CLIMATE CHANGE AND BOODEREEL NATIONAL PARK
IMPACTS, CHALLENGES, AND IMPLICATIONS
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ABSTRACT
Climate change poses problems on fauna and flora of protected areas. In this paper, the impacts on Booderee National Park are discussed. Booderee is an Australian national park approximately 100 miles south of Sydney and owned by indigenous people while being managed under shared governance together with the Australian government. The paper will also examine climate change implications for Booderee including potential changes in conservation goals and management strategies and will discuss how actions and monitoring activities are affected by climate change. Finally, comparisons will be made between Booderee and two other selected Australian national parks.
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INTRODUCTION

Booderee national park is one among more than 500 national parks in Australia (Australian Government, 2015). It is located at the south-east coast of Australia approximately 100 miles south of Sydney and is basically part of the Jervis Bay area while covering most of Bherwerre Peninsula and Bowen Island (Director of National Parks, 2010a). The park covers nearly 25 square miles of land area as well as almost 3.5 square miles of marine territory. Figure 1 gives a good overview of the location of Booderee.

![Figure 1: Overview of Booderee National Park (Director of National Parks, 2010a)](image)

Booderee national park’s management plan lists the site’s historic development: First settlements date back more than 20,000 years ago. When European settlers arrive around 1800, land dispossession from Aboriginal people start. After Booderee is first enacted as Jervis Bay Nature Reserve in 1971, the area becomes Jervis Bay National Park in 1992. Before, in 1986 about 1.6 square miles of land were given back to the Aboriginal community. In 1996, the Board of Management is founded with a majority of Aboriginal representatives. In 1997, the name is changed to Booderee national park in order to reflect the Aboriginal ownership of the land (Director of National Parks, 2015a).

According to the Director of National Parks, Booderee is habitat for 26 kinds of mammals, 200 bird species, 17 reptiles, 14 types of amphibians, 308 sorts of fish, and 625 different kinds of plant species. It is special because of its implemented shared governance: The protected area is owned by local indigenous people and governed by the Board of Management which makes cooperation between indigenous people and the Australian government possible. More than 100 historical Aboriginal sites are protected and allow visitors to experience the indigenous culture of the Wreck Bay Aboriginal community (Director of National Parks, 2009b). In conclusion, Booderee is not just a
protected area for natural heritage but also for the cultural history of the territory next to Jervis Bay.

Climate change has become a serious problem in our times. Rising carbon levels in the atmosphere trap solar radiation, thus leading to an increase of average temperature on Earth. In this way, the increase of carbon dioxide and other so-called greenhouse gases is leading to a change of global climate with tremendous impacts on humans and ecosystems. Protected areas are no exception: While ecosystems are protected because of the value of their biodiversity, climate change poses many problems on flora and fauna due to changes in seasonal patterns like rainfall or temperature trend. Especially endangered species can be negatively affected, even causing extinction of such plants and animals. Booderee has already experienced a downward trend in terms of biodiversity together with other protected areas in Australia (Director of National Parks, 2009b). In the next chapters, we are going to discuss these impacts more in detail.

### 2 CLIMATE CHANGE IMPACTS

Booderee provides habitat for five endangered and 11 at least vulnerable animal species, furthermore the magenta lilly-pilly is listed as a vulnerable plant within Booderee territories (Director of National Parks, 2009b). In 2008, Hyder Consulting prepared a report on behalf of the Australian government about the impacts of climate change on Australia’s protected areas. It summarizes unique features of Booderee national park as follows: Besides the endangered species which were already mentioned, the park provided “[o]ne of the most diverse marine environments recorded in temperate Australia, with tropical and temperate species represented” (Hyder Consulting, 2008, p. 42). Other mentioned characteristics are large seagrass meadows, exceptional water clarity, the importance of Bowen Island as a breeding colony for little penguins, and the protection of natural sandstone and dune ecosystems. Because of their endangered status, threatened species are very sensitive for environmental impacts that cause changes to their habitats. Since the park covers marine as well as terrestrial areas, climate change affects Booderee from two different sides.

