

## 1 Executive Summary

The potential impacts on Little Penguins have been considered under five broad headings: sea-level rise, decreased rainfall and humidity, ambient temperature rise, sea temperature changes and winds, southern oscillation index and acidification.

### Sea-level rise

There will be some small loss ( $\ll 1\%$ ) of penguin breeding habitat on the Summerland Peninsula due to sea level rise in the next 100 years but it is considered that breeding habitat is unlikely to be limited on the Peninsula in this period. However, there is likely to be some erosion in the vicinity of Whaleshead Creek and further east which has implications for the Penguin Parade.

It is anticipated that there will be some loss of productivity of inshore waters in Bass Strait due to sea-level rise also, which may ultimately result in reduced food availability for penguins.

### Decreased rainfall and humidity

It is predicted that there will be little appreciable direct impact of decreased rainfall and humidity on adult Little Penguins over the next century. However it seems likely that fire risk will increase and needs to be managed to ensure penguin survival is unaffected.

In addition, if the availability of anchovies is reduced by decreased rainfall, then adult penguin survival (and possibly breeding productivity) may be reduced.

### Increasing air temperatures

Increasing temperatures in burrows during daylight are likely to increase adult mortality slightly and chick mortality to an unknown extent.

Increasing burrow temperatures may also have a role in determining breeding success and this warrants investigation as does the scope for mitigation of burrow microclimates through vegetation management and artificial burrow design.

### Sea-surface temperatures in Bass Strait

Increasing sea-surface temperatures in Bass Strait may result in an earlier start to the breeding season, increases in breeding success and increases in first-year survival.

Decreases have been predicted in adult survival, but more work is required to confirm the direction of this relationship. More productive breeding seasons and higher first-year survival should improve recruitment into the breeding population.

Increased stratification of the water column may reduce productivity and, correspondingly, food availability for penguins but, conversely, increase foraging efficiency of Little Penguins.

### Winds, southern oscillation index and ocean acidification

Decreasing winds in the region are likely to reduce the recruitment of fish populations and hence the availability of food for penguins, with potential impacts on their survival and breeding success. It is unknown if wind direction and velocity directly affect penguin foraging success.

Decreasing SOI may reduce adult survival and increase juvenile survival but the mechanisms are unknown for either.

Increasing acidification may reduce food availability for penguins.

Overall there are a number of aspects of the biology of penguins that are likely to be affected, both positively and negatively, by predicted climate change over the next 100 years. Breeding productivity and juvenile survival seem likely to improve with increasing sea temperatures. Marine productivity and adult survival perhaps, seem likely to decline while the feeding behaviour of penguins will possibly experience both negative and positive impacts as a consequence of climate change. Some of the negative impacts can be addressed in the short-term, particularly those resulting from expected changes to the terrestrial environment.

A number of areas requiring further research have been identified including the effects of temperature on breeding success and adult survival, the effects of sea temperatures on adult survival and productivity and the effects of rainfall on food availability. Continual review will be essential as the predictions and implications for climate change develop further.

#### 1.4 Summary of tourism-related issues for further research

The impacts of climate change on the Little Penguin population of Phillip Island could have repercussions for the Phillip Island economy, and that of the Bass Coast Shire more broadly. The penguin population contributes to a strong and viable tourism industry on the Island. Of the more than 1000 businesses in the Shire, over half benefit directly from tourism. In 2007/08, a total of 491,780 people visited the Nature Park to see the penguin parade. Of these, 308,465 were international tourists spending a total of \$19.7 million, and 183,315 were Australian visitors spending a total of \$15.4 million.

#### Tourism scenarios under climate change

As noted, the impacts of climate change on the penguin population have not been detailed as yet. Nor has the impact on tourism of penguin population decline. Accordingly, three scenarios have been developed to hypothesise tourism decline, and the resulting economic impacts modelled. Scenario one models a small penguin population decline, with no notable change in economic impact. Scenario 2 involves significant population decline with similar economic impacts. And Scenario 3 models extreme population decline and associated visitation. These scenarios are summarised below.

Scenario	Features	Impact on visitation
Small population decline	Climate change causes population decline, but penguin parade continues every night.	Negligible change. Domestic and international tourism continues.
Large reduction in population	Population declines significantly, causing penguin sightings to become sporadic during winter months	Park closure to the public for winter months. International visitation suffers significant decline (50%) as tours remove penguins from itinerary. Domestic visitation declines during winter months only (30%).
Extreme reduction in population	Population declines dramatically, causing sporadic penguin sightings year round and rare sightings during winter months	International visitation collapses (90%) and domestic visitation dramatically reduced (80%). Viability of tourism threatened.

Source: MJA analysis

Scenario one models a small penguin population decline, with no notable change in economic impact. Scenario 2 involves significant population decline with similar economic impacts, Scenario 3 models extreme population decline and associated visitation. Scenario 2 involves a sizeable decrease in economic activity once tourism is notably affected by penguin population decline. This involves a decline in direct economic output of \$14.5m per year, and with flow-on, a decrease in total gross output of \$28.6m per year. The decrease in direct value added associated with Scenario 2 is \$11m per year, and with flow-on, \$18m per year. Total employment loss in the Bass Coast Shire (direct and indirect) is estimated at 66 full time jobs.

Scenario 3, involving more extreme penguin population decline, is modelled to have more dramatic impacts on associated tourism. This involves a decline in direct economic output of \$30m per year, and with flow-on, a decrease in total gross output of \$57m per year. The decrease in direct value added associated with Scenario 3 is \$21.4m per year, and with flow-on, \$34.6m per year. Total employment loss (direct and indirect) is estimated at 118 full time jobs.

MJA stresses that these scenarios are purely hypothetical. They have been compiled in the absence of detailed understanding of the likely impacts on penguin population of climate change and without survey analysis of visitor preferences relating to penguin tourism.

Further work in these areas could establish a more robust understanding of the regional economic impacts of climate change on the Phillip Island Little Penguin colony.



Map locating the study with reference to SECCCA councils

## 2 Introduction

The global phenomenon of climate change is expected to bring about a range of impacts that will be experienced differently at local levels, from increased temperatures, storm surges and eroded coasts. There is considerable work underway to model the nature of these impacts for human populations and for the coastal infrastructure on which they depend. There is not the same amount of study being directed to climate change impacts on biodiversity, unfortunately.

It is known that the distribution of some bird species is changing. In the first Bird Atlas (Blakers et al, 1984) Crested pigeons (*Ocyphaps lophotes*) were recorded in 615 of the one minute grids, nineteen years later the second Bird Atlas (Barrett et al, 2003) recorded the species in 649 one minute grids, while Long-billed corellas (*Cacatua tenuirostris*) over the same period increased from being recorded in 14 one minute grids to 86. The converse, a reduction in range, is also true for other species. The Regent honeyeater (*Xanthomyza phrygia*) was found in 38 grids in 1984 but 32 in 2003, while the Hooded robin (*Melanodryas cucullata*), found in 466 one minute grids in 1984, was found in only 416 in 2003. With changes in distribution, it is almost certain that there will be changes in total population numbers.

The reasons for changes in distribution are myriad – habitat loss, introduced predators and competition from exotic species for nest sites will all play a part. Biophysical changes, in temperature, fire regimes and average rainfall, are also likely to have an impact. Climate change is bringing about many biophysical changes.

The Little penguin (*Eudyptula minor*) is a species of some significance to Victorians. Penguins attract people, many people. Robyn Williams, presenter of ABC Radio's Science Show, remarked "they might be attracted to penguins because they're lovely and cute but they look at them as eccentric, different, more like us than birds." (Perceptions of Beauty, Science Show, ABC Radio, September 2007). Melbourne Zoo has

long featured a Little penguin exhibit, Melbourne Aquarium has now installed A Penguin's World featuring King and Gentoo penguins, while Philip Island Penguin Parade is Victoria's largest regional tourism venue.

Penguins attract public interest so if attention is to be given to non-human impacts of climate change, penguins can serve as a species with which to do this. Apart from the moral issue of sitting by while another life form suffers through our misdeeds, at the Philip Island Penguin Parade there can be quantified economic consequences from our misdeeds also. The thriving tourist industry based upon the Phillip Island penguin population could be jeopardised through climate change. Little penguins, then, are a powerful indicator species for climate change impacts. Rather than the canary in the coal mine to indicate dangerous concentrations of carbon monoxide, they provide the clarion call from the coast to tell us of the effects of dangerous levels of carbon dioxide in the atmosphere.

### **3 Impacts of Climate Change on Human Settlements in the Western Port Region: an Integrated Assessment**

The SECCCA conducted the project Impacts of Climate Change on Human Settlements in the Western Port Region: an Integrated Assessment to assist member councils identify the risks that climate change poses for their communities and the infrastructure on which they depend.

This project was one of five national adaptation projects funded by the Australian Government's Department of Climate Change, with additional funding from the Victorian Government's Department of Sustainability and Environment. The project was conducted in four phases:

(i) projecting changes to key climate drivers and associated biophysical impacts in the region. Changes examined included sea level rises, average and extreme rainfall, storm surge, temperature and fire weather. Outputs of this phase are provided in three biophysical impacts reports, available on [www.SECCCA.org.au](http://www.SECCCA.org.au). This phase of the project was conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

(ii) examining the nature and extent of potential impacts to the region's built environment (land, housing and public and private infrastructure) as well as an assessment of the social and economic implications of the impacts and the vulnerability of different localities and groups. Marsden Jacob Associates (MJA) conducted this phase of the project, with input from CSIRO.

(iii) identifying and developing a priority list of risks to local governments associated with the impacts. A series of risk assessments, led by Broadleaf International and involving upwards of 60 council staff, were undertaken with each of the region's local councils. These reports were prepared for internal use and incorporation into the work programs of each local council.

(iv) adaptation options and barriers to effective response to the high priority risks were explored with local councils, state government and other key regional decision makers. The adaptation responses available to councils, whether policy responses, engineering responses or behaviour change as a consequence of community activity, are canvassed in the report Impacts of climate change on settlements in the Western Port Region - Climate Change Risks and Adaptation Report, also available on [www.SECCCA.org.au](http://www.SECCCA.org.au).

The CSIRO projections for biophysical impacts for the Bass Coast Shire, in which the Penguin Parade is located follow.

## Bass Coast Shire

Climate variable*	Indicative change**		Exposed people***	Exposed property and infrastructure***
	2030	2070		
<b>Temperature</b>				
Average annual temperature	↑ 0.5-1.3°C	↑ 1-3.5°C	<ul style="list-style-type: none"> <li>entire population, especially 6,000 elderly</li> </ul>	<ul style="list-style-type: none"> <li>most roads</li> <li>most railways lines</li> <li>some building materials</li> <li>buildings or services that require cooling</li> </ul>
Days per yr > 30 °C (16 current)	↑ 1 - 5	↑ 4 - 16		
Days per yr > 40 °C (0 current)	↑ 1	↑ 2		
<b>Average rainfall</b>				
Average annual	↓ 0-8 %	↓ 0-23 %	<ul style="list-style-type: none"> <li>entire population</li> </ul>	<ul style="list-style-type: none"> <li>municipal parks and gardens</li> <li>playing fields</li> <li>water &amp; wastewater infrastructure</li> <li>other infrastructure on clay soils</li> </ul>
Catchment stream flows	↓ 25 %	↓ >50 %		
Droughts	↑ frequency & severity			
<b>Extreme rainfall</b>				
2 hour	↑ 22 %	↑ 59 %	<ul style="list-style-type: none"> <li>150 people</li> </ul>	<ul style="list-style-type: none"> <li>55 residences, principally rural</li> <li>11 commercial and other properties</li> <li>16 km of roads including Bass Highway and Korumburra-Wonthaggi Rd, 9 bridges</li> </ul>
12 hour	↑ 17 %	↑ 41 %		
24 hour	↑ 14 %	↑ 39 %		
72 hour	↓ 2 %	↑ 39 %		
Maximum flood heights	↑	↑		
Flood return intervals (ARI)	↓ flash ↔ riverine	↓ flash ↓ riverine		
<b>Sea level rise / storm surge</b>				
Sea level rise	↑ 0.17 m	↑ 0.49 m	<ul style="list-style-type: none"> <li>560 people</li> <li>possibly additional people and properties in the vicinity of Inverloch</li> </ul>	<ul style="list-style-type: none"> <li>261 residences</li> <li>approx. 30 commercial and other properties</li> <li>most beaches and foreshore reserves including at Cowes and Inverloch</li> <li>most boating facilities</li> <li>15km of roads including Bass Highway</li> </ul>
Storm tide – max. height, 1:100 year ARI (current 2.10m, Cowes)	2.29 m	2.74 m		
Storm surge – change to 1:100 year ARI	↓ to 1:50 - 1:20	↓ to 1:20 - 1:4		
Inundation area Phillip Island (1:100 year storm surge)	2.2 sq km	2.8 sq km		
Inundation area mainland**** (1:100 year storm surge)	2.5 sq km	4.5 sq km		
<b>Fire weather</b>				
No. of very high and extreme forest fire risk days (~ 9 days current)	↑ 1 - 2	↑ 2 - 5	<ul style="list-style-type: none"> <li>up to 2,800 people, mostly adjacent to bushland</li> </ul>	<ul style="list-style-type: none"> <li>1,280 residences</li> <li>50 commercial and industrial</li> <li>240 public use and unspecified including schools, medical facilities and numerous reserves</li> <li>87 km of roads</li> </ul>
No. of very high and extreme grass fire risk days (~ 95 days current)	↑ 7 - 15	↑ 9 - 30		

\* Note, information on windiness and storms is the same for all LGA. It is summarised in Table A, Executive summary.

\*\* Key to climate changes: ↑ increase; ↓ decrease; ↔ no significant change. Absence of number next to arrow indicates magnitude of change has not been quantified.

Most sensitive locations	Economic and social impacts	Vulnerable sectors	Vulnerable groups
<ul style="list-style-type: none"> <li>inland areas (particularly urban)</li> <li>areas with high concentrations of elderly and infants (esp. Wonthaggi, Inverloch)</li> </ul>	<ul style="list-style-type: none"> <li>increased mortality and morbidity in vulnerable groups</li> <li>increased infrastructure maintenance costs</li> <li>disruptions to transport networks</li> <li>increased risk of food and water born disease outbreaks</li> <li>increased summer peak demand</li> <li>increased cooling costs</li> </ul>	<ul style="list-style-type: none"> <li>transport</li> <li>construction</li> <li>local government services such as child care, environmental health</li> </ul>	<ul style="list-style-type: none"> <li>elderly (6,000)</li> <li>infants (1,300)</li> <li>residents in low quality housing (e.g. rental) or low income households</li> </ul>
<ul style="list-style-type: none"> <li>areas not connected to mains supply</li> <li>high water requirement sites</li> <li>wetlands, heritage gardens and other reserves</li> </ul>	<ul style="list-style-type: none"> <li>increased water prices</li> <li>increased reliance on non-traditional supply sources</li> <li>access to water for some activities</li> <li>viability of some water dependent businesses and activities</li> <li>increased maintenance costs, some infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>nurseries, garden services, etc</li> <li>local government services such as parks, recreation</li> <li>water suppliers and retailers</li> </ul>	<ul style="list-style-type: none"> <li>households not connected to mains supply</li> <li>low income households (possibly)</li> </ul>
<ul style="list-style-type: none"> <li>Bass River flood plain</li> </ul>	<ul style="list-style-type: none"> <li>increased flood damage to public infrastructure, especially roads and bridges</li> <li>increased flood damage costs to residential and commercial buildings (minimal)</li> <li>disruption to transport</li> <li>increased emergency services demand and costs</li> </ul>	<ul style="list-style-type: none"> <li>local government</li> <li>transport</li> <li>rural</li> </ul>	<ul style="list-style-type: none"> <li>low income households</li> <li>businesses and properties without adequate insurance</li> <li>residences with limited freeboard above 1:100 year flood (e.g. &lt;300 mm clearance)</li> </ul>
<ul style="list-style-type: none"> <li>Cowes, Rhyll, Cape Woolamai</li> <li>Bass River</li> <li>Grantville, Coronet Bay</li> <li>Possibly in vicinity of Inverloch</li> </ul>	<ul style="list-style-type: none"> <li>partial or (in worst case) complete loss of land values in affected areas</li> <li>major amenity impacts associated with damage to beaches and foreshore reserves</li> <li>impacts on businesses dependent on beach related tourism, especially Phillip Island and Inverloch</li> <li>increased insurance costs or lack of access to insurance</li> <li>costs associated with beach and foreshore maintenance (e.g. beach renourishment)</li> </ul>	<ul style="list-style-type: none"> <li>tourism</li> <li>recreation and boating</li> <li>local government</li> </ul>	<ul style="list-style-type: none"> <li>low income households</li> <li>elderly households</li> </ul>
<ul style="list-style-type: none"> <li>Phillip Island around Cowes and Rhyll</li> <li>a large area in the north of the shire to the east and south of Grantville</li> <li>north and south of Wonthaggi</li> </ul>	<ul style="list-style-type: none"> <li>increased damage costs to residential properties</li> <li>health impacts including loss of life and air quality</li> <li>increased emergency service costs</li> <li>stress, social disruption</li> </ul>	<ul style="list-style-type: none"> <li>residential</li> <li>emergency services</li> <li>local government</li> <li>transport</li> </ul>	<ul style="list-style-type: none"> <li>people living in older housing (in exposed areas)</li> <li>properties that have not been adequately prepared</li> <li>low income households</li> </ul>

\*\*\* Based on current (2006) population and projected changes to 2070. \*\*\*\* Does not include area around Inverloch, where further analysis is required.

Participants in the project included council staff from the 5 member councils of the SECCCA, state agency staff and representatives of the Australian government. They identified, through the risk assessment process, that there were risks posed to the region's biodiversity through climate change but this was outside the scope of the project, based as it was in examining impacts on human settlements.

Western Port has been the focus of a considerable amount of research-based investigation from as far back as 1974 when Maurice Shapiro led the work described in the seminal Shapiro report. This was published as A preliminary report on the Westernport Bay environmental study : report for the period 1973-1974 (abridged version) / Director: Professor Maurice A. Shapiro. by Shapiro, Maurice A., Victoria. Ministry for Conservation. Melbourne: Ministry for Conservation, 1975.

This work spawned the Western Port Awareness Program conducted through the rest of the 70s and into the 80s. The paper titled Western Port Shorebirds Site, found at the URL as follows:  
[HTTP://WWW.DSE.VIC.GOV.AU/CA256F310024B628/0/3550A4CB4987DA76CA2572D700827BB7/\\$FILE/WESTERN+PORT+EAAF+FNS+SIS\\_MAP.PDF](http://www.dse.vic.gov.au/CA256F310024B628/0/3550A4CB4987DA76CA2572D700827BB7/$FILE/WESTERN+PORT+EAAF+FNS+SIS_MAP.PDF)

summarises many of the issues that face Western Port and it contains an extensive list of references to the various studies that have been conducted.

The SECCCA has in turn conducted a number of spin-off projects from the project Impacts of Climate Change on Human Settlements in the Western Port Region: an Integrated Assessment. The report from this project can be found at < [http://www.SECCCA.org.au/uploads/projects/Socio-Economic\\_Impacts\\_Report.pdf](http://www.SECCCA.org.au/uploads/projects/Socio-Economic_Impacts_Report.pdf)>

This project, conducted on behalf of the Department of Sustainability and Environment, is one such spin-off project. In response to the projections for increased average and extreme temperatures, the SECCCA has conducted a project on behalf of its member councils to develop heat wave strategies for the care and protection of the community. As a result of the likelihood of an increased incidence of extreme weather, a project to help protect communities from the dangers of emergency events is about to commence.

Victoria University is completing a project to assess the health and viability of salt-marsh communities around the Victorian coast, with particular focus on Western Port, while the Central Coastal Board and Birds Australia have commenced a project Western Port Welcomes Waterbirds to look at the climate change issues that might affect the migratory warders that are so much a feature of the Western Port environment.

The Mornington Peninsula and Western Port Biosphere Foundation is conducting projects aimed at improving the environmental conditions of the catchment of Watson's Creek and protecting local populations of the Southern Brown Bandicoot. The Sea-Grass Partnership is very active in restoring plant communities in Western Port.

The result of these many projects should be a protected and even improved Western Port environment such that the requirements for the health of populations of important species such as Fairy penguins can be protected.

## References

Geoff Barrett, Andrew Silcocks, Simon Barry, Ross Cunningham and Rory Poulter, The New Atlas of Australian Birds, RAOU, 2003

M Blakers, SJJF Davies and P N Reilly, The Atlas of Australian Birds, Melbourne University Press, 1984.

## 4 Project brief

The Western Port Greenhouse Alliance was commissioned to conduct a project to investigate whether Little penguins at the Phillip Island Penguin Parade were vulnerable to climate change impacts and if so, might the viability of the parade as a tourism attraction be compromised.

