions for its management.	By 2014
4.2.3	• Continue to improve water use efficiency. Develop a Water Management Strategy • Continue to use cut grass as a mulch and soil humus builder • building staff capacity in irrigation management through targeted training programs.	By 2012
4.2.4	Negotiate with Cradle Coast Water to source an additional non-potable water supply to irrigate the living collection.	Ongoing
4.2.5	Continue to implement existing feral and native animal monitoring and control programs.	Ongoing
4.2.6	Continue to monitor and control weed populations.	Ongoing
4.2.7	Prepare for a contingency reserve to repair or replace flood damaged infrastructure. All new infrastructure to be reinforced or relocated	By 2020

4.3 Reduce the carbon footprint of the Arboretum

Activities such as water and electricity use, transport, design and development of new infrastructure and waste management all contribute to the carbon footprint of the TAI. TAI has no capacity to collects data on its carbon footprint but should follow general trends in targeting and reducing its carbon footprint. TAI aims to reduce greenhouse gas emissions from operational activities (such as energy use, transport and waste management).

Recommended Management Actions		**Timeframe**
4.3.1	Undertake actions to reduce carbon emissions that considers energy use (including lighting, heating and cooling), waste, water and support infrastructure (e.g. insulation) across all buildings, vehicles and equipment used at the gardens.	Ongoing
4.3.2	Develop an Environmental Management Plan for the site that identifies actions to reduce the carbon footprint of garden infrastructure and the impact on carbon emissions associated with each mitigation action.	By 2015
4.3.3	Continue to implement sustainable transport options including car pooling to off-site meetings, procurement of energy efficient vehicles and minimising long-haul travel using telecommunication options.	Ongoing
4.3.4	Develop a waste monitoring system and set targets to improve waste management.	By 2013
4.3.5	Join any appropriate carbon trading programs and dedicate that income to practical emission reductions, plant conservation or education activities	Ongoing

4.4 Work with communities, industries and stakeholders to mitigate and adapt to climate change

Climate change will have an impact on many communities, industries and stakeholders across Australia and they will need to mitigate their carbon footprint and adapt to the projected changes. TAI will work with local communities and stakeholders to identify and support proactive measures to reduce the negative impacts of climate change and to adapt where climate change induced impacts are unavoidable. The increase in frequency and intensity of extreme weather events will necessitate the development of risk control measures to protect life, infrastructure and the values of the TAI.

Recommended Management Actions		Timeframe
4.4.1	Protect biodiversity from the adverse effects of climate change by co-operating with a distributed National Seedbank Network to ensure efficiency of seed collection efforts and to input into global efforts after 2015.	By 2015 then ongoing
4.4.2	Develop strategic partnerships with user groups of seed banks such as species recovery programs.	Ongoing
4.4.3	Work with neighbours and relevant disaster management agencies to test emergency response plans and capacity to react to extreme weather events.	Ongoing
4.4.4	Conduct an infrastructure risk assessment to identify risks from climate change impacts and extreme weather events as part of the ongoing Risk Watch Program.	Ongoing
4.4.5	Work with the Australian botanical community to document past and future distribution of Australian plants.	Ongoing

4.5 Communicate the implications of, and our management response to, climate change

Climate change is a global issue affecting all aspects of our community and it is vital we share our knowledge with stakeholders, government bodies and the general public. This will ensure that stakeholders and the public are informed about potential climate change impacts and the management directions that are being taken. This also ensures that efforts between government agencies, scientific researchers and the community are well coordinated. TAI already has an ongoing program of community engagement through a broad range of education, botanical information, interpretation and community awareness activities to which climate change implications and responses need to be incorporated.

Recommended Management Actions		Timeframe
4.5.1	Follow the development of a key climate change and biodiversity messages and marketing approach for use by all botanic gardens by the Australian National Botanic Garden in conjunction with the Department of Climate Change and Energy Efficiency.	Ongoing
4.5.2	Develop a pilot or demonstration citizen-based science project linked with the phenology program as a focus to facilitate collaborative action.	By 2013
4.5.3	Demonstrate and promote TAI responses to climate change.	By 2011

4.5.4	Continue the relationship between the Australian Network for Plant Conservation (ANPC) and TAI, to ensure effective skills and knowledge transfer to plant conservation practitioners throughout Australia, particularly to regional and community-based groups such as APS NW Tas.	Ongoing
4.5.5	Develop and trial a climate change education programme for visiting school groups.	By 2011
4.5.6	Disseminate information to visitors and the community on actions TAI is implementing to reduce TAI's carbon footprint.	Ongoing

Implementation and Review

The Tasmanian Arboretum Inc - Climate Change Strategy 2013-2028 is to be implemented over a fifteen year period. The strategy is consistent with the aims and objectives of The Tasmanian Arboretum Inc. Implementation of the recommended management actions is subject to budgetary and resource constraints. The strategy will be reviewed on a rolling basis to take account of new information and changes in policy direction.

References

- Council of Heads of Australian Botanic Gardens (CHABG) 2008. *National Strategy and Action Plan for the Role of Australia's Botanic Gardens in Adapting to Climate Change*. Commonwealth of Australia, Canberra, Australia.
- CSIRO 2007. *Climate Change in the Murrumbidgee Catchment*. A report prepared for the New South Wales Government. CSIRO, Australia.
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