According to Hyder Consulting, CO₂ concentration is expected to rise by 165 ppm until 2030 and 365 ppm until 2070. This would lead to an average annual temperature increase of 1.3°C respectively 4.0°C, thus causing an increase of annual days with temperatures above 35°C by 3 days in 2030 and 15 days in 2070. While the average sea level is assumed to rise by 17 cm in the 2030 case scenario and 50 cm until 2070, rainfall numbers are very uncertain and could either show higher or lower amount of rainfall per year (Hyder Consulting, 2008).

#### 2.1 Fire Intensity and Frequency

One of the most frequently mentioned impacts of climate change is the increased risk of bush fires: Research shows that increasing CO₂ levels are beneficial for photosynthesis. It is therefore expected that the rising carbon levels will be advantageous for undergrowth, thus leading to more fuel load in the forests (Director of National Parks, 2010a). The Director of National Parks concludes further, that this fact together with rising temperatures and increased evaporation will expose Booderee national park to higher risks of fire. Fire is expected to appear more frequent and intense. Because some plant species is better capable to survive wild fires than others, it is easy to infer how such a change would be beneficial for more fire resistant species and in this way, the natural composition and finally, Booderee’s biodiversity would change (Director of National Parks, 2010a). The impact of fire is dependent on the interconnectedness of the land as well as the habitat itself that represents obstacles for fire to spread out and species to recover through introduction from
unaffected places. Of course, wild fires will also cause damage to infrastructure and facilities in the park.

2.2 Sea Level Rise

Rising sea level poses a high risk on the coast line of Booderee. While a lot of different bird species are currently using the high tide water line as their nesting spaces, such places will get lost due to erosion and flooding in the future (Hyder Consulting, 2008). Hyder Consulting also estimates that the loss of coastal habitat will cause changes in foraging and diet habits and that the increasing soil contamination could lead to higher turbidity of sea water which again would negatively affect marine species that is dependent on the clarity of its habitat.

2.3 Storm Intensity and Frequency

Climate change is expected to cause more frequent and severer storms (Director of National Parks, 2010a). Strong winds and heavy rainfalls will induce devastations similar to the ones caused by sea level rise. Because rainfall is projected to become more variable with longer periods of drought in between, more frequent local flooding is expected due to the limited absorbing capacity of soil after drought periods (Hyder Consulting, 2008). Hyder Consulting estimates coastal areas and especially Bowen Island could be affected. This is alarming because Bowen Island is providing breeding habitat for little penguins and other bird species. Storms will intensify erosive forces, therefore damaging natural habitat. Another factor is the salinization of soil close to the water front trough temporary sea water flooding in consequence of storms.

The increased likelihood of severe storms also exposes cultural heritage to higher risk. Erosion and winds could damage artefacts of indigenous culture and therefore, climate change creates a challenge not just for natural attributes of Booderee but also for unique witnesses of the history of human culture (Director of National Parks, 2010a).

2.4 Higher Temperature

Temperature is an important indicator for flora and fauna to adjust seasonal patterns. “Higher annual average temperatures are likely to affect triggers for life cycle events, population ecology and the occurrence of suitable habitats for a range of species” (Director of National Parks, 2010a, p. 6): Climate change disturbs the natural rhythm of species worldwide. Changing life cycles can cause serious foraging problems when species that are lower in the food chain are not available in the right quantities at the right time. Population increase of endangered species or extinction are feasible. Booderee will experience changes in wildlife population distribution for sure.

2.5 Changing Ocean Current

Jervis Bay is influenced by the East Australian Current which flows southwards along the Australian coast (Director of National Parks, 2010a). The East Australian Current provides nutrients for marine life through upwelling and cycling and is therefore an important factor for food supply in the park. It is expected that climate change will have altering effects on ocean currents. However, predictions are difficult and contradictory: Some researchers assume that the East Australian Current will alter in a way that sea grass growth is facilitated while others estimate invasive species could be brought into the protected area, therefore taking over habitat of native flora and fauna. This would of course represent a serious problem regarding the protection goals of Booderee national park as covered in the next paragraph.
## 2.6 Invasive Species

Booderee national park is a well attuned composition of natural species and environmental conditions. Climate change would alter habitat conditions and disturb the sensitive balance. Hyder Consulting estimates that in a consequence, native plants and animals could be disadvantaged while species from other places could find new pleasant conditions in Booderee. These species would be considered invasive because of their origin and could endanger local flora and fauna. Examples for explicit concerns are kikuyu grass and bitou bush as terrestrial species as well as marine algae like caulerpa taxifolia (Hyder Consulting, 2008). The spread of invasive species evokes more competition for available habitat and could thus negatively influence native plant and wildlife (Director of National Parks, 2010a).