### The potential impacts of climate change on the Phillip Island Little Penguin colony - regional implications



#### Project Brief

### 1 Background

The Phillip Island Penguin Parade is an iconic component of Victoria's tourism industry, in 2003 attracting over 540,000 domestic and international visitors and contributing millions of dollars in tourism to the region.

The Little penguin (*Eudyptula minor*) population on Summerland Beach, Phillip Island, numbers about 5000 and each night, in front of hundreds of local and international tourists, these penguins make their way from the water to the dunes to their nesting burrows. The penguin colony has been carefully managed for some 30 years now with many actual and potential anthropogenic threats being addressed to ensure that the population remains secure.

We have entered a time of significant climate change, with a range of possible threats to biodiversity, human populations and the infrastructure that supports our settlements and activities. It is important that we use the information we have available to us to ensure that this colony of our smallest species of penguin continues to thrive, for their own benefit and for the benefit of the millions of visitors who come to watch them.

### 2 Phillip Island Penguin Colony Project

The Western Port Greenhouse Alliance is involved currently in a project, the **Impacts of Climate Change on Human Settlements in the Western Port Region: An Integrated Assessment Project** to model likely biophysical impacts due to climate change in the Western Port region. This project, **The impacts of climate change on Phillip Island Little Penguins**, will utilise the climate change modelling for the Western Port region to investigate the likely impacts of changes on the penguin population at Phillip Island. The information produced from this research will assist the project team, together with other stakeholders, to make some assessments about strategies for ensuring the sustainability of the population and the tourism industry that is dependent upon them.

The total project budget is to be \$50,000 which will include research into the impact of climate change on the Phillip Island Little Penguin population and their ecology, socio-economic impacts, adaptation workshops, project management and communications.

It is expected that this project will be undertaken between October 2007 and October 2008. The Western Port Greenhouse Alliance will be the lead organisation and will deliver the project in association with the Department of Sustainability and Environment, Phillip Island Nature Park, Tourism Victoria and Bass Coast Shire Council.

### 3 Project Objectives

- 3.1 To investigate likely biological and ecological impacts of climate change on the Little Penguin population at the Phillip Island Penguin Parade.
- 3.2 To investigate the impacts of climate change on the Penguin Parade and wider region.
- 3.3 To recommend, within the adaptation options for the region, strategies for the protection of the Little Penguin colony and the associated tourism infrastructure.



## **4 Project components**

- 4.1 Determine the biological impacts of climate change on the Little Penguin population at the Phillip Island Penguin Parade.

The project will use existing data (biological, phenological and meteorological) and climate predictions for Western Port to determine what impacts climate changes (sea level rise, temperature changes, storm surge, etc) may have on the ecology of Little Penguins at the Phillip Island Penguin Parade. Food availability, changes to breeding success, protection of nesting sites, population distribution changes etc. will be included.

Further to this, a number of specific risks as a result of climate change may be investigated in more detail, for example sea temperature impacts on the Little Penguins at the Phillip Island Penguin Parade.

- 4.2 Investigate the impacts of climate change on the Penguin Parade and wider region.

This step will involve an analysis of the potential social and economic impacts of climate change on the Penguin Parade including infrastructure, tourism and people.

It will also provide an indication of the social and economic costs to the region and the State.

- 4.3 Investigate the implications of possible climate change impacts on the tourism infrastructure

The following are some of the elements to be investigated:

- Current numbers of visitors to the region
- Current economic benefits to the region and to the State
- Current affects on local businesses of penguin-generated tourism
- Future numbers of visitors to the region based on an analysis of the penguin's likely biological responses and consequences for tourism
- How will local businesses be affected by climate change impacts on Phillip Island Penguins?
- Future economic benefits/losses to the region and the State

- 4.4 Recommend adaptation options for the region.

Utilising the information provided by the first two steps of the project, stakeholders will be brought together to discuss options for adaptation and further needs and opportunities. Stakeholders are likely to include scientists, experts, state government departments and agencies, local government, relevant organisations and interested members of the public.

This process is likely to be undertaken through a consultative process which may involve workshops to address the risks to each group and investigate how these may be responded to.

## **5 Communications**

The SECCCA will work with project team members to communicate the findings of the research and recommendations for adaptation to a wider audience.

## **6 Project Partners**

- Western Port Greenhouse Alliance (project management)
- Department of Sustainability and Environment (project sponsor)
- Phillip Island Nature Park (biological research)
- Bureau of Meteorology (data provision)

## 7 Project Budget

Western Port Greenhouse Alliance	\$5,000	Project coordination and management, administration
SECCCA	\$10,000	Workshop facilitation, access to resources and equipment. Production of final report - synthesis of ecological and socio-economic results with future options.
Phillip Island Nature Park	\$20,000	Biological Research
Marsden Jacob Associates	\$10,000	Socio-economic modelling
<b>Total budget</b>	<b>\$45,000</b>	

## 8 Project Schedule

The project will be conducted according to the following schedule.

Milestone Description		Due Date	Milestone value
1	Confirm project brief and establish contract with DSE	31/01/07	20,000
2	Progress report to DSE, including establishment of project team and project implementation plan. MoUs with project partners completed	End May 08	20,000
3	. Progress Report to DSE	15/09/08	
4	Final report to DSE, including financial acquittal	15/12/08	5,000

## 9 Project Governance

The SECCCA will establish and coordinate a Project Team which will consist of representatives from each of the project partners as listed above. The Project Team will meet throughout the life of the project on an as-needs basis and will be responsible for ensuring the project meets its objectives and that the project remains relevant to stakeholders.

The SECCCA will be responsible for coordination and administration of this team and will provide it with infrastructure services.

## **5 Climate change and little penguins – reports from project partners**

The project was conducted in two discrete phases, with project partner Phillip Island Nature Parks conducting an investigation into the biological impacts of climate change on the Little Penguin population at the Phillip Island Penguin Parade and project partner Marsden Jacob Associates analysing the potential social and economic impacts of climate change on the Penguin Parade and to the region and the State.

Each phase is reported upon separately with each project partner presenting their findings in their own report.

5.1 is the report *Climate Change and little penguins* by Phillip Island Nature Parks.

5.2 is the report *The potential impacts of climate change on the Phillip Island Little Penguin colony - regional economic impacts* by Marsden Jacob Associates.

These reports are presented here as they were received, apart from changes to the pagination to comprise a single consolidated report. The Executive Summary to be found at the start of this project report is a synthesis of these two partner's reports.

## 5.1

# CLIMATE CHANGE AND LITTLE PENGUINS

Peter Dann<sup>1</sup> and Lynda Chambers<sup>2</sup>

*for Western Port Greenhouse Alliance*



<sup>1</sup>Research Department, Phillip Island Nature Parks,  
P. O. Box 97, Cowes, Phillip Island  
Victoria, 3922  
Australia  
[pdann@penguins.org.au](mailto:pdann@penguins.org.au)

<sup>2</sup>Centre for Australian Weather and Climate Research  
Bureau of Meteorology  
GPO Box 1289, Melbourne, Victoria, 3001, Australia

March 2009

## TABLE OF CONTENTS

<b>SUMMARY</b>	<b>14</b>
<b>ACKNOWLEDGEMENTS</b>	<b>15</b>
<b>BACKGROUND</b>	<b>15</b>
<b>APPROACH</b>	<b>16</b>
<b>PROJECTED CHANGES IN CLIMATE</b>	<b>17</b>
<b>POTENTIAL INTERACTIONS BETWEEN THE LIFE HISTORIES OF LITTLE PENGUINS ON PHILLIP ISLAND AND PREDICTED CLIMATE CHANGE</b>	
1. SEA-LEVEL RISE-WESTERN PORT AND BASS STRAIT	20
2. DECREASED RAINFALL (AND HUMIDITY)	28
3. AMBIENT TEMPERATURE RISE ON PHILLIP ISLAND	33
4. SEA TEMPERATURES IN BASS STRAIT AND OCEAN CURRENTS (INCLUDING THERMOCLINES AND ENSO EVENTS)	36
5. WIND, SOUTHERN OSCILLATION INDEX AND OCEAN ACIDIFICATION	42
<b>CONCLUSIONS</b>	<b>44</b>
<b>REFERENCES</b>	<b>45</b>
<b>APPENDICES</b>	<b>48</b>

## SUMMARY

This project uses climate change modelling for Phillip Island, the Western Port region and Bass Strait to investigate the likely impacts of changes on the penguin population at Phillip Island over the next 100 years.

The aims of this project were:

- 1 To review the predictions for climate change during the next 100 years for Phillip Island, the Western Port region and Bass Strait;
- 2 To investigate the impacts of climate change on the penguin population on Phillip Island and at the Penguin Parade in particular;
- 3 To recommend, within the adaptation options for the region, strategies for the protection of the Little Penguin colony and the associated tourism infrastructure.

The potential impacts on Little Penguins have been considered under five broad headings: sea-level rise, decreased rainfall and humidity, ambient temperature rise, sea temperature changes and winds, southern oscillation index and acidification.

### Sea-level rise

There will be some small loss (<< 1 %) of penguin breeding habitat on the Summerland Peninsula due to sea level rise in the next 100 years but it is considered that breeding habitat is unlikely to be limited on the Peninsula in this period. However, there is likely to be some erosion in the vicinity of Whaleshead Creek and further east which has implications for the Penguin Parade.

It is anticipated that there will be some loss of productivity of inshore waters in Bass Strait due to sea-level rise also, which may ultimately result in reduced food availability for penguins.

### Decreased rainfall and humidity

It is predicted that there will be little appreciable direct impact of decreased rainfall and humidity on adult Little Penguins over the next century. However it seems likely that fire risk will increase and needs to be managed to ensure penguin survival is unaffected.

In addition, if the availability of anchovies is reduced by decreased rainfall, then adult penguin survival (and possibly breeding productivity) may be reduced.

### Increasing air temperatures

Increasing temperatures in burrows during daylight are likely to increase adult mortality slightly and chick mortality to an unknown extent.

Increasing burrow temperatures may also have a role in determining breeding success and this warrants investigation as does the scope for mitigation of burrow microclimates through vegetation management and artificial burrow design.

### Sea-surface temperatures in Bass Strait

Increasing sea-surface temperatures in Bass Strait may result in an earlier start to the breeding season, increases in breeding success and increases in first-year survival.

Decreases have been predicted in adult survival, but more work is required to confirm the direction of this relationship. More productive breeding seasons and higher first-year survival should improve recruitment into the breeding population.

Increased stratification of the water column may reduce productivity and, correspondingly, food availability for penguins but, conversely, increase foraging efficiency of Little Penguins.

### Winds, southern oscillation index and ocean acidification

Decreasing winds in the region are likely to reduce the recruitment of fish populations and hence the availability of food for penguins, with potential impacts on their survival and breeding success. It is unknown if wind direction and velocity directly affect penguin foraging success.

Decreasing SOI may reduce adult survival and increase juvenile survival but the mechanisms are unknown for either.

Increasing acidification may reduce food availability for penguins.

Overall there are a number of aspects of the biology of penguins that are likely to be affected, both positively and negatively, by predicted climate change over the next 100 years. Breeding productivity and juvenile survival seem likely to improve with increasing sea temperatures. Marine productivity and adult survival perhaps, seem likely to decline while the feeding behaviour of penguins will possibly experience both negative and positive impacts as a consequence of climate change. Some of the negative impacts can be addressed in the short-term, particularly those resulting from expected changes to the terrestrial environment.

A number of areas requiring further research have been identified including the effects of temperature on breeding success and adult survival, the effects of sea temperatures on adult survival and productivity and the effects of rainfall on food availability. Continual review will be essential as the predictions and implications for climate change develop further.

### **ACKNOWLEDGEMENTS**

We wish to thank Greg Hunt (Western Port Greenhouse Alliance) and Ian Mansergh (Department of Sustainability and Environment) for guiding the project, Jon Fallaw for preparing the figures indicating potential changes in sea-levels, Kathleen McInnes for permission to use Figure 1.2 and a table from her report and David Ball (DPI) for permission to use Figure 1.3. Kathleen McInnes, Andre Chiaradia, Roz Jessop, Richard Dakin, Leanne Renwick, Roger Kirkwood and John Fallaw (PINP), kindly read various parts of drafts of this report. Dan Pleiter (SECCCA) and Rhonda Boyle (DSE) also provided helpful assistance.

### **BACKGROUND**

The Phillip Island Penguin Parade is an iconic component of Victoria's tourism industry, in 2003 attracting 500,000 domestic and international visitors and contributing millions of dollars in tourism to the region.

Up to a thousand Little Penguins *Eudyptula minor* come ashore on Summerland Beach, Phillip Island, in front of local and international tourists. These penguins make their way from the water to the dunes and their nesting burrows. The penguin colony has been carefully managed for some 30 years now with many actual and potential anthropogenic threats being addressed to ensure that the population remains secure (Dann 1992).

We have entered a time of significant climate change, with a range of possible threats to biodiversity, human populations and the infrastructure that supports our settlements and activities. It is important that we use the information we have available to us to ensure that this colony of our smallest species of penguin continues to thrive, for their own benefit, and for the benefit of the millions of visitors who come to watch them.

### **Phillip Island Penguin Project**

The Western Port Greenhouse Alliance is currently involved in a project, the ***Impacts of Climate Change on Human Settlements in the Western Port Region: An Integrated Assessment Project*** to model likely biophysical impacts due to climate change in the Western Port region. This project, **The impacts of climate change on Phillip Island Little Penguins**, will utilise the climate change modelling for the Western Port region to investigate the likely impacts of changes on the penguin population at Phillip Island. The information produced from this research will assist the project team, together with other stakeholders, to make some assessments about strategies for ensuring the sustainability of the penguin population and the tourism industry that is dependent upon them.

### **Project Objectives**

- 1 To review the predictions for climate change during the next 100 years for Phillip Island, the Western Port region and Bass Strait.
- 2 To investigate the impacts of climate change on the penguin population on Phillip Island.

- 3 To recommend, within the adaptation options for the region, strategies for the protection of the Little Penguin colony and the associated tourism infrastructure.

## APPROACH

Our approach has been to review climate change predictions for the Western Port and Port Phillip Bay (including Phillip Island) region, for Bass Strait and marine areas in general. We have obtained climate data from the Bureau of Meteorology, for the Phillip Island Penguin Reserve ([http://www.bom.gov.au/climate/averages/tables/cw\\_086354\\_All.shtml](http://www.bom.gov.au/climate/averages/tables/cw_086354_All.shtml)) and this report relies heavily on: Climate Change in Port Phillip and Western Port (Published by the Victorian Government Department of Sustainability and Environment, Melbourne, June 2008; [www.climatechange.vic.gov.au](http://www.climatechange.vic.gov.au)) and Poloczanska *et al.* 2007. It should be noted that there is recent evidence (Copenhagen 2009) that some critical parameters are tracking closer to the worst case scenarios, however, detailed analysis is not yet available for Australia.

Having established the most probable climate scenarios for Phillip Island, the Western Port region and Bass Strait, we reviewed the scientific literature and the long-term datasets from the Phillip Island Nature Park (see summary below) with a view to identifying likely impacts on penguins. These may be direct effects on the physiology and behaviour of penguins or indirect effects ranging from factors operating on the ecology and behaviour of their prey or on primary and secondary productivity in the pelagic ecosystem of Bass Strait. We have examined the demographic datasets to detect any observed changes consistent with climate change trajectories (e.g. time and success of breeding). Ultimately we have attempted to identify impacts on the distribution and abundance of Little Penguins on Phillip Island.

Long-term datasets are central to documenting and understanding the response of species to climate change. Australian scientists have long claimed that the lack of observable climate signals in the marine environment in this region is a consequence of the paucity of ecological time series (Poloczanska *et al.* 2007). The long-term datasets available for Little Penguins on Phillip Island are highly unusual in their duration (40 years for some parameters) and have allowed quite sophisticated insights into this species' likely responses to climate change.

The long-term datasets for penguins breeding on Phillip Island are as follows:

- Adult weights, pair bonds, limited adult & juvenile survival data (more post-1980) since 1968;
- Timing of breeding, hatching success, fledging success, mass at fledging since 1968;
- Parade counts (nightly counts of the number of birds crossing the beach) since 1977;
- Diet composition since 1982 (60% of years);
- Breeding distribution on the Summerland Peninsula on Phillip Island since 1984;
- Radio-tracking during breeding season 1986-1990; Satellite tracking during breeding season since 2002;
- Diving behaviour since 2001.

Using these penguin data sets, our review looks at likely impacts of five general areas of projected changes in climate with the life histories of Little Penguins and their habitat on Phillip Island:

2. Sea-level rise in Western Port and Bass Strait;
3. Decreased rainfall (and humidity) on Phillip Island and in Bass Strait;
4. Ambient temperature rise on Phillip Island;
5. Sea temperatures in Bass Strait and ocean currents (including thermoclines and ENSO events);
6. Wind, Southern Oscillation Index and ocean acidification.



## PROJECTED CHANGES IN CLIMATE

### Background

In recent decades a number of changes have been observed in the climate system which may provide some context for likely implications of future projected climate shifts.

### Surface Air Temperature

Compared to the 1961-1990 average, air surface temperatures in the Port Phillip / Western Port region were around 0.4 °C warmer during the period 1998-2007. Both maximum and minimum temperature increased, with the largest change occurring during summer (~0.5 °C). In addition to changes in mean temperature, the average number of days of over 30 °C increased (~3 additional days per year), as did the number of days over 35 °C (~1 day per year)[see Figure 1.1]. At the other extreme, there were fewer cold nights (minimum temperatures < 5 °C; ~4 few days per year).

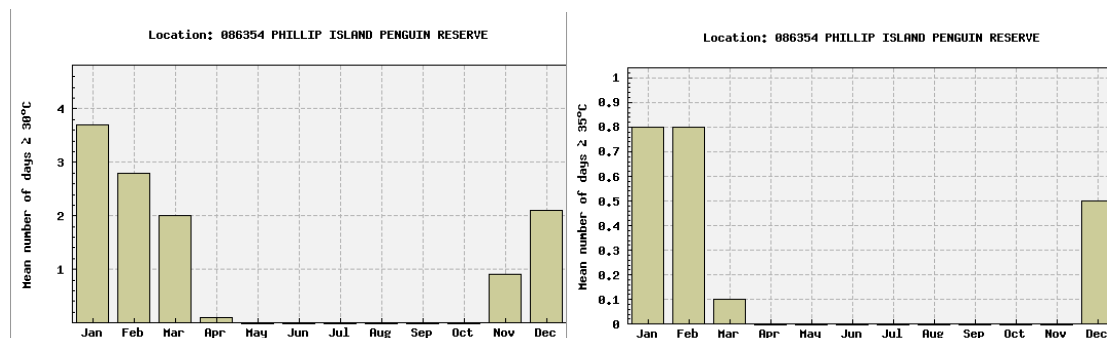


Figure 1.1. Current monthly distribution of extreme maximum temperatures for Phillip Island Penguin Reserve (based on the period 1981-2008); average number of days a) over 30 °C, b) over 35 °C (Source: Bureau of Meteorology, Melbourne).

### Precipitation

Phillip Island Penguin Reserve rainfall tends to peak over the winter months (Figure 1.2.), June to August. In recent times (1998-2007) rainfall in the Port Phillip / Western Port region has declined by around 14%, compared to the long term average (1961-1990). This decline was largest during the autumn and winter periods. There was also a decrease in the number of days on which rain fell (around 15 fewer days per year).

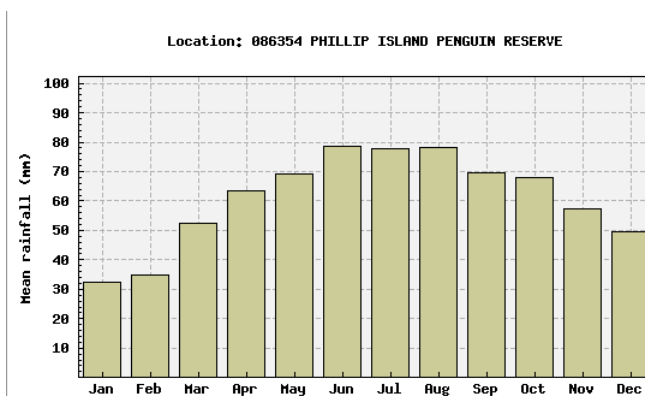


Figure 1.2. Current monthly distribution of precipitation for Phillip Island Penguin Reserve (based on the period 1981-2008). (Source: Bureau of Meteorology, Melbourne)

### Changes in other climate variables

Wonthaggi meteorological data (1971 to present) indicates a weak, but significant, trend towards more dangerous fire weather days in the autumn and spring periods (though currently there are few of these days). There is some indication that the length of the fire season may be increasing (C. Lucas, Bureau of Meteorology, personal communication).

There is evidence that some ocean regions around Australia are currently warming and that currents are changing on the east coast.

### Climate change models

The Intergovernmental Panel on Climate Change (IPCC), the United Nations agency charged with developing projections of climate change and the impacts that might be expected, use a number of models based on a range of assumptions to develop their projections. These assume various emissions scenarios which are dependent on the success of international efforts to limit the use of fossil fuels.

Throughout most of this report, three emissions scenarios will be considered (from up to 23 models). They are:

- Lower emissions (B1), which assumes a rapid shift to less fossil-fuel intensive industries;
- Medium emissions (A1B), which is based on a balanced use of different energy sources, i.e. not just fossil fuels;

Higher emissions (A1F1). Continued strong economic growth based on a dependence on fossil fuels. Models suggest that this scenario is likely to result in higher temperature increases than A2 (shown in Figure 1.3).

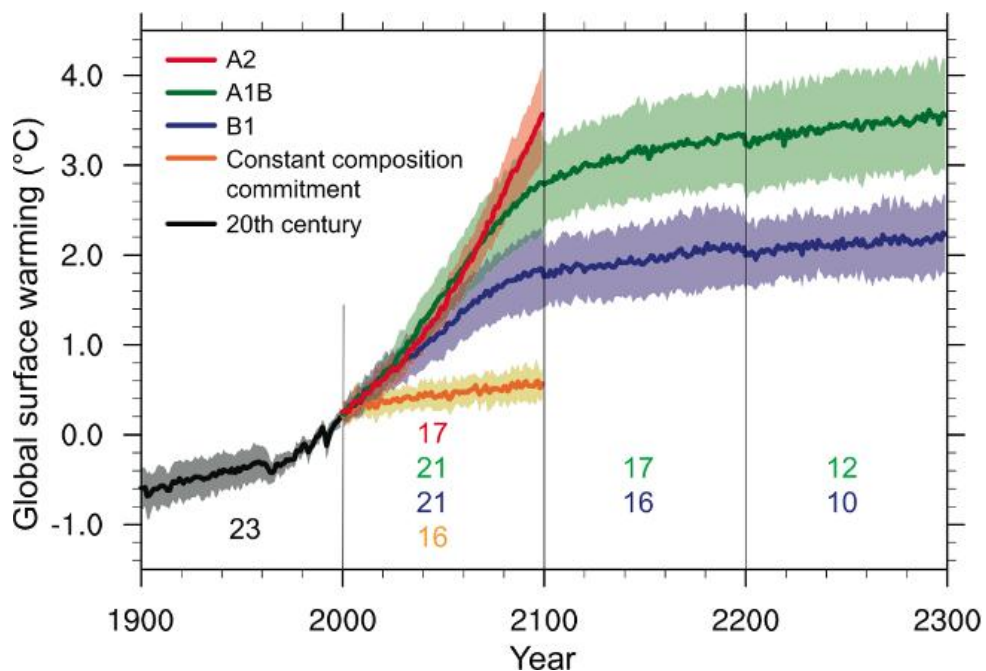


Figure 1.3. (IPCC WGI Figure TS.32). Multi-model means of surface warming (compared to the 1980–1999 base period) for the SRES scenarios A2 (red), A1B (green) and B1 (blue), shown as continuations of the 20th-century simulation. The latter two scenarios are continued beyond the year 2100 with forcing (pressure of change) kept constant. An additional experiment, in which the forcing is kept at the year 2000 level, is also shown (orange). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi-model means, shading denotes the  $\pm 1$  standard deviation range. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario (numbers indicated in figure). For the same reason, uncertainty across scenarios should not be interpreted from this figure.

## Projected changes in climate

### *Surface air (ambient) temperature – Port Phillip / Western Port Region*

- By 2030 an increase in annual average temperatures of around 0.8°C (with a range of uncertainty of 0.6 to 1.1°C) is likely under medium emissions.
- By 2070 increases in annual average temperatures of around 1.3°C (0.9 to 1.8°C) and around 2.5°C (1.7 to 3.5°C) are likely under lower and higher emissions scenarios respectively.
- Average temperature is very likely to increase in all seasons, most significantly in summer and least in winter.
- The number of days > 35 °C is expected to double by 2030 and triple by 2070.
- Increased incident of drought (up to 20% more frequent by 2030) and more heat waves are expected.

### *Precipitation and humidity*

- By 2070 decreases in annual average rainfall totals of around 6% (0 to 12%) and around 11% (0 to 23%) are likely under lower and higher emissions scenarios respectively.
- Percentage decreases in seasonal average rainfall totals likely to be greatest in spring (could be almost double the percentage decreases in annual average rainfall).
- Decreased rainfall and increased evaporation rates are likely to decrease average streamflow.
- By 2030 a decrease in annual average relative humidity of around 0.5% (0.1 to 1.0%) is likely. By 2070 decreases in annual average relative humidity of around 0.8% (0.1 to 1.7%) and around 1.6% (0.2 to 3.2%) are likely under low and high emissions scenarios respectively.
- Intensity of heavy daily rainfall is likely to rise in most seasons.
- Fewer days of rainfall are anticipated with more droughts.

### *Sea surface temperature and ocean currents*

- Around Australia a warming of 1-2 °C is projected by the 2030's, with the greatest warming off south-eastern Australia (2 °C).
- By 2070, warming around Australia is projected to be in the range 2-3 °C, with the greatest warming off south-eastern Australia (3 °C). Warming is also likely below the surface with ~0.5-1.0 °C projected for 500 m depth.
- By 2030 the East Australian Current is expected to increase in strength and penetrate further south. By 2070 the strength of surface currents is generally projected to decline (0-1.2 m s<sup>-1</sup>). Around the same time greater stratification is expected, as is a shallowing of the mixed layer (by ~1 m), which is likely to reduce nutrient inputs from deep waters.

### *Sea level rise and storm surge*

- A rise in sea level in the range 0.3-0.5 m is projected for the Australian region by 2030. By 2070 the range is 0.6-0.74 m, with the greatest increase on the east coast. However, the upper bound could be much higher (see Solomon et al. 2007).
- For Bass Strait, by 2030 the mid-range scenario has a sea level rise of 0.11 m (0.06 m for the lower and 0.17 m for the higher emission scenarios). By 2070 the mid-range scenario is 0.32 m (lower emission scenario 0.15; higher 0.49).

- The area of Bass Coast currently inundated by average high or spring tides is 2.35 km<sup>2</sup>. Under current climate conditions the area inundated by a 1 in 100 year event is 3.97 km<sup>2</sup>, but under a higher emission scenario this area is projected to rise to 4.66 km<sup>2</sup> by 2030 and 7.23 km<sup>2</sup> by 2070.

#### Fire

- More dangerous fire weather days are expected in autumn and spring, together with a lengthening of the fire season (*C. Lucas, BoM, personal communication*).

## 1. SEA-LEVEL RISE-WESTERN PORT AND BASS STRAIT

### Background

Sea-level rise, together with storm surges, will increase the risk to low-lying coastal areas on Phillip Island of inundation and erosion.

The frequency of inundation of low-lying coastal areas is expected to increase as a direct result of sea-level rise and also as a result of storm surges and storm tide levels (Church *et al.* 2004, McInnes *et al.* 2008). Strong winds and falling air pressure can generate storm surges and severe wave conditions on vulnerable coastlines, which in turn can produce severe erosion and coastal flooding (McInnes *et al.* 2008). With no other changes to climate, rising sea levels will worsen the impact of these events by increasing the base sea level from which they develop (Church *et al.* 2004, McInnes in Pyper 2007).

The increased risk of inundation, erosion and storm surge and rising water tables will have a greater impact on dynamic coastal land forms, such as dunes, river outlets in softer sediments and other erosion-prone coasts. These land forms are likely to become more 'active', with increased net erosion and movement of fore-dunes inland under natural conditions (Church *et al.* 2004). Coastal areas vary dramatically in their vulnerability to coastal risks whether arising from climate change or coastal processes that operate even without climate change. High, hard rocky coasts have low risk while low lying or softer landforms are more at risk.

Sea-level rise and storm surges will increase coastal erosion, the degree of which will be dependent upon the local geomorphology. Soft substrates will be most affected, with an expected 50-100m of horizontal erosion for every one metre of sea-level rise (Bruun 1962). Rocky shorelines will be subject to comparatively little erosion. Other factors will contribute to the extent of inundation and include the effects and changes to local currents and sand accretion/erosion due to wind conditions or vegetation. Therefore there is some difficulty associated with precise modelling and predictions of impacts.

Rising sea level is likely to be a threat to bird species that nest on low-lying coastal areas as breeding sites are flooded or eroded (Galbraith *et al.* 2002). Little Penguin access to their breeding sites is generally along tracks that have been used for decades, and probably much longer. Access points are numerous but vary in quality around the Summerland Peninsula and the birds congregate at more sheltered sites with less physical hazards and reduced gradients into the hinterland. Sandy beaches are used wherever available and maybe preferred, as are creek outlets, particularly on sandy shore lines.

Changes in sea level are also likely to effect inshore productivity because the increase in water depth and consequent reduction in light availability to the sea bed will reduce the growth of subtidal marine plants (Short & Neckles 1999). For example, it is estimated that a 50-cm increase in sea level could result in a 30–40% reduction in growth of *Zostera marina*, a widespread Northern Hemisphere seagrass (Short & Neckles 1999).

### Change in sea-level and shoreline expected in the Western Port region

Coastal erosion along beaches, which provide access to Little Penguin colonies, is likely to increase with climate change, together with some inundation of low-lying breeding areas. Sea levels in Western Port are predicted to rise between 0.15 to 0.49 m by 2070 (see Table 1.1 from McInnes *et al.* 2008 – reproduced with permission).

Table 1.1. Projected mean sea level rise scenarios for Bass Strait (from McInnes *et al.* 2008; and derived from the IPCC Third Assessment Report (IPCC 2001) and Fourth Assessment Report (IPCC 2007)).

YEAR	2030			2070		
SCENARIO	LOW	MID	HIGH	LOW	MID	HIGH
PREDICTED SEA LEVEL RISE (M)	0.06	0.11	0.17	0.15	0.32	0.49

In addition to mean sea level rise, extreme sea level heights along the coast of Victoria are expected to increase at a greater rate than mean sea levels due to increases in the heights of storm surges (Mcadam *et al.* 2008). Mcadam *et al.* (2008) also predicted that wind speeds could change between -1% and 3%, tides could increase by up to 0.19 m in height and 1-in-100 year storm surge could increase in frequency, to between 1-in-40 and 1-in-6 years by 2030.

McInnes *et al.* (2008) examined the likely effects of climate change on extreme sea levels in the Western Port region and noted that storm surges are presently highest in the east of the bay, with values reaching 1 m relative to mean sea level, and relatively low sea levels occur in the northwest of the bay. The variations in sea levels across Western Port are the result of wind-driven predominantly westerly events, which maintain a gradient on sea levels with the highest levels in the east.

At present, in Western Port, Grantville in the east of the bay experiences relatively high storm surges, with a 1 in 100 year level of 0.97m, compared with 0.70m at Tooradin in the northwest (McInnes *et al.* 2008). On the Summerland Peninsula on Phillip Island (Figure 1.5, taken from McInnes *et al.* 2008), areas subject to inundation under a current climate 1 in 100 year event are shaded in yellow. The additional areas inundated by a 1 in 100 year event under the 2030 high and 2070 high climate change scenarios are shaded in purple and red respectively.

The frequency of storm surges will increase at different rates under the different climate scenarios. For example, McInnes *et al.* (2008) have suggested that a 1 in 100 year event at Stony Point would become a 1 in 20 to 30 year event under a mid-range scenario by 2030 and a 1 in 20 year event under a worst case scenario. By 2070, such an event would occur approximately every 10 years under a mid-range scenario and every 4 years under a high-range scenario (McInnes *et al.* 2008).

Figure 1.4. Distribution of Little Penguin breeding areas on the Summerland Peninsula (December 2002).

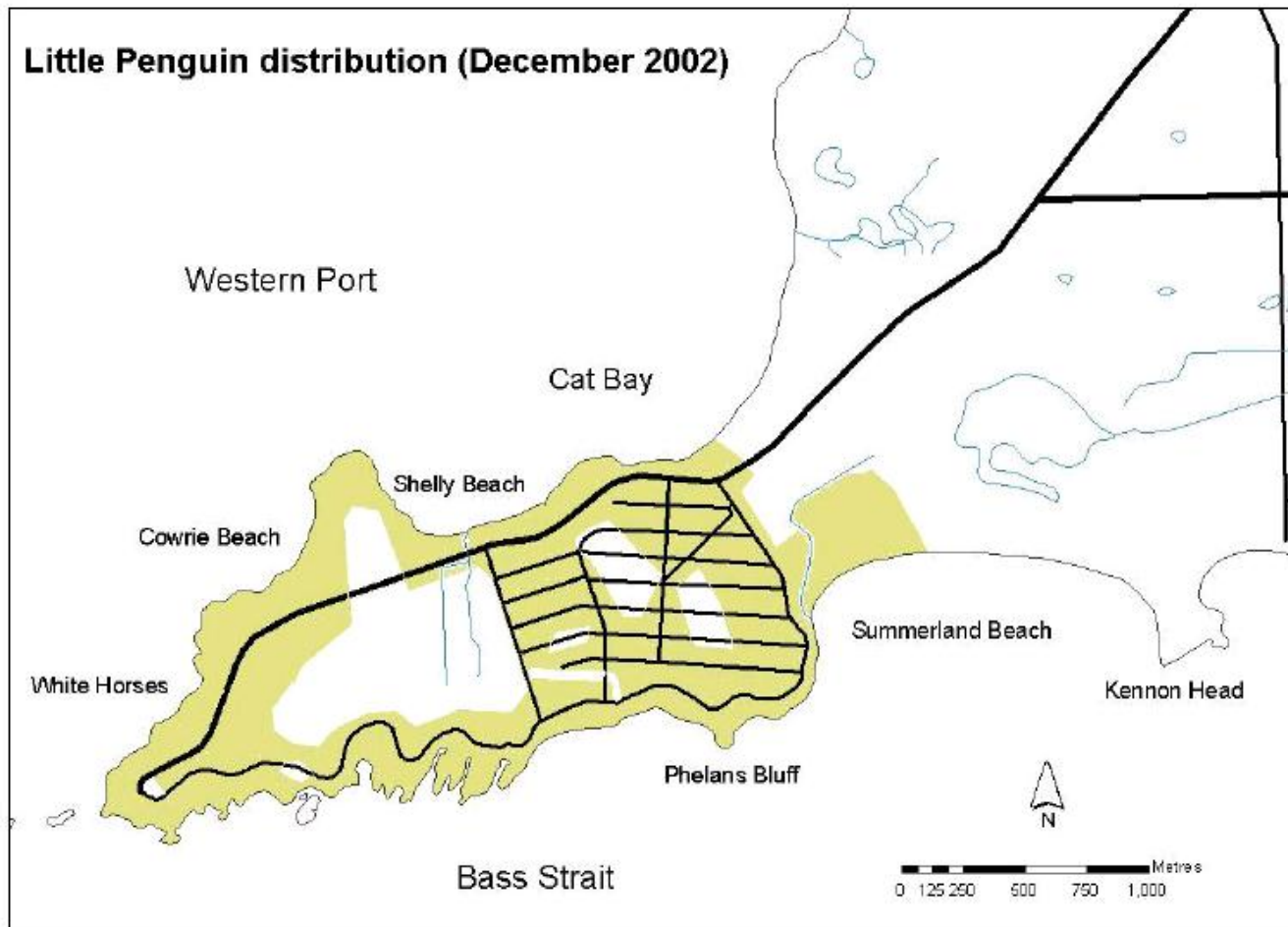


Figure 1.5. Areas subject to inundation under a current climate 1 in 100 year event are shaded in yellow. The additional areas inundated by a 1 in 100 year event under the 2030 high and 2070 high climate change scenarios are shaded in purple and red respectively (Reproduced with permission from McInnes *et al.* 2008).

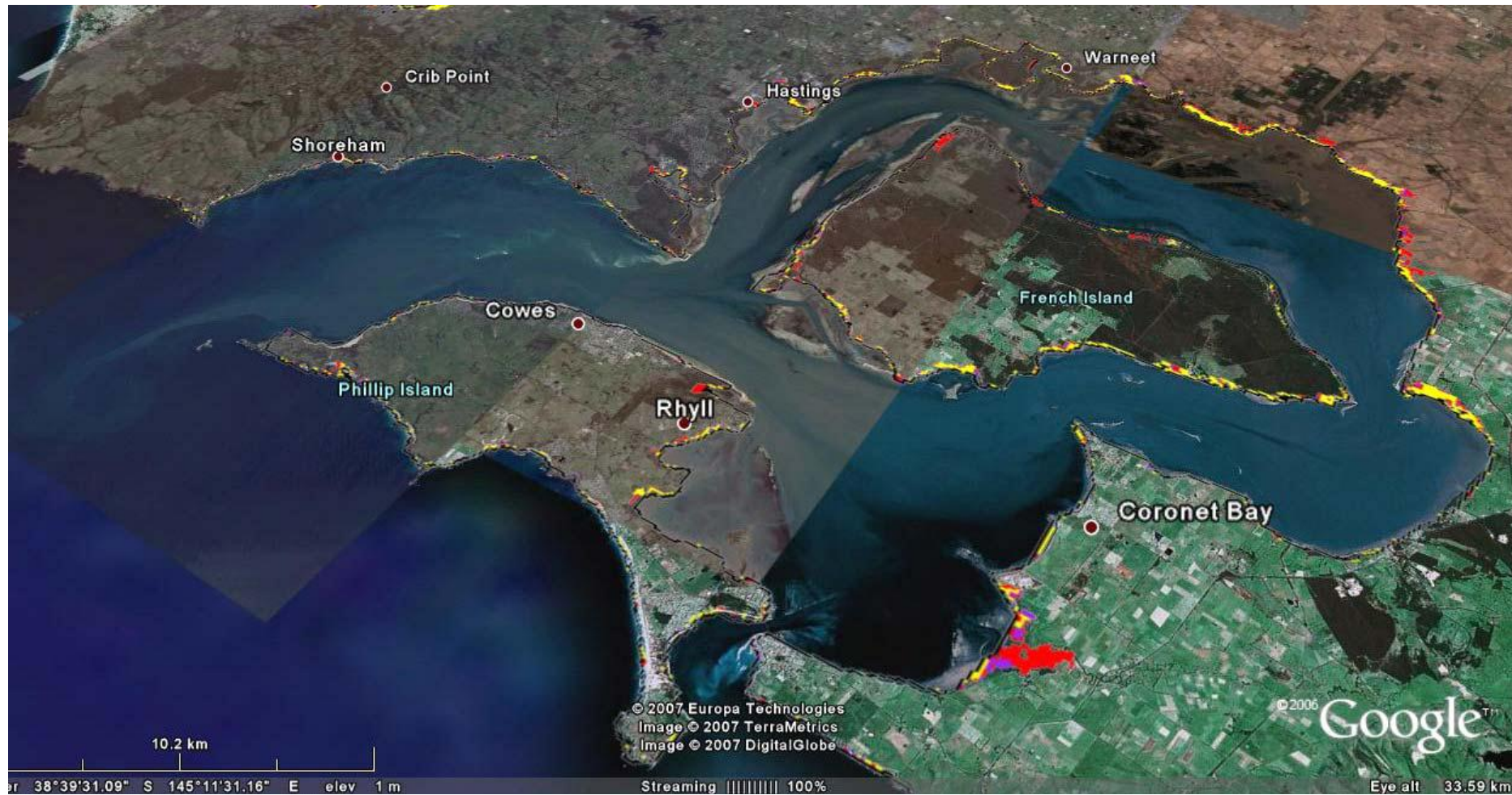


Figure 1.6. The geomorphology of the shoreline of the Summerland Peninsula (sourced from Victorian component of the Oil Spill Response Atlas managed by DPI Queensland).