### 3 IMPLICATIONS AND DERIVED MEASURES

Climate change creates challenges for traditional protected areas and their management. Michael Dunlop and Peter Brown summarized the dilemma in 2008: Climate change will necessarily lead to changes in the natural composition of territories. Changing climate conditions are beneficial for some species and unfavorable for others. Therefore, species will change genetically as well as in terms of assemblages. They will move and search for better spaces to live, others will intrude in former hostile habitats. Extinction is not avoidable but other endangered animals and plants could even benefit from changed living conditions. Climate change comes with transformation but questions on how this change will look like cannot be answered for sure (Dunlop & Brown, 2008).

Climate change therefore inevitably raises questions for every protected area and its management: What do I want to protect? What are my conservation goals?

In the past, biodiversity was usually seen as more or less stable. Protected areas were enacted to preserve biodiversity in a specific region. Conservation goals were therefore designed in order to promote further existence of natural composition as it was found when the park was established or as it was expected to be suitable for the territory. Many protected areas were created with fixed goals like the protection of specific species (Dunlop & Brown, 2008). Now, in times of climate change, we know that biodiversity's structure will change in the future. Booderee park management and other management boards have to decide whether they want to continue trying to conserve the area's population as it is, knowing that change is inevitable or whether they adapt their conservation goals to meet future challenges (Dunlop & Brown, 2008).

### 3.1 Climate Change Strategy

The 2010 Booderee National Park Climate Change Strategy recommends the following five steps:

1. Understand climate change implications,
2. implement adaptation measures to enhance resilience,
3. reduce the carbon footprint of the park and its management,
4. collaborate with different stakeholders like communities and industries in order to develop mitigation and adaptation projects, and finally
5. communicate information about climate change and Booderee’s management answers to the public (Director of National Parks, 2010a).

In the first step, understanding of climate change and its implications on Booderee should be enhanced. This includes disclosure of existing knowledge gaps and addressing of those in cooperation with research institutes in order to allow understanding and elimination of these gaps.
Extension of existing information and data management systems are expected to optimize conservation efforts and to support a risk assessment process to identify the likelihood of different climate impacts on Boobere in partnership with the Wreck Bay community (Director of National Parks, 2010a).

Step two addresses the earlier mentioned necessary shift, away from single species based conservation goals towards an ecosystem approach in which the protected area is considered as a comprehensive biodiversity system that interacts with other regions. Some of the keys are implementation of a weed and pest monitoring program to maximize resilience, continuing development of fire management strategies, and ongoing collaboration with the Australian National University, land planning agencies, and neighbor parks and stakeholders to ensure coordination beyond park borders. An interesting and by comparison concrete goal in terms of climate change implications is the search for areas that are likely to provide space for migratory latitudinal shift of species to find new habitats (Director of National Parks, 2010a).

As a third recommendation, Boobere national park is supposed to set a good example by reducing its own carbon footprint. This is planned to be achieved by minor measures like replacement of wood-fired BBQ places with electric or gas powered ones, switch to more efficient vehicles, conservation of energy through installation of efficient LED lighting systems, heat pump or solar water heating systems and motion sensors, and utilization of renewable energy through solar PV systems. It is also scheduled to participate in any further carbon trading programs in order to capitalize the carbon sequestering quality of the park (Director of National Parks, 2010a).

According to Boobere's climate change strategy, stakeholder collaboration includes promotion of renewable energy among the Wreck Bay community and other stakeholders, determination of employment opportunities for indigenous people to monitor climate change impacts, and support of tourism businesses to adapt their operations to climate change (Director of National Parks, 2010a).

Last but not least public communication is a corner stone of the elaborated climate change strategy: It is important to keep all stakeholders informed about the implications of climate change and the management’s responses. Furthermore, documents related to climate change should be available to the public on the websites of Boobere national park and the Australian government in order to spread information further (Director of National Parks, 2010a).