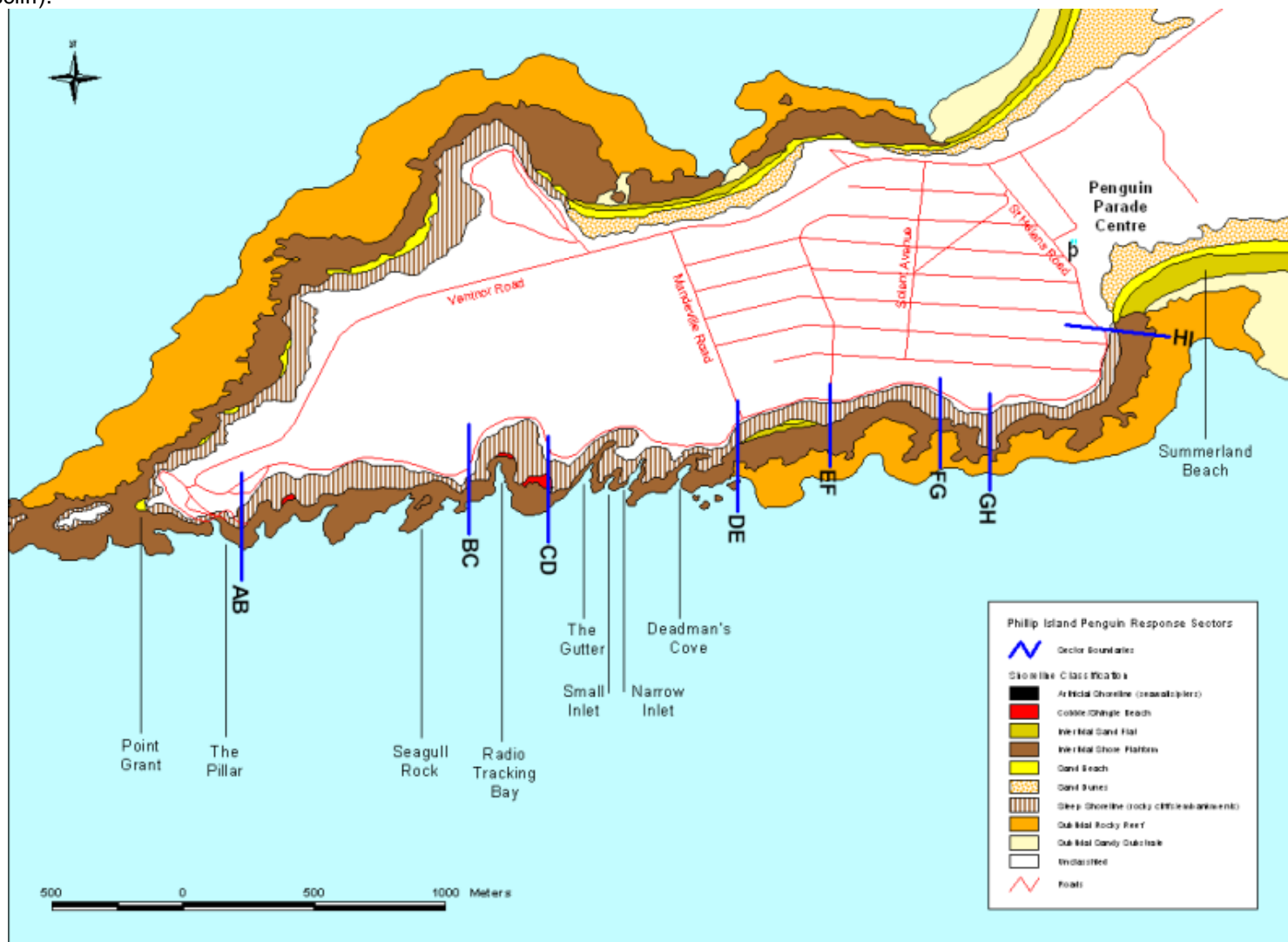




Figure 1.7. Mean sea-level contours for the Summerland Peninsula. Orange = current mean sea level, yellow = one metre rise (1 in a 100 year event currently), red = two metre rise, blue = three metre rise.



Figure 1.8. Mean sea-level contours for the Penguin Parade at the eastern end of the Summerland Peninsula. Orange = current mean sea level (2009), yellow = one metre rise (1 in a 100 year event currently), red = two metre rise, blue = three metre rise.



## **Potential effects of sea-level rise on penguins**

### ***Loss of breeding habitat through inundation and erosion***

Figure 1.4 illustrates the distribution of breeding penguins on the Summerland Peninsula and Figure 1.6 indicates where the sandy and rocky shorelines are. Approximately 27% of penguin breeding areas on Summerland Peninsula have a sandy shoreline and the remainder is rocky (Figure 1.6). The rocky shoreline will show relatively little response to sea-level change in the short to medium terms (Figure 1.7) but the sandy shorelines could be affected up to 50m inland for every 1 m sea-level rise (Figure 1.8), largely by increased instability through increasing frequency and intensity of storm surges and high seas.

In the long-term, some loss of breeding habitat will occur at Cowrie Beach and Cat Bay on the northern side of the Peninsula and on Summerland Beach on the southern coast (Figures 1.4 & 1.5). However the impact of this loss of habitat is unlikely to be significant over the next century since breeding habitat is apparently not a limiting factor on Phillip Island (Dann & Norman 2006) and there is plenty of suitable breeding habitat available further inland at all of these sites.

There will be some implications for the nightly viewing of penguins on the western side of the Penguin Parade, where the majority of the Parade penguins come ashore. This area is likely to experience increased instability in the vicinity of the creek mouth, albeit reduced by the protection afforded from storm surges by Phelans Bluff (Figures 1.4 & 1.8). In the longer term, infrastructural change will be required to accommodate shoreline variation. Options for shifting Parade infrastructure to other sites are unavailable due to lack of suitable places on the Summerland Peninsula with high numbers of penguins coming ashore and sandy beaches for optimal viewing.

### ***Penguin access to breeding sites***

#### *Changes in beach profile*

Marram grass *Ammophila arenaria* is a perennial European grass that was deliberately introduced to Phillip Island to stabilise coastal dunes. It results in sand dunes that are a significantly different shape to those produced by native vegetation. Generally large steep-faced dunes are promoted by marram grass and these dunes are more susceptible to wave erosion. In addition, the resulting steep banks on the foredune are an impediment to penguins crossing from the beach into their breeding areas on or behind the primary dune. Summerland Beach is the penguin breeding area most affected by this problem on Phillip Island. At present it is actively managed by constructing temporary penguin tracks up the face of the dune but this is a reactive rather than pro-active approach and the problem isn't always identified quickly. Replacement of the marram grass on Summerland Beach with native species will improve penguin access now and in the future as well as build in some resilience to increasing wave activity along the dune front in the centuries to come.

### **Summary of potential impacts on distribution and abundance on penguins**

There will be some small loss (<< 1 %) of breeding habitat on the Summerland Peninsula due to sea level rise in the next 100 years but it is considered that breeding habitat is unlikely to be limited on the Peninsula in this period. However, there is likely to be some erosion in the vicinity of Whaleshead Creek and further east. Accordingly, there are some implications for the viewing of penguins at the Penguin Parade. It is anticipated that there will be some loss of productivity of inshore waters in Bass Strait, which may ultimately result in reduced food availability for penguins.

## Resilience building and recommendations for actions including future research

- Removal of Marram Grass on the beach profile of Summerland, Cowrie & Shelly Beaches and Cat Bay (and replace with native species, e.g. Spinifex).
- Incorporate the “Future Coasts” data into the Phillip Island Nature Parks’ GIS system to allow better determination and visualisation of areas on the Summerland Peninsula likely to be most affected by sea-level rise and storm surge (see Appendix 1 for details of the “Future Coasts” project).
- Complete the purchasing of all private property in the Summerland Estate to allow the extension of penguin breeding areas further inland.
- Encourage the penguins to colonise the eastern side of the current breeding area at the Penguin Parade through active management (see Dann 1996) particularly by:
  1. eradicating foxes from Phillip Island
  2. improving access for penguins on the east side of the Parade
  3. optimising vegetation type and cover for breeding penguins

## 2. DECREASED RAINFALL (AND HUMIDITY)

### Background

Rainfall has relatively few direct effects on the survival or breeding success of penguins. Eggs and chicks have been lost through infrequent (once every 20 years) flooding of burrows on the lower section of Whaleshead Creek which runs through the Penguin Parade from Swan Lake to the sea at a frequency of less than once a year. Occasionally, after severe downpours, small landslides occur on the steeper parts of the Summerland Peninsula which have caused the deaths of a few adult penguins and loss of eggs in the past. This has occurred only twice in the last 28 years, mainly on the southern side of the Peninsula and has involved only a few mortalities.

However, rainfall has a number of potential indirect effects including those that affect

- the quality of breeding habitat, particularly the microclimate of burrows;
- fire risk;
- the availability of food.

### *Quality of breeding habitat, particularly the microclimate of burrows*

The two important variables of the microclimate of penguin burrows that may influence breeding success and adult survival are temperature and humidity. (Temperature effects on penguins will be dealt with in Section 3). Humidity may be a contributor to the hatching success of eggs, as they lose a considerable amount of water during the 35 days of incubation (Stahel & Gales 1987) and the rate of water loss is likely to be a function of humidity (Yom-Tov *et al.* 1986). Burrow humidity would be expected to vary with burrow type, depth and location, as well as the surrounding and covering vegetation type, structure and cover, aspect and topography.

### *Fire risk*

Decreasing rainfall and humidity, together with increasing droughts and air temperature, suggest that there will be some increase in fire risk in the penguin breeding habitat on the Summerland Peninsula. Fire has considerable negative implications for penguins with impacts on the quality of nesting habitat, the survival of adults and young and breeding success (Renwick *et al.* 2007).

### *Availability of food*

Freshwater input can improve fertilization and local planktonic production and therefore it is crucial for the survival of some fish larvae. In addition, the spawning of some species appears to be influenced by estuarine conditions. Anchovies *Engraulis australis*, an estuarine species, are a significant dietary component for Phillip Island penguins in general (Cullen *et al.* 1992, Chiaradia *et al.* in prep.) and, in Port Phillip Bay, comprise up to 78% of

the diet of St Kilda penguins (Chiaradia *et al.* in prep.). Anchovies are schooling pelagic fish and are taken commercially all year and throughout Port Phillip Bay. From 1973-84, the largest proportion of anchovies was taken by commercial fishers during winter, especially from the western shoreline and where freshwater flows into the northern parts of the Bay (Hall & MacDonald 1986). Adult anchovies feed primarily on zooplankton, probably the larger zooplankton such as copepods (Winstanley 1979, Last *et al.* 1983, Hall & MacDonald 1986). It is thought that anchovies spawn in estuarine environments and the two main sources of freshwater in Port Phillip Bay are the Yarra River and the Western Treatment Plant (Harris *et al.* 1996), which are likely to provide important spawning environments. Anchovy eggs have been collected in Port Phillip Bay from September to March with greater numbers occurring in December and January (Jenkins 1986). The timing of anchovy spawning in a Mediterranean anchovy *Engraulis encrasicolus* is influenced by freshwater inputs from the Ebro river in Spain (Lloret *et al.* 2004). It is unknown but likely that freshwater flows may be a factor in the timing and extent of spawning of anchovies in Port Phillip Bay.

#### **Change in rainfall and humidity in this region (Macadam *et al.* 2008)**

- By 2070 decreases in annual average rainfall totals of around 6% (0 to 12%) and around 11% (0 to 23%) are likely under low and high emissions scenarios respectively.
- Percentage decreases in seasonal average rainfall totals will be greatest in spring when they could be almost double the percentage decreases in annual average rainfall totals.
- Decreased rainfall and increased evapo-transpiration will lead to decreased average streamflow.
- The frequency of droughts will increase.
- By 2030 a decrease in annual average relative humidity of around 0.5% (0.1 to 1.0%) is likely.
- By 2070 decreases in annual average relative humidity of around 0.8% (0.1 to 1.7%) and around 1.6% (0.2 to 3.2%) are likely under low and high emissions scenarios respectively. Current monthly variation in relative humidity for Phillip Island Penguin Reserve for 1985 to 2008 is given in Figure 2.1.

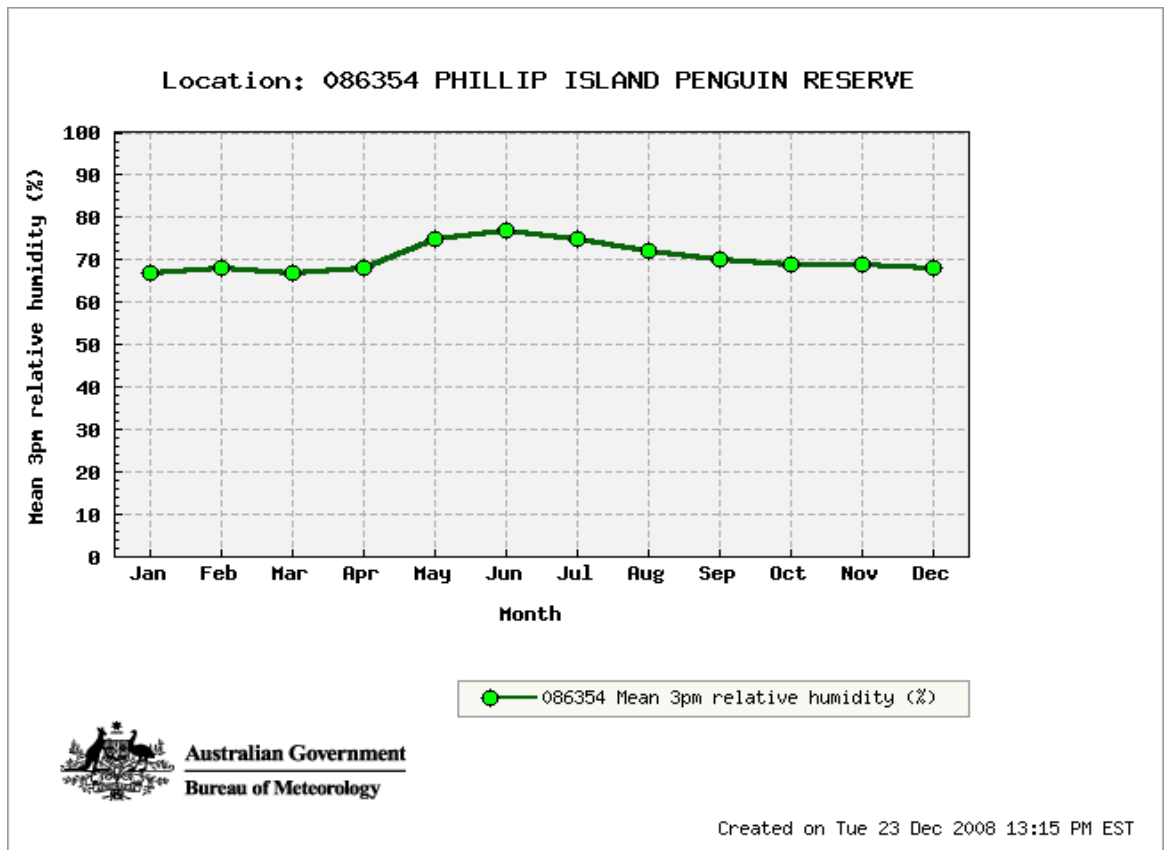


Figure 2.1. Monthly variation in humidity for 1985 to 2008 at the Penguin Reserve on Phillip Island (Source: Bureau of Meteorology, Melbourne).

### Potential effects of decreasing rainfall and humidity on penguins

#### ***Direct effects on adult survival and breeding success***

There is a relatively small and positive impact on penguin survival from decreased rainfall with potentially fewer nest flooding events and landslides. However this may be offset by an increased frequency of extreme events, resulting in floods and landslides.

#### ***Indirect effects***

##### *Microclimate of burrows*

As noted previously, humidity may be a contributor to the hatching success of eggs as they lose a considerable amount of water during the 35 days of incubation (Stahel & Gales 1987) and the rate of water loss is likely to be a function of humidity. It is likely that with decreasing rainfall, increased temperature and evaporation, humidity will decrease but it is unclear whether burrow humidity would decrease in concert with air humidity and whether this would have implications for breeding success. This requires further research (see recommendations).

##### *Fire risk*

##### *Increase in fire frequency*

With an increase in droughts, declines in rainfall and increases in air temperature, it seems probable that there will be some increase in fire risk on the Summerland Peninsula. Wonthaggi meteorological data (from 1971 to present) indicates weak, but significant, trend towards more dangerous fire weather days in autumn and spring (Bureau of Meteorology

2009). Fire has considerable implications for penguins with impacts on the quality of nesting habitat, the survival of adults and young and breeding success (Renwick *et al.* 2007).

#### Fire and breeding habitat

Fire reduces the quality of breeding habitat in the short-term through the destruction of vegetation and associated damage to burrow structure, collapse of burrows, erosion of soils and reduction in insulation of surviving burrows. The extent of the impact of fire varies with vegetation type and fire has a greater impact in grassland and scrubland and less in succulent herbfields. It was noticeable from a fire on Seal Island, east of Wilsons Promontory, that areas of succulent vegetation and the penguins living in them were largely unaffected by the fire (Renwick *et al.* 2007- see Appendix 2).

#### Fire and adult survival

Fire in a seabird colony can be destructive of both nests and adults and the synchronised breeding of many seabirds, when large numbers are present in a colony, makes them particularly vulnerable to fires when breeding. Experience from the Seal Island fire indicated that adult Little Penguins do not actively avoid fire and hence their responses to fire were surprisingly inappropriate and maladaptive. In many cases, dead penguins were found on Seal Island either in their burrows (often collapsed) or within metres of burrows. Birds nesting under vegetation appeared to remain until they were severely burnt or killed. Penguins were observed standing beside flames preening singed feathers, rather than moving away. Most live penguins suffered debilitating injuries including burns to their feet and legs, scorched feathers and blistered skin, swollen eyes, and many had difficulty breathing (Renwick *et al.* 2007). On Phillip Island, misty rain or fog following long spells of hot dry and dusty weather can result in the ignition of power-pole cross-arms, due to a build-up of salt and dust on the insulators or the red-hot salt crust falls down and ignites vegetation at the base of the pole. Corrosion of high voltage power lines can cause breakage and then fire when they fall to the ground (Chambers *et al.* 2009). This has occurred on four occasions on the Summerland Peninsula in the past 20 years.

Most of the current fire risk on the Summerland Peninsula could be removed with the undergrounding of all power lines. The risk of damage to penguins and habitat could be reduced further through planting of fire retardant indigenous vegetation.

#### Availability of food

Potential reduction/alteration of anchovy spawning patterns & anchovy survival in estuaries.

Port Phillip Bay is an important feeding area for Phillip Island penguins at some times of the year, notably during winter and early spring as well as during the incubation period. Some ten years ago, a report showed that between 30 and 60% of Phillip Island penguins (and probably all of the St Kilda penguins) spend time in Port Phillip Bay in July (Collins *et al.* 1999) Recent satellite tracking studies over June, July and August 2008 have confirmed that this is still the case with 58% of tracked birds going into Port Phillip Bay in July (Table 2.1, McCutcheon 2008, Dann *et al.* unpublished data).

	JUNE	JULY	AUG	TOTAL
Port Phillip Bay	2(14%)	11(58%)	1(5%)	14(26%)
South of Phillip Island	11	7	15	33
West Coast	1	-	4	5
Western Port	-	1	-	1
TOTAL	14	19	20	53

Table 2.1. Foraging trip destinations for Little Penguins from Phillip Island by month over winter in 2008.

In Port Phillip Bay, the penguins from Phillip Island are mainly present, and probably feeding, in the central eastern part of the Bay, in Corio Bay and off the Werribee Treatment Plant (Fig.2.2, McCutcheon 2008, Dann *et al.* unpublished data). The latter is an important source of freshwater and nutrients for the Bay upon which the abundance of prey may depend.

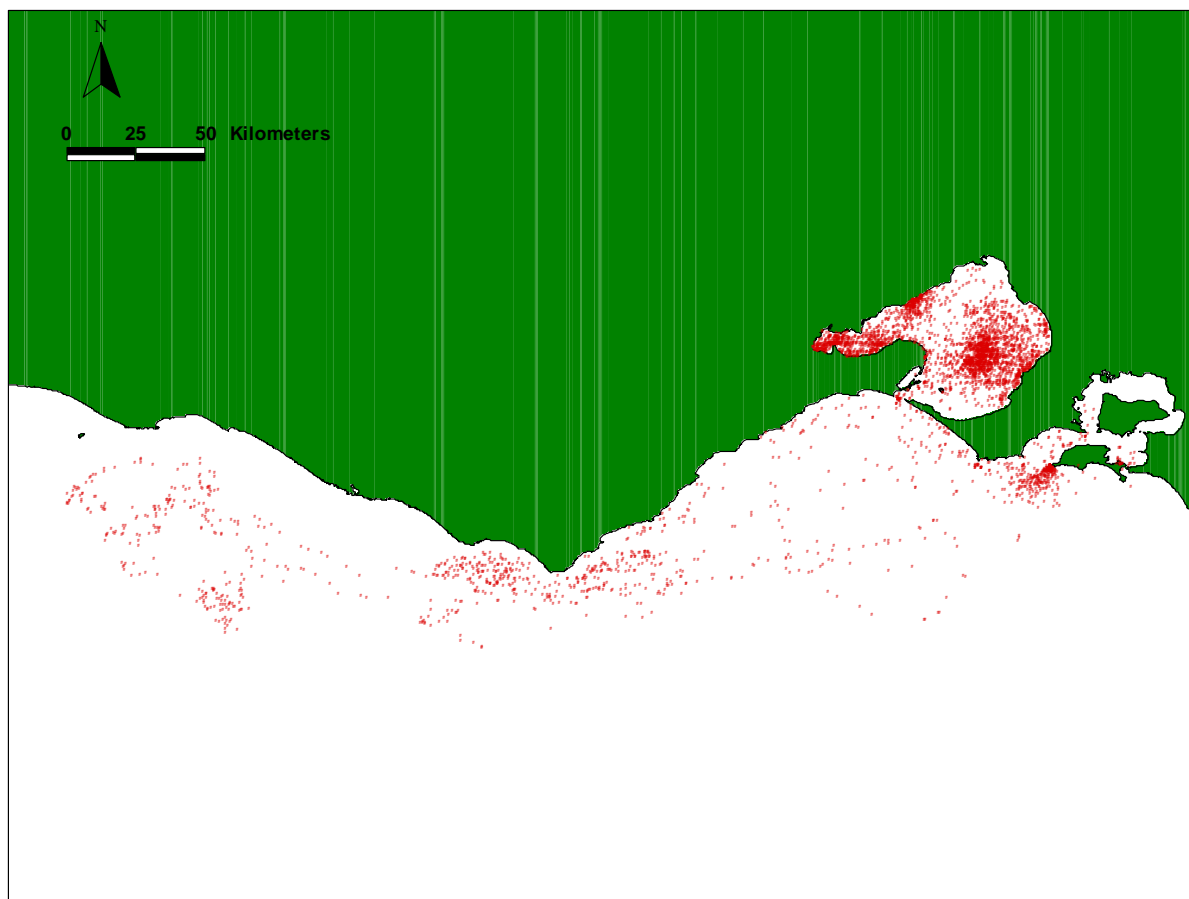


Figure 2.2. All of the locations of penguins tracked from Phillip Island between June and August 2008.

Collins *et al.* (1999) also recorded penguins from Phillip Island going into Port Phillip Bay between incubation shifts suggesting that it is important as a feeding area for Phillip Island birds through winter and into spring. This period also coincides with the one of the two periods of significant adult mortality in some years (Dann *et al.* 1992) suggesting that food is not always readily available at this time. The importance of Port Phillip Bay to penguins at crucial periods in their annual cycle appears associated with the availability of anchovies which in turn may be related to freshwater inputs into the Bay.

The stream flow from the Western Treatment Plant is likely to reduce dramatically as recycling programs become established in the short-term and a predicted decrease of up to 50% in river flows into the Bay suggests that if the timing or production of spawning of anchovies in the Bay are related to freshwater inputs, then the distribution and abundance of Little Penguins in the Bay may be affected similarly. It is important that any links between penguin survival (abundance), anchovy spawning and availability and freshwater flows are made. In the short-term the former can be assumed but, in this context, the links between freshwater flows and the survival, timing of spawning and productivity are paramount.



### **Summary of potential impacts on distribution and abundance of penguins**

It is predicted that there will be little appreciable direct impact of decreased rainfall and humidity on adult Little Penguins over the next century. However it seems likely that fire risk will increase and needs to be managed to ensure penguin survival is unaffected. In addition, if the availability of anchovies is reduced by decreased rainfall, then adult survival (and possibly breeding productivity) may be reduced.

### **Resilience building and recommendations for actions including future research**

- Increase appropriate ground vegetation cover in penguin breeding habitat to reduce evaporation of soil moisture during periods of decreased rainfall and to reduce erosion after high rainfall events
- Investigate the role of burrow temperature and humidity in determining the breeding success of penguins, particularly hatching success and chick growth
- Honours project on relationship between burrow location and structure on nest temperature and humidity- commence June 2009. Project brief in Appendix 3.
- Reduce fire risk on Summerland Peninsula through:
  1. planting fire resistant local vegetation, particularly succulent species where appropriate,
  2. give high priority to fire response planning and training,
  3. ensure all power supply on Summerland Peninsula is underground.
- Establish if relationships exist between stream inflows (and temperature) into Port Phillip Bay and anchovy spawning and production.

## **3. AMBIENT TEMPERATURE RISE ON PHILLIP ISLAND**

### **Background**

Rising temperatures on Phillip Island have a number of potential effects on penguins including

- Increased hyperthermia for birds in burrows and, ultimately, increased mortality of those birds
- Reduced breeding success through desertion of burrows that are too hot for adults or through potential direct effects of temperature (and humidity) on the hatching and fledging successes of penguins

#### *Increasing hyperthermia and, ultimately, adult mortality*

Both of these may result from the direct effect of increased extreme temperatures but also from the indirect effect through loss of covering vegetation. Little Penguins, unlike many other seabirds, cannot withstand prolonged exposure to air temperatures above 35 °C (Stahel & Gales 1987). Since birds do not sweat, they generally keep their body temperature constant by panting. Penguins hyperventilate rather than pant. This pattern of large breaths, compared to the normal avian panting pattern of rapid shallow breaths, is energetically expensive, and the resultant level of evaporative cooling cannot keep body temperature from rising (Stahel & Gales 1987). Oxygen consumption in Little Penguins increases at ambient temperatures above 26-27 °C (Baudinette *et al.* 1986). Presumably this is associated with the increased need for evaporative cooling supplied by higher rates of ventilation. Birds experiencing hyperthermic conditions may increase their body temperatures by as much as 2-4 °C (Calder & King 1974). Stahel & Gales (1987) suggested

that when burrow temperatures increase beyond 35 °C, Little Penguins have a tolerance of only a few hours before body temperatures become dangerously high.

Hyperventilation may cause oxygen depletion in penguin burrows and, if the burrow is poorly ventilated, could increase the risk of hypoxic conditions developing in the burrow.

Hyperventilation also decreases the levels of carbon dioxide in the blood and this, with continued production, increases the body's pH. Hence, heat exposed penguins, in addition to problems with regulation internal temperature, also face disruption of the body's acid-base status (Stahel & Gales 1987).

In an analysis of 416 recorded causes of mortality of adult penguins on land at Phillip Island, 7 (1.7%) were considered due to heat stress (Dann 1992). Mortality on land is thought to be less than 10% of annual mortality (Dann 1992) suggesting that heat stress may account for 0.17% of total annual adult mortality.

Heat exposure is unlikely to be significant for penguins at sea and their coming ashore at dusk and leaving before dawn allows them to avoid daytime temperatures on land. However during incubation, guard stage of chick-rearing and moult, adults must remain in burrows during the day. The microclimate of the burrow determines their exposure to high temperatures and this, in turn, is a reflection of the structure of the burrow and the insulation qualities of the surrounding vegetation

#### *Reducing breeding success*

The two important variables of the microclimate of penguin burrows that may influence breeding success are temperature and humidity. (Potential humidity effects on penguin breeding success are covered in Section 2). High temperatures may influence breeding success (Stahel & Gales 1987) but there have been no definitive studies of how it may operate on penguin eggs or chicks. Little Penguins readily use artificial boxes for breeding (Jessop & Dann, in prep.) which provides opportunities to measure the microclimate of burrows accurately (Ropert-Coudert *et al.* 2004) as well as to design burrows with improved microclimates than may enhance survival and breeding success. Burrow temperature would be expected to vary with burrow type, depth and location as well as the surrounding and covering vegetation type, structure and cover (Ropert-Coudert *et al.* 2004).

#### **Change in ambient temperatures expected in this region (Macadam *et al.* 2008)**

- By 2030 an increase in annual average temperatures of around 0.8°C (with a range of uncertainty of 0.5 to 1.1°C) is likely.
- By 2070 increases in annual average temperatures of around 1.3°C (0.9 to 1.8°C) and around 2.5°C (1.7 to 3.5°C) are likely under low and high emissions scenarios respectively.
- Average temperatures will increase in all seasons, most significantly in summer and least in winter.
- The number of days > 35 °C is expected to double by 2030 and triple by 2070.

#### **Potential effects of ambient temperature rise on penguins**

##### ***Adult survival***

Currently 0.17% of estimated annual mortality of adult Little Penguins on Phillip Island can be attributed to heat stress and, based on a tripling of days greater than 35°C, heat stress could triple by 2070. However, this is a conservative extrapolation based on a linear

relationship between temperature and physiological effects on penguins. If the relationship is curvilinear then increasing temperatures will have a much greater impact on penguin survival. Penguins are susceptible to heat stress while they are confined to burrows during daylight hours for incubation or chick brooding or on-land during the annual moult. At other times of the year, they do not need to stay ashore for extended periods.

In addition, a potentially significant cost associated with rising temperatures is the likelihood that the maintenance cost of penguins will increase. The daily energy budgets of penguins will increase in tandem with increasing temperatures over 27 °C as they expend energy to maintain core temperatures.

Fire risk may increase with increasing temperature and so too may adult mortality and breeding failure (covered in Section 2).

### **Breeding success**

#### *Microclimate of burrows*

Temperature has been identified as one of two important variables of the microclimate of penguin burrows that may influence breeding success and adult survival (Section 2). Temperature may be a contributor to the hatching success of eggs, either directly or through impacts on desertion rates, and the growth rates of chicks. Burrow temperature would be expected to vary with burrow type, depth and location as well as the surrounding and covering vegetation type, structure and cover. Internal temperatures of penguin nest boxes may be manipulated through insulation (Jessop & Dann, in prep.) and ventilation (Ropert-Coudert *et al.* 2004). Location is likely to be particularly important on the Summerland Peninsula where up to a 12 °C difference has been recorded between the northern and southern facing sides (Dann unpublished obs.). Both these aspects require further research (see recommendations).

### **Summary of potential impacts on distribution and abundance on penguins**

Increasing temperatures in burrows during daylight are likely to increase adult and chick mortality and, based on a tripling of days greater than 35 °C and assuming a conservative linear function, will constitute c. 0.51% of annual adult mortality by 2070. Increasing burrow temperatures may also have a role in determining breeding success and this warrants investigation as does the scope for mitigation of burrow microclimates through vegetation management and artificial burrow design.

### **Resilience building and recommendations for actions including future research**

- Increase appropriate ground vegetation cover in penguin breeding habitat to reduce internal temperatures of burrows on hot days
- Investigate the role of burrow temperature in determining the breeding success of penguins, particularly hatching success and design an artificial burrow with optimal microclimate (temperature & humidity) - see Section 2. A project to examine breeding success in relation to temperature in artificial burrows is currently in train (Chiaradia *et al.* personal communication) and a project brief for a study to look at temperature and humidity in natural burrows is given in Appendix 3.
- Compare breeding success and ambient temperatures of Little Penguins on northern (warmer) & southern (cooler) sides of the Summerland Peninsula between 1984 and 2008.

#### 4. SEA TEMPERATURES IN BASS STRAIT AND OCEAN CURRENTS (INCLUDING THERMOCLINES AND ENSO EVENTS)

##### Background

Ocean temperatures may influence the timing and success of breeding of seabirds (Ainley & Boekelheide 1990, Guinet *et al.* 1998, Inchausti *et al.* 2003, Irons *et al.* 2008, Cullen *et al.* 2009). Chambers (2004) noted that the effects of warmer SSTs on seabirds varied between Equatorial regions and regions of higher latitude such as southern Australia.

Penguin breeding may be affected by changes in marine productivity associated with SSTs and driven by oceanographic processes (Middleton & Cirano 2002). Sea surface temperatures around south-eastern Australia are influenced by waters from four regions (Gibbs 1992). Bass Strait water around Phillip Island originates mostly from the west, flowing east across South Australia as low nutrient subtropical water from the Great Australian Bight. From the north, the East Australian Current (EAC) flows south bringing eddies of warm nutrient-poor tropical water of the Pacific Ocean. There is mixed subtropical Central Tasman water in the east. In the south and in deep water beyond the continental shelf, the cold nutrient-rich subantarctic water originates from below the Subtropical Convergence Zone and the eastward flowing Antarctic Circumpolar Current in higher latitudes. The interaction of these four water masses, which is influenced by the seasonal wind patterns, determines the nature of the marine environment of the Little Penguins and the productivity of marine ecosystems in south-eastern Australia.

Oceanic warming in south-eastern Australia is likely to cause poleward shifts in species ranges and a shift in abundance toward species tolerant of warmer waters (Poloczanska *et al.* 2007). For example, Tasmanian fish distributions have been reported shifting south together with an increase in the proportion of species that prefer warmer waters (Welsford & Lyle 2003). Correspondingly, in the northern hemisphere, fish distributions in the north Atlantic Ocean appear to be shifting northwards (Beare *et al.* 2004, Byrkjedal *et al.* 2004, Perry *et al.* 2005, Rose 2005a, 2005b). Fortescue (1998), in a study of Little Penguins from Bowen Island, reported an increase in the abundance of various fish species during periods of warmer water temperatures in Jervis Bay, New South Wales. Bunce (2000) stated that pilchards *Sardinops sagax* move into Port Phillip Bay during warm water periods.

Phillip Island Little Penguins rarely travel outside Bass Strait (Collins *et al.* 1999, Hoskins *et al.* 2008) and therefore are dependent upon the waters of the Strait for all their food requirements.

Sea temperatures in Bass Strait are likely to have a profound direct influence on the productivity of the Bass Strait pelagic ecosystem and accordingly, an influence on the demography of penguins, particularly on:

- Timing and success of breeding in penguins
- Survival of adult and juvenile (first-year) penguins

##### **Change in sea-surface temperatures, stratification and ocean currents expected in this region (Poloczanska *et al.* 2007).**

- Around Australia a warming of 1-2 °C is projected by the 2030s, with the greatest warming off south-eastern Australia (2 °C).
- By 2070, warming around Australia is projected to be in the range 2-3 °C, with the greatest warming off south-eastern Australia (3 °C). However, mitigating circumstances suggest that these values will not be reached in Bass Strait in the projected time periods.

- Warming is also likely below the surface with ~0.5-1.0 °C projected for 500 m depth. N. B. Bass Strait is 100m at its deepest. Predictions are for eastern Bass Strait to warm more than western Bass Strait.
- By 2030 the East Australian Current, a warm current, is expected to increase in strength and penetrate further south. By 2070 the strength of surface currents is generally projected to decline (0-1.2 m s<sup>-1</sup>).
- By 2030 greater stratification is expected, as is a shallowing of the mixed layer (by ~1 m), which is likely to reduce nutrient inputs from deep waters.

The CSIRO climate model projects the greatest warming off southeast Australia and this is the area of greatest warming this century in the entire Southern Hemisphere. This Tasman Sea warming is associated with systematic changes in the surface currents on the east coast of Australia; including a strengthening of the EAC and increased southward flow as far south as Tasmania (Figure 4.1).

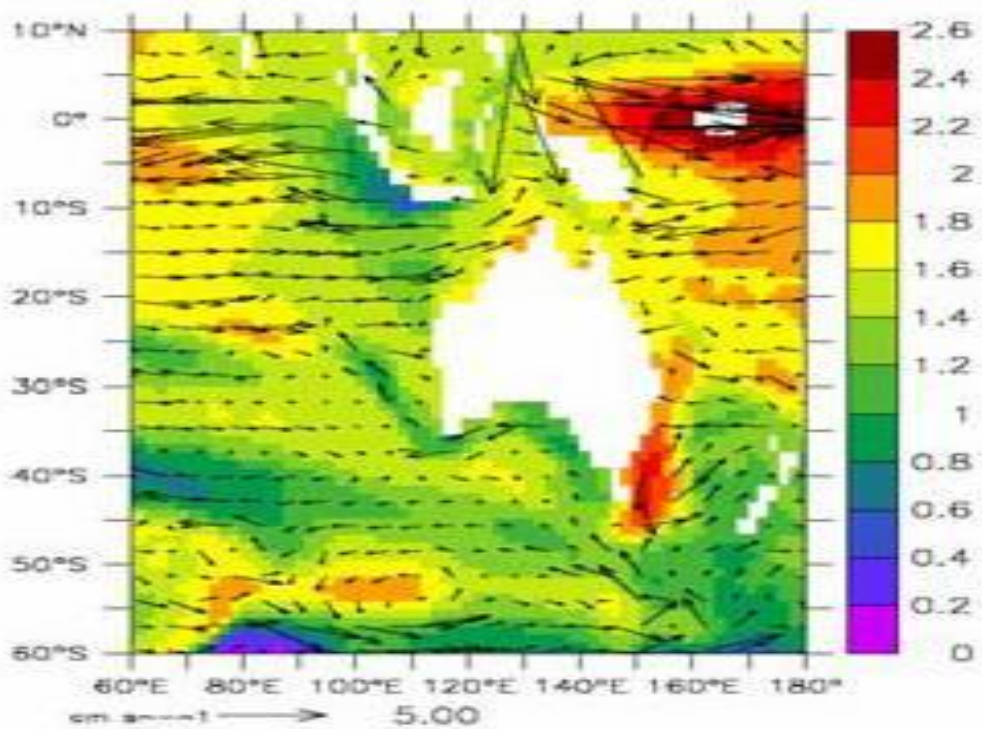


Figure 4.1. Projected SST and wind vector changes by 2070 compared to 1990 (from Poloczanska *et al.* 2007).

Based on the data of Cullen *et al.* (2009) decadal averages of SSTs for the Bass Strait region 35°S to 45°S and 138°E to 152°E are shown in Table 4.1. There has been a slight, but mainly statistically insignificant, warming in Bass Strait overall in the past 58 years but, until recently, the mean SSTs for March (Figure 4.2) which have the greatest impact on

penguins, showed a slight decline. The incomplete decadal average for 2000-2010 suggests a slight warming in recent times (Table 4.1).

<i>Decade</i>	<i>Summer</i>	<i>Autumn</i>	<i>March</i>
1950-1959	16.60	16.17	17.23
1960-1969	16.95	16.56	17.68
1970-1979	17.12	16.80	17.90
1980-1989	17.12	16.82	17.79
1990-1999	16.87	16.53	17.67
2000-2008	17.14	16.83	17.94
Trends	0.006 °C/year (p=0.071)	0.009 °C/year (p=0.135)	0.009 °C/year (p=0.031)

Table 4.1. Decadal averages for summer, autumn and March SSTs in Bass Strait for the region 35°S to 45°S and 138°E to 152°E. Also given are linear trends for each season.

### **Potential effects of ocean temperature rise in Bass Strait and changes in ocean currents on Phillip Island penguins**

***Sea-surface temperatures -timing and success of breeding*** (taken from Cullen, Chambers, Coutin & Dann 2009)

Sea surface temperature (SST) variation has been shown to be associated with the timing and success of breeding of Little Penguins on Phillip Island (Cullen *et al.* 2009). Egg-laying date, chick mass and the number of chicks fledged per pair were correlated with SST in the first three months of the year prior to breeding, in slightly different ways (Cullen *et al.* 2009). SST provided more accurate predictions of mean laying date (53% variance) than of chicks produced per pair (22%) or mean chick mass at fledging (16%). This model predicted an early egg-laying date, higher average chick mass at fledging and a higher number of chicks produced per breeding pair when SSTs in Bass Strait are warmer than average in March. The models presented by Cullen *et al.* (2009) predict that an increase in SSTs is likely to lead to a reversal of the trend towards later breeding and suggest improved growth of the colony of Little Penguins on Phillip Island, at least in the immediate future. Although this is surprising, given that increasing SSTs in Bass Strait may enhance breeding productivity, the model would not be expected to hold once Bass Strait SSTs exceed those experienced in the development of the model, i.e. during the last 35 years.

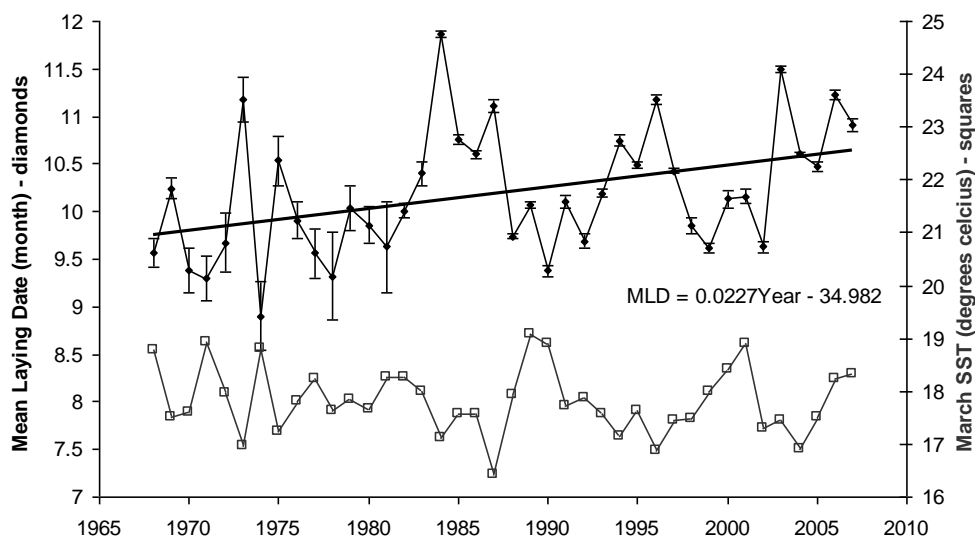


Figure 4.2. Temporal trend in annual timing of mean laying date of Little Penguins on Phillip Island (with associated standard errors). Also shown are the March SST values for the SSTs in the Bass Strait region 35°S to 45°S and 138°E to 152°E (from Cullen *et al.* 2009).