The discussed five-step approach is in general no specific Boobere action plan. As it turns out, Parks Australia developed the main points of this strategy as an overall framework to oppose climate change implications on all its protected areas (Director of National Parks, 2009a).

3.2 Management Plan

In 2015, the climate change responses were factored into the second management plan for the decade 2015-2025. Passage 6.11 in Boobere national park's management plan formulates the aim: “Climate change impacts on park values are better understood and management actions and planning are adapted to take account of the latest available information” (Director of National Parks, 2015a, p. 82). The management plan is clearly biased by the climate change strategy document. It calls for further research to support understanding of impacts of climate change on Boobere and participation in national strategies for carbon trading should be considered. Management priorities shall be adapted to derived climate impacts in order to find appropriate solutions including ecosystems management, emergency response capacity, infrastructure design and maintenance, and visitor management and safety (Director of National Parks, 2015a).

The policy description “[...] the Director and the Board, in consultation with relevant stakeholders, will jointly decide on further monitoring requirements and whether protective,
rehabilitation or adaptation measures are feasible. If cost effective, appropriate responses and actions will be implemented” (Director of National Parks, 2015a, p. 83) remains vague and sketchy and is formulated as open as possible to take any future threats into account. With two dedicated pages in a 183 pages comprising management plan and just a few mentions in other sections, it seems that climate change is currently not in the main focus of the Board of Management. Even more surprising is the fact that the latest Director of National Parks annual report mentions climate change only once – not in connection with threats for conservation goals but instead just in the context of carbon footprint reduction of Australian parks (Director of National Parks, 2015b).

3.3 Actions and Monitoring

Measures in Booderee are not directly related to climate change because of the indirect character of the proposed climate change strategy: Actions are just adapted in a way to meet conservation goals like for instance the maintenance of a specific population. Climate change is therefore more understood as a factor influencing the achievability of biodiversity goals in the national park – less as a separate phenomenon that would need separate conservation measures and attention like for instance invasive species.

In order to do so, fox numbers are kept low through baiting since the early 2000s: The number of baits is adapted to the fox population. In 2014, 1,080 baits were used and shooters were employed to shoot shy foxes (Director of National Parks, 2014b). This long term control allowed the reintroduction of long-nosed potoroo to Booderee. In a consequence to the fox population control, threatened bird species population is recovering (Director of National Parks, 2013). Such birds are eastern bristlebird, hooded plover, sooty oystercatcher, and pied oystercatcher. Mammals that benefit from fox control are besides the long-nosed potoroo the long-nosed bandicoot, common brushtail possum, and eastern chestnut mouse (Director of National Parks, 2012).

The population of the mentioned species is monitored by different approaches depending on the place of its natural occurrence. While the foxes themselves are caught by fauna cameras, birds are monitored through early morning surveys including calls and sightings or monthly surveys by boat. Mammals are usually counted by the use of several traps across the park or cameras (Director of National Parks, 2013) (Director of National Parks, 2015b). In this way, a feedback loop exists to provide information on the effectiveness of conservation measures. Most key species show stable numbers while the common brushtail possum’s population decreased in all annual reports starting from 2011. The long-nosed bandicoot could be stabilized after several years of decline (Director of National Parks, 2015b).

Another measure for biodiversity protection is the combat against highly invasive bitou bush by hand spraying, ground spraying, hand pulling, and aerial helicopter spraying (Director of National Parks, 2015b). After bitou bush coverage was tremendously reduced by 90% in high infestation areas and about 75% in areas of medium infestation between 2011 and 2012 (Director of National Parks, 2012), numbers are now steady since five years (Director of National Parks, 2015b). Monitoring is undertaken by aerial surveys every three years which determine local bitou density and record them in a geographical information system (Director of National Parks, 2012).

In order to improve nesting opportunities for little penguin, kikuyu weed is controlled by aerial spraying in nesting areas on Bowen Island (Director of National Parks, 2014b) (Director of National Parks, 2015b). The success of this action is monitored through counting of little penguin individuals during night landings (Director of National Parks, 2015b) or monitoring of chick mortality (Director of National Parks, 2012).
All these actions and its result monitoring is undertaken to mitigate indirect climate change impacts on Booderee national park. Actual implementation of other proposed measures like utilization of renewable energy is not documented in the annual report (Director of National Parks, 2015b).