Month	Mean Laying Date	Chicks per Pair	Chick Mass
January	-0.307	0.184	0.166
February	-0.498*	0.278	0.229
March	-0.736*	0.491*	0.433*
April	-0.495*	0.409*	0.342
May	-0.422*	0.348	0.279
June	-0.200	0.245	0.138
July	-0.082	0.210	0.083
August	0.068	0.317	-0.016
September	0.134	0.040	-0.106
October	-	-0.055	-0.059

Table 4.2. Correlation coefficients between the Little Penguin breeding variables (Mean laying date, chicks per pair and chick mass) and regionally averaged monthly SSTs, 1968 to 1998. Months beyond September were not considered for mean laying date as, in some years, the breeding season has already commenced.

\* Correlations significant at the 5% level (from Cullen *et al.* 2009).

As a rough guide to the potential effect of a 2 °C and 3 °C rise on the timing of breeding of Little Penguins, we have used the observed March SST values from Cullen *et al.* (2009) over the full period (1968-2008) and added either 2 or 3 °C to these values and used the regression equation from Cullen *et al.* (2009) to give an idea of the potential range of mean laying dates expected if this equation were to continue to hold (Table 3).

	Mean Date	SE Mean
2°C rise	8.5503	0.0757
3°C rise	7.7790	0.0757

Table 4.3. Potential mean laying dates of Little Penguins at Phillip Island under scenarios of a 2 °C and 3 °C rise in SST in Bass Strait in March.

Under this model the laying dates would be expected to become much earlier than they are currently, e.g. mean laying date under a 2 °C rise in SST would be mid-August.

A word of caution is required with this analysis as there are many assumptions that may be violated in these two predictions. This model is not designed to go beyond the historical SST values and it is dangerous to extrapolate any regression model too far into the 'future'. For example, as SSTs rise there may be a (currently unknown) point at which the relationships between SSTs, Little Penguins and the prey on which they depend breaks down or changes, thereby invalidating the model. Large-scale changes in relationships have already been observed between the Southern Oscillation Index and rainfall and temperature in Australia (Nicholls *et al.* 1996). It is also unlikely that the same level of variability in the SSTs would continue under the projected temperature rises. An overall rise of 2 or 3 °C is unlikely to be consistent over all months, with some months experiencing a greater or less warming – this is not reflected in this analysis.

#### ***Sea-surface temperatures- juvenile (first year) survival***

Sidhu (2007) examined the relationship between juvenile (first-year) survival of Little Penguins breeding on Phillip Island and sea-surface temperatures in south-eastern Australia. She found that the strongest relationship was between first-year survival and the mean SST in the summer of the previous year. There was also a significant association with the autumn mean SST for that year (Sidhu 2007). The significant regression coefficients were both positive suggesting that increased survival of first year birds is associated with warmer sea surface temperatures in both summer and autumn.

It is not surprising that there is a relationship between juvenile survival and environmental conditions in autumn. Most chicks are banded slightly before fledging in December–February (Reilly & Cullen 1984) and by the beginning of autumn; almost all of the newly-fledged birds from the previous breeding season will have gone to sea. Autumn is the peak mortality period for these young birds that are inexperienced in finding food (Dann *et al.* 1992), and SSTs are very likely to have an influence on the availability of food at this critical time.

#### ***Sea-surface temperatures - adult survival***

Sidhu (2007) also examined the relationship between adult survival of Little Penguins breeding on Phillip Island and sea-surface temperatures in south-eastern Australia. She found that the strongest relationships were for the current autumn and winter, and to a lesser extent, the current summer, i.e. the adult survival probability in the 2000 calendar year was best explained by the mean SSTs in the autumn and winter of 2000, and to a lesser extent, the summer (Jan-Feb) of 2000. The relationships were negative, suggesting that cooler SSTs in autumn and winter are associated with increased adult survival, which is the reverse of the relationship between SST and first-year survival. Dann *et al.* (1992) reported that adult mortality peaks in autumn after moult, and again in early spring. During the moult in February or March, adults fast for 15–20 days, and then go back to sea to feed (Reilly and Cullen, 1983), suggesting that food supply before and after moulting plays a pivotal role in adult survival. Hoskins *et al.* (2008) found that the foraging of adult Little Penguins was strongly correlated with a relatively narrow range of SST during chick-rearing, perhaps reflecting the distribution of prey species.

#### **Potential effects of increased stratification of water column on penguins**

Increased stratification may influence penguins directly through processes operating on their foraging efficiencies and indirectly through processes operating on primary and secondary productivity.

Stratification may have a direct impact on how successfully penguins feed. Ropert-Coudert *et al.* (in review) found an association between stratification and foraging and breeding



success of Little Penguins. A reduction in the thermocline was associated with a decrease in foraging and breeding success of penguins.

Mixing depth and mixing intensity in the surface ocean and the associated stratification are key factors for the production of phytoplankton and of higher trophic levels because they fundamentally affect the supply of nutrients and light (Poloczanska *et al.* 2007). With predictions of an increase in stratification and a reduction in the depth of the mixed layer around most of continental Australia Poloczanska *et al.* 2007), comes a likely reduction in productivity of pelagic ecosystems. Most Australian waters are therefore likely to become more depauperate in nutrients with repercussions for production and biomass of most pelagic (and benthic) food webs (Poloczanska *et al.* 2007). Cyanobacteria, flagellates and dinoflagellates (including nuisance and harmful algal bloom species) are expected to increase in abundance where vertical mixing decreases and the 'microbial loop' may be favoured over the relatively more productive 'classic' food web in affected areas. In Tasmanian waters, zonal westerly winds stimulate deeper and/or stronger vertical mixing and affect the timing and duration of phytoplankton blooms (Harris *et al.* 1988).

### **Summary of potential impacts of oceanic changes on distribution and abundance on penguins**

Increasing sea-surface temperatures in Bass Strait may result in an earlier start to the breeding season, increases in breeding success and increases in first-year survival. Decreases have been predicted in adult survival, but more work is required to confirm the direction of this relationship. More productive breeding seasons and higher first-year survival should improve recruitment into the breeding population. Increased stratification of the water column may reduce productivity and, correspondingly, food availability for penguins but, conversely, increase foraging efficiency of Little Penguins.

### **Resilience building and recommendations for actions including future research**

- Continue Phillip Island Nature Park's commitment to long-term studies of breeding, demography and foraging of Little Penguins. Long-term datasets are the key to documenting and understanding the response of species to climate change and the Little Penguin study at Phillip Island is one of the longest running studies of a marine species in Australia
- Model the impact of shortening or lengthening the breeding season has on productivity of penguins
- Investigate if the timing of breeding of penguins at Phillip Island has continued to track the autumn SSTs in Bass Strait following the apparent change in trend since 2000
- Review the linkages between SSTs in autumn and the timing and success of breeding in penguins, giving priority to those involving prey species
- Determine with more confidence the relationship between sea-surface temperatures and adult survival with more confidence
- Determine if there are any competitive interactions between fisheries and Phillip Island penguins. Building resilience to reductions in food availability for penguins could include reducing competition from fisheries
- Investigate the role of climate on fish recruitment (spawning and survival) in Bass Strait

## 5. WIND, SOUTHERN OSCILLATION INDEX AND OCEAN ACIDIFICATION

### Background

There are a number of environmental parameters, not covered in the previous sections of this report, associated with the marine environment that have been identified by Poloczanska *et al.* (2007) as having implications for the abundance and distribution of marine animals. Wind patterns, the southern oscillation index and ocean acidification are three of these that we believe will have some relevance to Little Penguins on Phillip Island in the future.

### Wind patterns

Wind direction and velocity play an important role in the transport of cooler water masses into central Bass Strait and a major role in the vertical mixing of the water column (see Section 4 on stratification). Apart from the likely impact these processes have on fish spawning patterns and survival, they may also influence the foraging success of penguins directly.

### Southern Oscillation Index

The Southern Oscillation Index (SOI) measures the air pressure difference between Tahiti and Darwin (Allan *et al.* 1996) and associations with a number of aspects of seabird population demography have been reported (La Cock 1986, Jenouvrier *et al.* 2005). El Niño episodes are characterised by sustained negative SOI values, and are associated with weaker Pacific Trade winds, generally reduced rainfall in eastern and northern Australia, and a cooler SST in Australian waters. Sustained highly positive SOIs are indicative of a La Niña episode, which is associated with stronger Pacific Trade winds, an increase in rainfall in eastern and northern Australia, and a warmer SST.

### Ocean acidification

Changes to the atmospheric concentration of CO<sub>2</sub> and hence carbonate ions in the water column represents a serious threat to calcifying organisms (Raven *et al.* 2005). pH is an important determinant of the growth rate of phytoplankton species and the direct effect of ocean acidification on calcifying zooplankton will be to increase shell maintenance costs and reduce growth. How these changes will affect primary and secondary production in pelagic food chains is difficult to predict at our current level of knowledge of these processes and the functioning of pelagic food webs.

The physiology of fish and squid may be influenced by increasing CO<sub>2</sub> levels in the oceans because it influences tissue acid-base regulation and thus metabolism Poloczanska *et al.* (2007). Squid are acutely sensitive to even small changes in ambient CO<sub>2</sub> (Portner *et al.* 2004). Pelagic fish generally have lower metabolic rates and some venous oxygen reserve so are only moderately sensitive to changes in ambient CO<sub>2</sub> (Poloczanska *et al.* 2007).

### Changes in wind, SOI & pH expected in this region

- Climate models consistently project a poleward shift in the zonal winds that normally cross the southern part of Australia (Jones & Widmann 2004).
- The Southern Oscillation Index has decreased in recent years and the relationship between SOI and rainfall has weakened in Australia, after the mid-1970s (Nicholls *et al.* 1996, Suppiah 2004).
- pH of world's oceans is expected to increase (Raven *et al.* 2005).

## Potential effects on penguins

### **Decreasing wind strength**

Wind may play direct and indirect roles in determining the survival and breeding success of penguins. It is not known if wind affects the foraging success of penguins directly, and therefore has some implications for their survival and breeding success, but this needs to be determined if we are to understand the impacts of wind on penguins in the future.

Wind is one of the significant determinants of currents and vertical mixing in the water column and the projected weakening of winds in southern Australia may reduce fish recruitment (Poloczanska *et al.* 2007). Strong relationships between wind strength and recruitment exist for blue grenadier *Macrurus novaezelandiae* in outer continental shelf waters (Thresher *et al.* 1992) and, in southeastern Australia, Harris *et al.* (1992) found evidence that reduced production of the jack mackerel *Trachurus declivis* off Tasmania resulted from decreased wind stress and subsequent decreases in large zooplankton. Therefore there is a potential role for wind strength in the recruitment of prey species taken by penguins.

The influence of wind on vertical mixing is also relevant to stratification of the water column and its effects on penguins (see Section 4 for discussion).

### **Decreasing Southern Oscillation Index**

Sidhu (2007) found relationships between first-year and adult survival and the SOI. Higher first-year survival probability was associated with lower SOIs, whereas the opposite was the case for adult survival. Factors which affect adult survival have a greater impact on population size than do those related to first-year survival (Dann 1992).

Highly negative SOIs indicate the presence of El Niño conditions, which are generally associated with lower SSTs in the Australian region. Sidhu (2007) noted that this result appears to contradict those obtained for local-scale sea surface temperatures and highlights the complexity of the effect of climatic conditions on the survival of Little Penguins. Highly positive SOIs indicate the presence of La Niña conditions, which are generally associated with warmer SSTs in the Australian region. Correspondingly, Fortescue (1998) reported that positive phases of the SOI were associated with increased adult survival from one season to the next. It is also possible that the SOI and survival are related by thresholds rather than continuously. For example, extremely high or low SOIs (La Niña or El Niño conditions) may affect penguin survival, whereas moderate SOIs may have no effect (Sidhu 2007).

### **Increasing acidification**

Potential effects of acidification of oceanic water on penguins are likely to be twofold: Firstly, through negative effects operating on primary and secondary productivity and, ultimately, on the availability of food for penguins.

Secondly, through potentially negative effects on squid. Goulds Squid *Notodarus gouldii* is an important food of penguins in Bass Strait.

### **Summary of potential impacts on distribution and abundance on penguins**

Decreasing winds in the region are likely to reduce the recruitment of fish populations and hence the availability of food for penguins, with potential impacts on their survival and breeding success. It is unknown if wind direction and velocity directly affect penguin foraging success. Decreasing SOI may reduce adult survival and increase juvenile survival but the mechanisms are unknown for either. Increasing acidification may reduce food availability for penguins.

## Resilience building and recommendations for actions including future research

- Develop a trophic model of the Bass Strait ecosystem to allow assessment of sensitivities to oceanic variables for higher predators and potential interactions.
- Determine the effects of wind on the foraging success of Little Penguins
- Analyse the relationships between SOI and survival of adult and first-year penguins

## CONCLUSIONS

Overall there are a number of aspects of the biology of penguins that are likely to be affected, both positively and negatively, by predicted climate change over the next 100 years (see Table below). Breeding productivity and juvenile survival seem likely to improve with increasing sea temperatures. Marine productivity and adult survival perhaps, seem likely to decline while the feeding behaviour of penguins will possibly experience both negative and positive impacts as a consequence of climate change. Some of the negatively impacts can be addressed on small scales in the short-term, particularly those resulting from expected changes to the terrestrial environment.

A number of areas requiring further research have been identified including the effects of ambient and burrow temperatures on breeding success and adult survival, the effects of sea temperatures on adult survival and productivity and the effects of rainfall on food availability. Continual review will be essential as the predictions and implications for climate change develop further.

Predicted climate change effect	Potential impacts on Little Penguins
Sea-level rise-Western Port and Bass Strait	Insignificant loss of breeding habitat in next 100 years Patterns of access to colonies disrupted on sandy shores Potential loss of inshore marine productivity in the long-term
Decreased rainfall (and humidity)	Fire risk will increase and adult mortality and some habitat loss will increase accordingly Reduction in stream flows may effect anchovy spawning and productivity
Ambient temperature rise on Phillip Island	Slight increase in adult mortality Potential change in breeding success
Increasing sea temperatures in Bass Strait and ocean currents (including thermoclines and ENSO events)	Highly likely to result in earlier and more productive breeding seasons in the short and medium terms Likely to result in greater survival of penguins in their first year Possibly cause increase in adult mortality but more work required Increased stratification may reduce marine productivity but increase penguin feeding efficiency
Wind, southern oscillation index and ocean acidification	Decreasing winds likely to reduce fish recruitment and food availability for penguins Decreasing SOI may reduce adult survival but increase juvenile survival Increasing ocean acidification may reduce food availability

## REFERENCES

- Ainley, D. B. R. (1990). Seabirds of the Farallon Islands. Stanford, California., Stanford University Press
- Allan, R., Lindsay, J. & Parker, D. (1996). El Niño Southern Oscillation and climate variability. Collingwood, Australia, CSIRO.
- Baudinette, R. V., Gill, P. & O'Driscoll, M. (1986). Energetics of the Little Penguin, *Eudyptula minor*: Temperature Regulation, the Calorigenic Effect of Food, and Moulting. Aust. J. Zool. 34: 35-45.
- Beare, D. J., Burns, F., Greig, A., Jones, E.G., Peach, K., Kienzle, M., McKenzie, E. & Reid, D.G. (2004). Longterm increases in prevalence of North Sea fishes having southern biogeographic affinities. Marine Ecology Progress Series 284: 269–278.
- Bruun, P. (1962). Sea-level Rise as a Cause of Shore Erosion. Journal of Waterways 88: 117-130.
- Bunce, A., F.I. Norman, N. Brothers & R. Gales (2002). Long-term trends in the Australasian gannet (*Morus serrator*) population in Australia: the effect of climate change and commercial fisheries. Marine Biology 141: 263-269.
- Byrkjedal, I., Godo, O.R. & Heino, M. (2004). "Northward range extensions of some mesopelagic fishes in the Northeastern Atlantic. Sarsia 89: 484–489.
- Calder, W. A. & King, J. R. (1974). Thermal and caloric relations of birds. Avian Biology. D.S. Farner, & J. R. King. New York, Academic Press. IV: Pp. 259-413
- Chambers, L. E. (2004). The impact of climate on Little Penguin breeding success. BMRC Research Report. Melbourne, Australia, Bureau of Meteorology Research Centre.
- Chambers, L. E., Renwick, L. and Dann, P. (2009). Climate, fire and Little Penguins. Strategic Assessment of the Vulnerability of Australia's Biodiversity to Climate Change., CSIRO Melbourne.
- Church, J. A., Hunter, J.I, McInnes, K. & White, N. J. (2004). Sea-level rise and the frequency of extreme event around the Australian coastline.
- Collins, M., Cullen, J. M. & Dann, P. (1999). Seasonal and annual foraging movements of Little Penguins. Wildlife Research 26: 705-721.
- Copenhagen (2009) DOI: [http://climatecongress.ku.dk/newsroom/congress\\_key\\_messages/](http://climatecongress.ku.dk/newsroom/congress_key_messages/)
- Cullen, J. M., Montague, T. L. & Hull, C. (1992). Food of Little Penguins *Eudyptula minor* in Victoria: comparison of three localities between 1985 and 1988. Emu 91: 318-341.
- Cullen, J. M., L. E. Chambers, Coutin, P. & Dann, P. (2009). Predicting onset and success of breeding in little penguins *Eudyptula minor* from ocean temperatures. Marine Ecology Progress Series 378: 269-278.
- Dann, P. (1992). Distribution, population trends and factors influencing the population size of Little Penguins *Eudyptula minor* on Phillip Island, Victoria. Emu 91: 263-272.
- Dann, P., Cullen, J.M., Thoday, R. & Jessop, R. (1992). The movements and patterns of mortality at sea of Little Penguins *Eudyptula minor* from Phillip Island, Victoria. Emu 91: 278-286.
- Dann, P. (1996). Population Management Strategy for Little Penguins on Phillip Island, Phillip Island Nature Park Board of Management.
- Dann, P., Jessop, R. & Healy, M. (2001). The distribution and abundance of Little Penguins at sea in Western Port, Victoria. Victorian Naturalist 118: 230-235.
- Fortescue, M. (1998). The marine and terrestrial ecology of a northern population of the Little Penguin, *Eudyptula minor*, from Bowen Island, Jervis Bay. Canberra, Australia, University of Canberra. PhD.
- Galbraith, H., Jones, R., Park, R., Clough, J., Herrod-Julius, S., Harrington, B. & Page, G. (2002). Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds 25: 173–183.
- Gibbs, C. (1992). Oceanography of Bass Strait: implications for the food supply of Little Penguins *Eudyptula minor*. Emu 91: 395–401.
- Guinet, C., Chastel O, Koudil M, Durbec J-P & Jouventin P (1998). Effects of warm sea-surface temperature anomalies on the blue petrel at the Kerguelen Islands. Proceedings of the Royal Society of London B 265: 1001-1006.

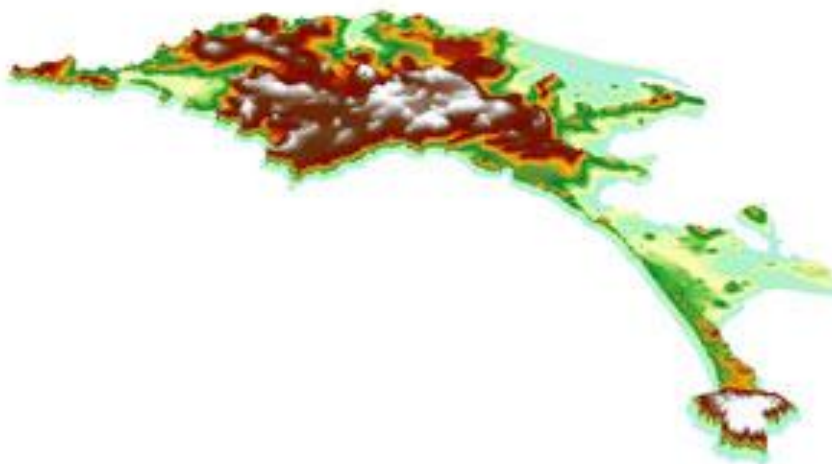
- Hall, D. N. & McDonald, C. (1986). Commercial fishery situation report: net and line fisheries of Port Phillip Bay, Victoria, 1914-1984. Marine Fisheries Report Fisheries Division, Department of Conservation, Forests and Lands, Victoria. 10.
- Harris, G., Davies P, Nunez M. & Meyers G (1988). Interannual variability in climate and fisheries in Tasmania. Nature 333: 754-757.
- Harris, G., Batley, G., Fox, D., Hall, D., Jernakoff, P., Molloy, R., Murray, A., Newell, B., Parslow, J., Skyring, G. & Walker, S. (1996). Port Phillip Bay Environmental Study: Final Report. Dickson, ACT. CSIRO
- Hoskins, A. J., Dann, P., Ropert-Coudert, Y., Kato, A., Chiaradia, A., Costa, D. P. & Arnould, J. P.Y. (2008). Foraging behaviour and habitat selection at sea in Little Penguins *Eudyptula minor* during the chick-guard stage of breeding. Marine Ecology Progress Series 366: 293-303.
- Inchausti, P., Guinet C, Koudil M, Durbec J-P, Barbraud C, Weimerskirch H, Cherel Y & Jouventin P (2003). Inter-annual variability in the breeding performance of seabirds in relation to oceanographic anomalies that affect the Crozet and the Kerguelen sectors of the Southern Ocean. Journal of Avian Biology 34: 170-176.
- IPCC (2001). Climate Change 2001: The Science of Climate Change. Summary for Policymakers and Technical Summary of the Working Group I Report. Intergovernmental Panel on Climate Change. . C. U. Press: 98.
- IPCC (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers. : 18.
- Irons, D., Anker-Nilssen T, Gaston AJ, Byrd GV, Gilchrist G, Hario M, Hjermquist M, Krasnov YV, Mosbech A, Olsen B, Petersen A, Reid JB, Robertson GJ, Strom H & Wohl KD (2008). Fluctuations in circumpolar seabird populations linked to climate oscillations. Global Change Biology 14: 1455-1463.
- Jenkins, G. P. (1986). Composition, seasonality and distribution of ichthyoplankton in Port Phillip Bay, Victoria. Aust. J. Mar. Freshwater Res 37: 507-520.
- Jessop, R. & Dann, P. (in prep.). Breeding success of Little Penguins in natural and artificial burrows.
- Jones, J. M. & Widman, M. (2004). Early peak in Antarctic oscillation index. Nature 432: 290–291.
- La Cock, G. (1986). The Southern Oscillation, environmental anomalies, and mortality of two southern African seabirds. Climatic Change 8: 173-184.
- Last, P. R., Scott, E.O.G. & Talbot, F.H. (1983). Fishes of Tasmania. Tasmania, Australia. Tasmanian Fisheries Development Authority
- Lloret, J., Palomera, I., Salat, J. & Sole, I. (2004). Impact of freshwater input and wind on landings of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in shelf waters surrounding the Ebre (Ebro) River delta (north-western Mediterranean). Fisheries Oceanography 13: 102-110.
- Macadam, I., Ricketts, J. & Bathols, J. (2008). Climate Change Projections for the Western Port Region. Impacts of Climate Change on Human Settlements in the Western Port Region: An Integrated Assessment, CSIRO Marine and Atmospheric Research.
- McCutcheon, C. (2008). Winter foraging areas of Little Penguins. Burwood, Deakin University. B.Sc(Hons).
- McInnes, K., Macadam, I., Hubbert, G., O'Grady, J. and Abbs, D. (2007). Assessing the impact of climate change on extreme sea levels, CSIRO Marine and Atmospheric Research.
- McInnes, K. L., Macadam, I. and O'Grady, J. (2008). Effect of Climate Change on Extreme Sea Levels in the Western Port Region. CSIRO Marine and Atmospheric Research. Impacts of Climate Change on Human Settlements in the Western Port Region: An Integrated Assessment.
- Middleton, J. F., Cirano M (2002). A northern boundary current along Australia's southern shelves: the Flinders Current. J Geophys Res C 107: 3129.
- Nicholls, N., Lavery, B., Frederiksen, C.S., Drosowsky, W., Torok, S.J. (1996). Recent apparent changes in relationships between the El Nino – Southern Oscillation and Australian rainfall and temperature. Geophysical Research Letters 23: 3357-3360.

- Perry, A. L., Low, P.J., Ellis, J.R. & Reynolds, J.D. (2005). Climate change and distribution shifts in marine fishes. Science 308: 1912–1915.
- Poloczanska, E. S., R.C. Babcock, A. Butler, A.J. Hobday, O. Hoegh-Guldberg, T.J. Kunz, R. Matear, D. Milton, T.A. Okey & A.J. Richardson (2007). Climate change and Australian marine life. Cleveland, CRC Press.
- Pörtner, H. O., Langenbuch, M. & Reipschläger, A. (2004). Biological impact of elevated ocean CO<sub>2</sub> concentrations: lessons from animal physiology and earth history. Journal of Oceanography 60: 705–718.
- Pyper, W. (2007). Preparing for sea-level rise. Ecos 137: 14-17.
- Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., Shepherd, J., Turley, C. & and A. Watson (2005). Ocean Acidification due to Increasing Atmospheric Carbon Dioxide. London: Royal Society Special Report.
- Reilly, P. N. & Cullen, J. M. (1982). The Little Penguin *Eudyptula minor* in Victoria III. Dispersal of chicks and survival after banding. Emu 82: 137-142.
- Reilly, P. N. & Cullen, J. M. (1983). The Little Penguin *Eudyptula minor* in Victoria, IV: The moult. Emu 83: 94-98.
- Renwick, L., Dann, P. and Thompson, S. (2007). Effect of fire on Little Penguins at Seal Island, south-eastern Australia. 6th International Penguin Conference Abstracts.
- Ropert-Coudert, Y., Cannell, B. and Kato, A. (2004). Temperature inside nest boxes of Little Penguins. Wildlife Society Bulletin 32: 177-182.
- Rose, G. A. (2005a). On distributional responses of North Atlantic fish to climate change. ICES Journal of Marine Science 62: 1360–1374.
- Rose, G. A. (2005b). Capelin (*Mallotus villosus*) distribution and climate: a sea 'canary' for marine ecosystem change. ICES Journal of Marine Science 62: 1524–1530.
- Short, F. T., Neckles, H.A. (1999). The effects of global climate change on seagrasses." Aquatic Botany 63:169-196.
- Sidhu, L. (2007). Analysis of Recovery-Recapture data for Little Penguins. School of Physical, Environmental and Mathematical Sciences. Canberra, The University of New South Wales, Australian Defence Force Academy. PhD.
- Sidhu, L. A., Catchpole, E. A. and Dann, P. (2007). Mark-recapture-recovery modelling and age-related survival in Little Penguins *Eudyptula minor*. Auk 124: 815-827.
- Stahel, C. and R. Gales (1987). Little penguins : fairy penguins in Australia. Australia, New South Wales University Press.
- Suppiah, R. (2004). Trends in the southern oscillation phenomenon and Australian rainfall and changes in their relationship. International Journal of Climatology 24: 269-290.
- Thresher, R. E., Nichols, P.D., Gunn, J.S., Bruce, B.D. & Furlani, D.M. (1992). Evidence for microbial production based on seagrass detritus supporting a planktonic food chain. Limnology and Oceanography 37: 1754–1758.
- Welsford, D. C. L., J.M. (2003). Redbait (*Emmelichthys nitidus*): a synopsis of fishery and biological data. TAFI Technical Report 20, Tasmania, Australia.
- Winstanley, R. H. (1979). Pilchard and anchovy. CSIRO Fisheries Situation Report, CSIRO, Cronulla.
- Yom-Tov, Y., Wilson, R. and Amos A. R. (1986). Water loss from Jackass Penguin *Spheniscus demersus* eggs during natural incubation. Ibis 128.

## APPENDIX 1.

### DETAILS OF “FUTURE COASTS” PROJECT

#### *Future Coasts*



Future Coasts is a major project of the Victorian Government to assess the physical vulnerability of Victoria's coast to climate change, and develop strategies to help communities and industry respond and adapt. Laser imaging and digital elevation modelling (DEM) are used in Future Coasts to provide high resolution 3D representations of the land and sea floor. Land based data for Phillip Island will be available in February 2009.

This image is an example of a 3D visualisation of a DEM based on Phillip Island. This image is produced by laying a photograph of Phillip Island over the DEM.

This information will be combined with modelling sea level rise, storm surge, inundation and erosion to identify how the coastline is likely to change over time. This will inform where longer-term adaptation work should be focused and aid decision making. The final package of outcomes from Future Coasts will include a geographic information systems (GIS) tool which will help identify areas along the Victorian coastline which are at greatest risk from sea level rise and storm surge

---



## APPENDIX 2



# Effect of fire on Little Penguins at Seal Island, south-eastern Australia



Leanne Renwick<sup>1</sup>, Peter Dann<sup>1</sup> & Sally Thompson<sup>2</sup>

<sup>1</sup> Research Department, Phillip Island Nature Parks, PO Box 97, Cowes, Vic 3922, Australia

<sup>2</sup> School of Life and Environmental Sciences, Deakin University, Melbourne

### Introduction

On 24<sup>th</sup> October 2005, lightning started a fire on Seal Island, Victoria. Seal Island is an important breeding site for seabirds, including Little Penguins. The fire burnt 90% of the island before it was extinguished on 28<sup>th</sup> October by Phillip Island Nature Parks (PINP) staff and volunteers. We examined the impact of the fire on the penguins.

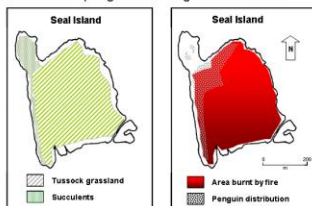


### The island

Vegetation: 90% Tussock grassland (*Poa poiformis*), 10% is dominated by succulents. Penguin burrow density is highest in the tussocks. Penguin population: Was estimated in 1992 at 560 - 720 burrows (Dann, unpublished data), giving a breeding population of c.1120 - 1440 individuals.

### The fire

95% of tussock grassland was burnt, the fragments that remained unburnt were due to the efforts of PINP staff in halting the fire. Succulent vegetation and penguins in these areas were largely unaffected. Most Little Penguins were incubating. ~ 90% of the penguin breeding area was burnt.



### Penguin behaviour

Responses of the penguins to the fire were surprisingly inappropriate and maladaptive. Birds did not avoid the fire. Many remained in their burrows where they died. Penguins were observed standing beside flames preening singed feathers rather than moving away.



Penguin killed in burrow under *Poa* tussock

### Immediate effects

On 28<sup>th</sup> October, we recorded 185 dead and 90 live penguins. Most (63%) dead penguins sexed were female, probably because the fire coincided with the main egg-laying period, when females are more prevalent at Little Penguin colonies. Most live penguins suffered debilitating injuries including burns to the feet and legs, singed feathers and blistered skin, swollen eyes, and many had difficulty breathing. Most would not have survived. Live penguins were mostly gathered under rocks at the water's edge. Presumably, they had tried to leave on feeding trips but returned as they were not water-proof or had walked over smouldering ground after coming ashore and had sustained burns to their feet and legs.



Penguin with severe burns

### Impact on the breeding population

On 8<sup>th</sup> September, 2 x 20m wide transects (one around the edge of the island and the other through the centre) were performed to count dead penguins.

Including those recorded dead on 28<sup>th</sup> October, we estimated there were at least 371 dead penguins present, 26 - 33% of the breeding population.

More are likely to have died at sea, due to injuries received, and others would have been buried in collapsed burrows.

Almost all burrows in the burnt tussock grassland were destroyed. Burrow structure relied on the tussocks and humus in the soil. With this removed, the soil was gravel like and impossible for penguins to burrow into.

In Jan 2007, we recorded occupied nests at three previously established research sites, which were adjacent to the area that could be protected. Where 26 burrows were evident in Nov. 1996, there were 6 burrows in Jan. 2007.



	Total used burrows in study area pre-fire & post-fire		
	Site3	Site2	Site1
pre-fire (Nov 1996)	8	9	9
post-fire (Jan 2007)	1	3	2

### Conclusion

Fires, either natural or otherwise, occur occasionally on islands in Bass Strait and seabirds typically suffer 'heavy casualties'<sup>1,2,3,4</sup>. Our observations demonstrate that penguins are particularly vulnerable to fire in their breeding habitat.

Fires in the breeding season, when the greatest numbers of birds are ashore, are particularly devastating. In this case, the fire's impact was increased because it coincided with the peak egg-laying period.

The immediate impact of the Seal Island fire was to kill an estimated 1/3<sup>rd</sup> of the breeding population, to injure at least a further 10% and to disrupt breeding of those that survived. An additional consequence was the destruction of breeding sites in the tussock grassland which will take several years before they return to pre-fire quality. The longer term consequences of this fire on the population is yet to be determined.

Should we intervene in fire events in seabird colonies?

- from an animal welfare perspective- yes
- from a wildlife management perspective- yes, particularly if the fire is anthropogenic in origin
- from an ecological perspective- uncertain, until long-term effect of fire on population size is determined



Tussock habitat destroyed by fire



New growth on *Poa* tussock only 11 days after fire

### References

- Brothers, N. & Harris, S. 1999: The effects of fire on burrow-nesting seabirds particularly short-tailed shearwaters (*Puffinus tenuirostris*) and their habitat in Tasmania. *Pap. Proc. R. Soc. Tasm.* 133(1): 15-22.
- Brothers, N., Pemberton, D., Pryor, H. & Halley, V. 2001: Tasmania's Offshore Islands: seabirds and other natural features; Tasmanian Museum and Art Gallery, Hobart.
- Harris, M.P. & Deerson, D.M. 1980: Seal Island, Seal Islands Group, Victoria - Seabird Island No. 82. *Corella* 4:69-70.
- White, G. 1980. Islands of South-west Tasmania; G. White, Sydney.

### Acknowledgements

Thanks to PINP staff and volunteers who helped with the fire and penguins at Seal Island, and to Roger Kirkwood for supplying the photos.

## APPENDIX 3

### PROPOSAL FOR HONOURS STUDENT PROJECT: EFFECT OF BURROW TEMPERATURE AND HUMIDITY ON BREEDING SUCCESS - IMPLICATIONS OF CLIMATE CHANGE

#### Aims:

- Measure variation in nest temperature and humidity during breeding period
- Determine relationships between temperature & humidity with location (north vs south sides of the Summerland Peninsula), habitat, substrate and breeding success
- Determine if any long-term trends in temperatures and breeding success (41 year data set)
- Implications for climate change
- Design optimal nesting box for penguins (insulation & ventilation)

#### Background

Both burrow temperature and humidity effect hatching success in birds and many environmental and individual variables influence the microclimate of penguin burrows, such as vegetation type and cover, substrate type, aspect, burrow type, as well as synchronisation of parental behaviour and parental experience. Microclimate may also have an effect on chick growth and survival. Heat stress occurs in chicks and adults in particularly hot weather and adults must expend energy to thermoregulate in ambient temperatures over 27 degrees. The PINP have 41 years of data on breeding success and the opportunity exists to examine long-term relationships with air temperatures and relative humidity over this period. Internal temperatures of penguin nest boxes may be manipulated through insulation (Jessop and Dann, in prep.) and ventilation (Ropert-Coudert *et al.* 2004). A practical outcome of this project will be the production of specifications for an artificial penguin burrow with an optimal microclimate.

#### Methods

- Measure the temperatures and humidity in 20 natural burrows (10-Poa grassland, 10 – Succulent herbfield) in each of two areas (northern and southern sites) for whole period of breeding
- Measure ambient temperature and humidity at both sites
- Measure hatching and fledging success in all burrows
- Air temperature and relative humidity from Rhyll Meteorological Station

#### Personnel

Dr Peter Dann- Research Department, Phillip Island Nature Park  
Dr John Arnould- Deakin University  
Ashton Marsh, Honours student – Deakin University

#### Outputs

Honours thesis  
Design for optimal penguin burrow  
Paper in peer-reviewed journal  
Presentation at International Penguin Conference in 2010 in Boston

#### References

Jessop, R. and Dann, P. (in prep.). A comparison of breeding success and burrow fidelity between Little Penguins *Eudyptula minor* nesting in artificial and natural burrows

Ropert-Coudert, Y., Cannell, B. and Kato, A. (2004). "Temperature inside nest boxes of Little Penguins." Wildlife Society Bulletin **32**: 177-182.

## **APPENDIX 4**

### **MEDIA & EDUCATION ASSOCIATED WITH THE PROJECT**

NBC Today Show (USA audience 9 million) - potential impacts of climate change on Little Penguins

Central Coastal Board (Victoria) – talk on climate change implications for Little Penguins

ABC Drive Melbourne & Sydney – general discussion about current and future prospects for Little Penguins including climate change

Southern Cross TV network- studio interview and general discussion on potential effects of climate change on penguins and marine ecosystems

Information talks to Penguin Foundation, Phillip Island Nature Park staff including Parade rangers, environment department and education team.

---

The potential impacts of climate change on the Phillip Island Little Penguin colony - regional economic impacts

---

A report prepared for the Westernport Greenhouse Alliance

Draft: 7 November 2008  
Edited: 27 March. 2009

Marsden Jacob  
*Associates*

Marsden Jacob Associates  
Financial & Economic Consultants

ABN 66 663 324 657  
ACN 072 233 204

Internet: <http://www.marsdenjacob.com.au>  
E-mail: [economists@marsdenjacob.com.au](mailto:economists@marsdenjacob.com.au)

Postal address: Level 3, 683 Burke Road, Camberwell  
Victoria 3124 AUSTRALIA  
Telephone: (03) 9882 1600 International: +61 3 9882 1600  
Facsimile: (03) 9882 1300 International: +61 3 9882 1300

Author: Kym Whiteoak [kym.whiteoak@marsdenjacob.com.au](mailto:kym.whiteoak@marsdenjacob.com.au)

This report may be cited as: Marsden Jacob Associates. 2008. The potential impacts of climate change on the Phillip Island Little Penguin colony - regional economic impacts.

Copyright © Marsden Jacob Associates Pty Ltd 2008

This report has been prepared in accordance with the scope of services described in the contract or agreement between Marsden Jacob Associates Pty Ltd ACN 072 233 204 (MJA) and the Client. Any findings, conclusions or recommendations only apply to the aforementioned circumstances and no greater reliance should be assumed or drawn by the Client. Furthermore, the report has been prepared solely for use by the Client and Marsden Jacob Associates accepts no responsibility for its use by other parties.



*Financial & Economic Consultants*

*Level 5, 100 Eagle Street, Brisbane, Queensland 4000*

*Tel: (07) 3229 7701, Fax: 07 32297944*

*Email: [economists@marsdenjacob.com.au](mailto:economists@marsdenjacob.com.au)*

## TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY .....	55
1. INTRODUCTION.....	60
1.1. STUDY PURPOSE.....	60
1.2. PHILLIP ISLAND AND BASS COAST SHIRE TOURISM ECONOMY.....	60
2. APPROACH .....	62
2.1. REGIONAL ECONOMIC IMPACT ASSESSMENT .....	62
2.2. TOURISM SCENARIOS UNDER CLIMATE CHANGE.....	63
2.3. ECONOMIC FLOW-ON.....	66
3. RESULTS: ECONOMIC IMPACT OF REDUCED TOURISM.....	67
3.1. SCENARIO 1 .....	67
3.2. SCENARIO 2 .....	67
3.3. SCENARIO 3 .....	68
3.4. CONCLUSIONS .....	68
ATTACHMENT 1: ECONOMIC IMPACT ANALYSIS – TECHNICAL DOCUMENT .....	70

## **Executive Summary**

### **Introduction**

The impacts of climate change on the Little Penguin population of Phillip Island could have repercussions for the Phillip Island economy, and that of the Bass Coast Shire more broadly.

While tangible data on the direct impacts of climate change on the Little Penguin population has not yet been gathered, it is possible to explore the economic impacts that might occur should climate change-induced population decline occur. For this, a number of hypothetical economic impact scenarios have been modelled.

### **Phillip Island and Bass Coast Shire tourism economy**

The penguin population contributes to a strong and viable tourism industry on the island. Tourist visitation for the penguins underpins not just the activities of Phillip Island Nature Parks, but also flows on to the rest of the local economy, as the park employs local workers and visitors spend tourism dollars in the local area.

Of the more than 1000 businesses in the Shire, over half benefit directly from tourism. Tourism businesses<sup>1</sup> account for one quarter of total businesses, and a further third of businesses directly benefit from tourist visitation (on average, one quarter of their income is derived from tourists).

Tourism in the area is synonymous with Phillip Island, receiving over 2 million visitors in 2007.<sup>2</sup> A survey undertaken in 2004/05 found that 94 per cent of visitors to the shire visited the Island. Some 80 to 90 per cent of respondents considered Phillip Island their primary destination and 69 per cent considered it their only destination.<sup>3</sup>

### **Approach to assessing regional economic impacts**

This study reports the findings of a regional economic impact assessment on the Bass Coast Shire economy. The study explores the potential economic impacts on the shire of a decline in tourist visitation to Phillip Island associated with climate change-induced impacts on the Little Penguin population.

Economic impact assessment, as distinct from an assessment of 'economic value', provides high level insight into the economic significance of an event, attraction or industry (in this case the penguin colony of Phillip Island Nature Park). The measure of economic impact focuses just on the Bass Coast Shire and estimates the net economic loss to the shire due to the loss of economic activity associated with the penguins. As such, it uses visitation from outside the shire and attributes an economic expenditure to that visitation.

---

<sup>1</sup> These are businesses that cater almost exclusively for tourists, including visitor accommodation, wineries, attractions, tours and activities, restaurants. Data from Urban Enterprise, 2005.

<sup>2</sup> Tourism Research Australia This data does not include international day visitors, numbering up to 300,000 per year.

<sup>3</sup> Urban Enterprise, 2005.