4 COMPARISON TO OTHER AUSTRALIAN PARKS

As already mentioned in the previous section, Parks of Australia implemented the same climate change action plan framework for all Australian national parks (Director of National Parks, 2009a). The main five-step strategy is adapted to every park’s individual needs. In the following, Booderee’s climate change strategy is compared to two other national parks.

4.1 Kakadu National Park

As visible in figure 2, Kakadu national park is located at the north coast of Australia approximately 125 miles east of Darwin (Director of National Parks, 2010b). With 7,650 square miles, the park is much bigger than Booderee. Half of the park was given back to the Aboriginal community under the Aboriginal Land Rights Act in 1976. Since then, the land is leased back to the Director of National Parks in order to be managed as Kakadu national park (Director of National Parks, 2016). Just as in Booderee, Kakadu is managed under an implemented shared governance approach that includes a Board of Management in which the Aboriginal community collaborates with the Australian government. According to the Director of National Parks, the park is further expected to be more resilient to climate change impacts also because of its sandstone structures which provide an accommodating micro climate for many species that are endangered in the consequence of climate change.

Kakadu shares many aspects of its climate action plan with Booderee. Over several passages, the listed recommended management methods are identical. One major difference is the specifically added danger by saltwater intrusion through rising sea level. Coastal plains of Kakadu are located just a few feet above sea level. Furthermore, the park includes wetlands which are important habitat for migratory birds and other species. These wetlands are at risk to become salty which would create problems for animals and plants that are dependent on those.

Management actions are adapted to the specific biodiversity of Kakadu. Endangered key species are northern quoll, northern brown bandicoot, northern brushtail possum, brush-tailed rabbit-rat, black-footed tree-rat, pale field rat, flatback turtle, and estuarine crocodile (Director of National Parks, 2012). According to the last five annual reports the population of those mentioned species is almost steadily decreasing. Just the latter mentioned estuarine crocodile and flatback turtle show steady or increasing numbers in the last years (Director of National Parks, 2015b). To support vulnerable flora and fauna, Kakadu park management heavily relies on controlled fire management to improve habitat quality (Director of National Parks, 2015b). The 2014-2015 report is the first that lists supplemental measures like threatened species workshops and support of national research programs to determine impacts of feral cats on local mammals. Also, wild dog control is undertaken together with educational programs to inform the public about the consequences of wild dog feeding on local fauna. Monitoring is maintained through survey, sighting and road kill records.
Threats to local plants and wildlife are water buffalos and feral pigs as well as mimosa and multiple weeds. Monitored development indicates negative trends similar to the negative effects in the evolution of Kakadu's endangered species. While the monitoring itself is undertaken by incidental sightings, helicopter mapping, and observation at specific sites, actions cover eradication programs, pesticide and fire use, and opportunistic measures (Director of National Parks, 2015b). Even though all these provisions are not directly related to climate change, they show the specific conservation challenges in Kakadu national park. It also demonstrates how individual measures have to be adapted to the needs of the park and that besides the climate change action plan, the Australian parks mainly focus on individual actions under an opportunistic mindset to manage their protected areas in the face of climate change.

4.2 Christmas Island National Park

Christmas Island is another interesting national park in Australia. As shown in figure 3, the island is located approximately 1,600 miles north-west of Perth, 2,700 miles west of Darwin, and 310 miles south of Jakarta. The terrestrial protected territory covers an area of around 50 square miles which relates to around 60% of the island area. Additionally, marine territory is protected down to a depth of 164 feet below water surface (Director of National Parks, 2011).

Christmas Island national park is special because of its remoteness. Isolation from the main land allowed the island to develop a unique biosphere almost completely independently from nature elsewhere. This characteristic makes Christmas Island's species highly valuable but also highly vulnerable especially to invasive species and other external influences. Together with more than 100 migratory sea bird species, the park is home for 88 coral and over 600 fish species, and two turtle species (Director of National Parks, 2011).

Figure 2: Location of Kakadu (Director of National Parks, 2010b)
The climate change strategy from 2011 provides for the same five-step framework as already discussed for Booderee and Kakadu. However, implementation is adapted to the specific needs of the marine-terrestrial protected area and therefore, climate change impacts are extended compared to Booderee: The red crab represents the island’s dominant key species (Director of National Parks, 2011). Because its migration is dependent on the start of the wet season, rainfall reduction and shifts in the natural rhythm are one example for how climate change can disturb the sensitive local balance of flora, fauna, and environment. Also, water acidification through increasing atmospheric carbon dioxide levels and rising water temperature could trigger coral bleaching and decreasing fish stock (Director of National Parks, 2011). Acidification would also lead to aggravated conditions for marine life that develops a calcium carbonate shell and disturbances in marine population would not just affect the food chain below the water line but also sea bird species which is heavily dependent on fish.

The management plan for Christmas Island defines the goal regarding climate change as follows: “The Director will work with stakeholders and encourage, and where feasible support, research and investigations into potential climate change impacts, and the development of mitigation and adaptive responses” (Director of National Parks, 2014a, p. 63). Even though this policy is formulated differently compared to Booderee’s, the general idea also remains relatively vague. The policy is further explained by three actions which should be implemented: First, climate change based research is asked to be prioritized and supported to gain more knowledge about climate change impacts on Christmas Island and adequate mitigation and adaptation strategies. Second, a climate change strategy should be implemented and reviewed in order to improve park management according to the lessons learned from research. And lastly, management priorities and programs have to be changed to take the research outcomes into consideration (Director of National Parks, 2014a). This case again shows that the Australian climate change strategy rather provides a generic framework within its borders conservation goals are adapted if necessary instead of changing conservation aims in general.
The Director of Parks’ 2014-2015 annual report reveals exceptionally high numbers of key performance indicators for Christmas Island. Nearly all listed endangered species indicate upward trends. Christmas Island flying-fox, lister’s gecko, forest skink, and others are supported through research projects that aim to determine the species’ threats and captive breeding projects that allow captive breeding in case if the already critical low population should further decrease. However, such captive breeding efforts can be difficult as the spread of an unknown disease among captive individuals of lister’s geckos shows (Director of National Parks, 2015b). Fortunately, threat species such as the yellow crazy ant, false curry bush, Siam weed, and feral cat are kept in check as mostly declining populations evaluated by surveys and camera traps show. Especially feral cats are combated via a large scale removal program which removed 600 individuals in 2014-2015. Siam weed is detected by unmanned aerial vehicles and image recognition software (Director of National Parks, 2015b).

Christmas Island confirms the insight that Booderee national park makes use of Australia’s generic climate change strategy. The comparison reveals how the five-step strategy itself is applied towards multiple protected areas in Australia and how the framework is adapted for the individual characteristics of each park.

5 CONCLUSION

Booderee national park is a good example for Australia’s reaction to climate change: The national parks each published a climate change strategy paper in which they describe a five-step strategy to tackle climate change impacts. The key points of the overall five-step framework are the same for every park while further specifications are carried out individually. For Booderee, more frequent and severe droughts and wild fires, rising sea level, and more storms are expected to pose risks on natural as well as cultural heritage through direct and indirect impacts like erosion and species invasion. In Booderee, management strategies call for cooperation between research institutions and local indigenous communities to facilitate investigation on climate change effects, optimize projections, and thus enhance understanding of weak spots in the management plan. Based on these insights, weed and pest monitoring programs are planned to be implemented to further improve resilience of the park’s biodiversity. Conservation goals are adapted to take into account potential shifts of species and their habitat, management strategies should be reviewed to provide for balancing measures to protect flora and fauna as far as possible, and monitoring is used to adjust conservation efforts according to climate change impacts. At the same time, Booderee minimizes its carbon footprint and aims to support local stakeholders to adapt to climate change consequences.

In conclusion, the Board of Management of Booderee national park seems to understand the challenges of climate change it is facing even though climate change does not seem to be on the top of its priority list. However, implementation is often not specific and concrete actions are primarily derived in a micro-perspective of “day-to-day” business, leading to measures that usually consist of aims to stabilize flora and fauna population. Macro-perspective approaches like the educational role of the park or even the reconsideration of Booderee’s conservation goals in terms of what should be preserved do not seem to be implemented yet.
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