In 2007/08, a total of 491,780 people visited the Nature Park to see the penguin parade. Of these, 308,465 were international tourists and 183,315 were Australian visitors. Of the Australian visitors, an estimated 178,796 were from outside the Bass Coast Shire.<sup>4</sup>

Relevant expenditure is assumed to be the average day visit to the Shire for domestic visitors and the average expenditure per night for international visitors.<sup>5</sup> (Table ES.1)

Table ES.1 : Visitor expenditure related to the penguin population, 2007/08

Visitor type	Visitor numbers	Expenditure per visitor (\$)	Total expenditure (\$ m)
Domestic day visitors	178,796	86	\$15.4
International visitor (night)	308,465	64	\$19.7
Total	487,251		\$35.1

Source: Visitor numbers - Phillip Island Nature Park (visitors from outside Bass Coast Shire); expenditure - Tourism Research Australia<sup>6</sup>

Flowing this data through the non-linear input-output model<sup>7</sup> provides the following result.

Table ES.2: Economic impact of visitors to the penguin parade

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	35.2	14.7	17.0	31.7	66.9
Value added (\$ m)	24.9	7.2	8.1	15.3	40.2
Factor income (\$ m)	16.5	2.8	3.5	6.4	22.9
Employment (FTEs)	74	22	30	62	136

Source: MJA estimates.

The annual economic impact of penguin visitation therefore has:

- a total gross output effect of \$66.9 m - made up of a direct effect of \$35.2 m and a flow-on (indirect) effect of \$31.7 m. Gross output refers to the value of increased production from penguin related tourism;
- a total value-added effect of \$40.7 m - made up of a direct effect of \$24.9 m and a flow-on (indirect) effect of \$15.3 m. Value-added is the measure usually preferred when

<sup>4</sup> Source: all data from Phillip Island Nature Parks. Estimation of local visitors: MJA analysis.

<sup>5</sup> International visitation per night is the only estimate available (no data exists on day visits), and the difference between domestic day visits and visitation per night was \$2.

<sup>6</sup> <http://www.tra.australia.com/content/documents/LGA%20Profiles/VIC/BassCoast%20LGA.pdf>

<sup>7</sup> The non-linear input-output (NLIO) model is designed by Professor John Mangan from the University of Queensland's Economic Policy Modelling Centre.



measuring economic impact. It measures the added value placed on intermediate products from the productive process;

- a factor income effect of \$22.9 m - made up of a direct effect of \$16.5 m and a flow-on (indirect) effect of \$6.4 m. Factor income refers to the share of value-added which is directly paid to individuals or firms in the form of wages or profits; and
- an employment effect of 136 Full -Time Equivalents (FTEs) - made up of 74 FTEs directly employed and 62 FTEs indirectly employed.

#### Tourism scenarios under climate change

As noted, the impacts of climate change on the penguin population have not been detailed as yet. Nor has the impact on tourism of penguin population decline.<sup>8</sup> Although reduced penguin numbers are likely to result in reduced visitation, this relationship is unlikely to be linear. Indeed, it is hypothesised in this study that a significant decline in visitation is unlikely to occur until such time as tourism operators are unable to guarantee penguin sightings on any given night.

Three scenarios have been developed to hypothesise tourism decline, and the resulting economic impacts modelled. Scenario 1 models a small penguin population decline, with no notable change in economic impact. Scenario 2 involves significant population decline with similar economic impacts while Scenario 3 models extreme population decline and associated visitation. These scenarios are summarised in Table ES.3.

Table ES.3 : Hypothetical scenarios for decreased visitation

Scenario	Features	Impact on visitation
Scenario 1 Small population decline	Climate change causes population decline, but penguin parade continues every night.	Negligible change. Domestic and international tourism continues.
Scenario 2 Large reduction in population	Population declines significantly, causing penguin sightings to become sporadic during winter months	Park closure to the public for winter months. International visitation suffers significant decline (50%) as tours remove penguins from itinerary. Domestic visitation declines during winter months only (30%).
Scenario 3 Extreme reduction in population	Population declines dramatically, causing sporadic penguin sightings year-round and rare sightings during winter months	International visitation collapses (90%) and domestic visitation dramatically reduced (80%). Viability of tourism threatened.

Source: MJA analysis

<sup>8</sup> Information on the impact of climate change on the penguin population would require detailed scientific study. A detailed understanding of the impacts on penguin numbers on visitation numbers would require detailed survey work to establish consumer preferences. Both these areas are outside the scope of this study, but could be undertaken for future work.

## Conclusions

The differing economic impacts of the three scenarios are summarised in Table ES.4. Differences in economic impacts compared with the status quo (Scenario 1) are shown in

Table ES.5.

As can be seen in Table ES.4 and

Table ES.5, Scenario 2 involves a sizeable decrease in economic activity once tourism is affected noticeably by penguin population decline. This involves a decline in direct economic output of \$14.5m per year, and with flow-on, a decrease in total gross output of \$28.6m per year. The decrease in direct value-added associated with Scenario 2 is \$11m per year, and with flow-on, \$18m per year. Total employment loss in the Bass Coast Shire (direct and indirect) is estimated at 66 full-time jobs.

Table ES.4: Economic impacts summary table, scenarios 1-3

	Direct Demand			Flow-on			Total Demand		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Gross output (\$ m)	35.2	20.7	5.1	31.7	17.6	4.6	66.9	38.3	9.7
Value added (\$ m)	24.9	13.9	3.5	15.3	8.5	2.1	40.2	22.4	5.6
Factor income (\$ m)	16.5	9.2	2.3	6.4	3.5	0.9	22.9	12.7	3.2
Employment (FTEs)	74	41	10	62	29	8	136	70	18

Source: MJA estimates.

Scenario 3, involving more extreme penguin population decline, is modelled to have more dramatic impacts on associated tourism. This involves a decline in direct economic output of \$30m per year, and with flow-on, a decrease in total gross output of \$57m per year. The decrease in direct value-added associated with Scenario 3 is \$21.4m per year, and with flow-on, \$34.6m per year. Total employment loss (direct and indirect) is estimated at 118 full-time jobs.

Table ES.5: Economic impacts difference table, scenarios 1-3

	Direct Demand			Flow-on			Total Demand		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Gross output (\$ m)	35.2	-14.5	-30.1	31.7	-14.1	-27.1	66.9	-28.6	-57.2
Value added (\$ m)	24.9	-11.0	-21.4	15.3	-6.8	-13.2	40.2	-17.8	-34.6
Factor income (\$ m)	16.5	-7.3	-14.2	6.4	-2.9	-5.5	22.9	-10.2	-19.7
Employment (FTEs)	74	-33	-64	62	-33	-54	136	-66	-118

Source: MJA estimates. Differences are relative to S1

MJA stresses that these scenarios are purely hypothetical. They have been compiled in the absence of detailed understanding of the likely impacts on penguin population of climate change and without survey analysis of visitor preferences relating to penguin tourism.

Further work in these areas could establish a more robust understanding of the regional economic impacts of climate change on the Phillip Island Little Penguin colony.

## 1. Introduction

### 1.1. Study purpose

The Phillip Island penguin population contributes to a strong and viable tourism industry on the island. Tourist visitation for the penguins underpins not just the activities of Phillip Island Nature Parks, but also flow-on effects to the rest of the local economy as the parks employ local workers and visitors spend tourism dollars in the local area.

Where climate change affects the future of the penguin population of Phillip Island, so too will it affect tourist visitation and the broader local economy. This report explores scenarios relating to a decrease in tourism visitation as a result of climate change affecting the penguin population.

### 1.2. Phillip Island and Bass Coast Shire tourism economy

The Bass Coast Shire has a large and active tourism sector, attracting holiday home visitors, other overnight visitors and day trippers. Visitors staying in holiday homes account for the vast majority of overnight visitors (82 per cent)<sup>9</sup>, and contribute around half of total visitor expenditure to the shire.<sup>10</sup> Despite this, the majority of visitors to the shire visit for the day.

Of the more than 1000 businesses in the shire, over half benefit directly from tourism. Tourism businesses<sup>11</sup> account for one quarter of total businesses, and a further third of businesses directly benefit from tourist visitation (on average, one quarter of their income is derived from tourists).

Tourism in the area is synonymous with Phillip Island, receiving over 2 million visitors in 2007.<sup>12</sup> A survey undertaken in 2004/05 found that 94 per cent of visitors to the shire visited the island. Some 80 to 90 per cent of respondents considered Phillip Island their primary destination and 69 per cent considered it their only destination.<sup>13</sup>

Phillip Island is home to the key tourist attractions in the shire. Almost 500,000 visitors attended the Penguin Parade in 2007/08<sup>14</sup>, while the Australian Motor Cycle Grand Prix attracted approximately 93,531 in 2006.<sup>15</sup>

---

<sup>9</sup> <http://www.tra.australia.com/content/documents/LGA%20Profiles/VIC/BassCoast%20LGA.pdf>

<sup>10</sup> Urban Enterprise, 2005. Bass Coast Shire, Economic Impact of Tourism. P.6

<sup>11</sup> These are businesses that cater almost exclusively for tourists, including visitor accommodation, wineries, attractions, tours and activities, restaurants. Data from Urban Enterprise, 2005.

<sup>12</sup> Tourism Research Australia. This data does not include international day visitors, numbering up to 300,000 per year.

<sup>13</sup> Urban Enterprise, 2005.

<sup>14</sup> 491,780 visitors to the Penguin Parade were recorded in 2007//08, a further 140,878 to the Koala Conservation Centre and 75,215 to Churchill Island.

<sup>15</sup> Bass Coast Shire Council, Phillip Island Community Profile  
<http://www.basscoast.vic.gov.au/content/content.asp?cid=472&ctid=1&cnid=2471#> (accessed 25.06.2008)

As a proportion of Bass Coast tourism, Phillip Island has:

- almost 60 per cent of holiday homes;
- over half of all specialised tourism businesses;
- around 83 per cent of all guest rooms in accommodation establishments; and
- around 86 per cent of all camping sites.<sup>16</sup>

Tourism's share of total employment is on Phillip Island 8.2 per cent, whereas for the State of Victoria tourism represents 5.1 per cent of total employment.<sup>17</sup> The Australia Victorian Tourism Employment Atlas 2005 states:

Phillip Island is the second highest tourism intensive campaign region in Victoria with one in twelve jobs attributable to tourism. Major developments which partly contributed to this growth were improved quality accommodation and Phillip Island Nature Park.

Of the 116 specialised tourism businesses (excluding accommodation) in the shire, 56 per cent are found on Phillip Island. They employ over 1000 people.

Phillip Island tourism is largely synonymous with its penguin population. In the survey noted above, 'Penguins and Australian fauna' was the most common characteristic associated with Phillip Island, and 67 per cent of respondents visited the penguin parade.

In terms of marketing, the natural wildlife within the Bass Coast Shire and the ocean beaches should continue to be a focus for marketing campaigns. Natural fauna is responsible for attracting the majority of visitors to the region.<sup>18</sup>

The penguin colony has become the centrepiece of a growing nature-based tourism sector in the region, as Phillip Island Nature Parks has added the Koala Conservation Centre and the Nobbies Centre featuring seals, sharks and dolphins.

Phillip Island Nature Parks now employs almost 200 people, with total operating revenue of almost \$14m in 2007/08.<sup>19</sup>

While not directly addressed in this analysis, it is worth noting that the growing nature-based tourism industry in the area, underpinned by the penguin colony, is a large contributor to the holiday home tourism market, in terms of demand for visits to the area and overall awareness of the area.

---

<sup>16</sup> Urban Enterprise, 2005. P.19

<sup>17</sup> Australia Victorian Tourism Employment Atlas 2005

<sup>18</sup> Urban Enterprise, 2005. P.100

<sup>19</sup> Phillip Island Nature Parks.

## **2. Approach**

### **2.1. Regional economic impact assessment**

This study reports the findings of a regional economic impact assessment on the Bass Coast Shire economy. The study explores the potential economic impacts on the shire of a decline in tourist visitation to Phillip Island associated with climate change-induced impacts on the little penguin population.

Economic impact assessment, as distinct from an assessment of 'economic value', provides high level insight into the economic significance of an event, attraction or industry (in this case the penguin colony of Phillip Island Nature Park). It provides a broad indication of the importance of ongoing operations to the regional economy by estimating the contribution of the penguin population in attracting visitors to the Bass Coast Shire.

The study does not estimate the 'economic value' of the penguin population to Victoria or Australia, which measures the net addition to the economy that is attributable to the penguin population. A study of this kind would measure the 'consumer surplus', reflecting the difference between actual expenditure and what consumers would be willing to pay.

A decline in tourism associated with changes to the penguin population does not mean that an equivalent expenditure is not made elsewhere in the Victorian economy. If the penguin population did not exist, a family might choose to visit a different nature-based tourism attraction elsewhere, or spend their money on home-based entertainment – something they would have preferred slightly less. A measure of net economic value would measure the change in consumer surplus associated with this loss.

The measure of economic impact focuses just on the Bass Coast Shire, and estimates the net economic loss to the shire if the economic activity associated with the penguins was lost. It uses visitation data from outside the shire and attributes an economic expenditure to that visitation.

#### **Visitor numbers**

In 2007/08, a total of 487,251 people visited the Nature Park to see the penguin parade. Of these, 308,465 were international tourists and 183,315 were Australian visitors. Of the Australian visitors, an estimated 178,796 were from outside the Bass Coast Shire.<sup>20</sup> As this study focuses on the impact of visitation to the region from outside the local area we exclude locals attending the penguin parade.

#### **Expenditure estimates**

For this assessment, Tourism Research Australia estimates for average expenditure have been applied to domestic and international visitor numbers to the Nature Park.

As such, this study assumes that for those who visit the Nature Park from outside the shire, the penguins are the primary incentive for their visit to the shire on that day. This will tend to overestimate the expenditure of those for whom the penguins were not the major reason for their visit and underestimate those who may have come for the penguins and stayed longer than one day.

---

<sup>20</sup> Source: all data from Phillip Island Nature Parks. Estimation of local visitors: MJA analysis.

Expenditure related to the penguins is assumed to be the average day visit expenditure to the shire for domestic visitors and the average expenditure per night for international visitors.<sup>21</sup>

Table 1 : Visitor expenditure related to the penguin population, 2007/08

Visitor type	Visitor numbers	Expenditure per visitor (\$)	Total expenditure (\$ m)
Domestic day visitors	178,796	86	\$15.4
International visitor (night)	308,465	64	\$19.7
Total	487,251		\$35.1

Source: Visitor numbers - Phillip Island Nature Park (visitors from outside Bass Coast Shire); expenditure - Tourism Research Australia<sup>22</sup>

## 2.2. Tourism scenarios under climate change

The aim of this project is to assess the possible impacts on the local economy associated with a negative impact of climate change on the penguin population of Phillip Island. It may be that climate change or climate change responses affect visitation by other means, such as through increasing petrol prices (due to an emissions trading scheme, for example). However, impacts of this nature are beyond the scope of this study and we restrict ourselves to analysing the impact of climate change on the penguin population itself and, through this, to visitor numbers.

Visitation to the region associated with the penguins is dependent upon a healthy penguin population, sustainable interaction between visitors and penguins and appropriate infrastructure to facilitate viewing. Clearly, infrastructure should facilitate viewing without adversely affecting sustainability of the interaction. Indeed, visitors are informed that their presence helps to improve the penguins' health by assisting the research program.

Therefore, the only remaining influence on penguin visitation within the scope of this project is the health and viability of the penguin population itself.

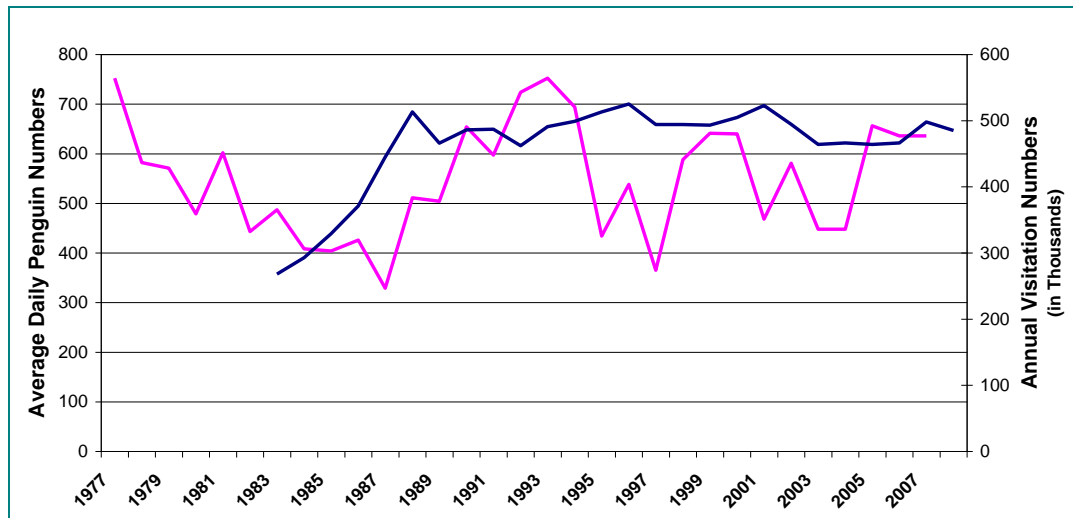
There is no clear relationship between healthy penguin numbers and visitor numbers over time.

Figure 1 shows the relationship between penguin numbers and visitor numbers since 1978, with the pink line representing average daily penguin sightings, and the blue line representing annual visitors (on the right hand axis). Clearly, visitor numbers have moved independently of average penguin numbers as the tourist attraction has matured into the professional project it is today. In recent years, as a mature industry, annual visitor numbers have been relatively stable.

<sup>21</sup> International visitation per night is the only estimate available (no data exists on day visits), and the difference between domestic day visits and visitation per night was \$2.

<sup>22</sup> <http://www.tra.australia.com/content/documents/LGA%20Profiles/VIC/BassCoast%20LGA.pdf>

Figure 1: Average daily penguin sightings and annual visitation numbers



MJA has developed plausible but hypothetical scenarios for visitation based on realistic assumptions about the penguin population of Phillip Island and its relationship with visitation. MJA stresses that these scenarios are based on assumptions, and providing statistical data would require detailed survey work beyond the scope of this study.

In general, sightings of penguins are more frequent during the summer months than the winter months, although in late summer (February/March) there is a short dip in penguin numbers at the parade.

It is reasonable to suggest that the continued viability of penguin visitation is dependent upon consistent penguin sightings year-round. Anecdotal evidence suggests that consistent viewing year-round is a prerequisite for the present scale of international visitation, as package tours will be reluctant to book visitors if they cannot guarantee penguin sightings.<sup>23</sup>

This is expected to be less of a problem for domestic visitation. Living locally, if penguin sightings in February/March and the winter months became sporadic,<sup>24</sup> domestic visitors could plan their trip in the summer months without undue inconvenience.

MJA is unable to predict the scale of penguin population decline that would lead to sporadic sightings of penguins at the daily parade. This would require detailed biophysical modelling that is beyond the scope of this project, but could be considered for further work if possible.

However, MJA has devised scenarios in which penguin population declines so as to affect visitation, primarily due to population decline occurring to an extent that sightings of penguins cannot be guaranteed year-round. Where this occurs, seasonal park closures occur and international tourism is especially affected as tours begin to drop the Nature Park from their itinerary.

<sup>23</sup> The failure of a small penguin tourism operation in Western Australia was in large part attributed to the small size of the penguin population, resulting in the inability to guarantee daily viewing of penguins (Pers. Comm Peter Dann, Research Manager, Phillip Island Nature Parks).

<sup>24</sup> Penguin numbers are lower in February/March during 'pre-moult' foraging trips, and during winter due to long foraging trips (Pers. Comm Peter Dann, Research Manager, Phillip Island Nature Parks).



Three hypothetical scenarios are outlined in Table 2. The first scenario reflects impacts on the penguin population such that penguin numbers decline, but not to an extent that results in no penguins being sighted. In this scenario, tourism is unaffected, based on the assertion that visitation will continue until penguin sightings can no longer be guaranteed.

In the second hypothetical scenario, the penguin population declines to the point that sightings of penguins during the winter months can no longer be guaranteed. In this scenario, domestic visitation declines especially over these months, and international visitation declines significantly as tours begin to remove the penguin parade from their itineraries. This is likely to cause the closure of commercial activities during the winter months, and significantly reduce international visitation year-round. Tours targeting international visitors are considered unlikely to retain the penguin parade on their itineraries if they are unable to guarantee visitors penguin viewing, resulting in a significant decline in international visitation.

The third scenario is a more dire one in which penguin numbers decline to the extent that penguin viewing is uncertain year-round, causing a dramatic decrease in domestic visitation (80 per cent) and the even greater loss of international visitation (90 per cent). International visitation is considered more vulnerable than domestic, as local visitors have lower opportunity costs associated with ‘gambling’ on penguin sightings. Unlike most domestic visitors, international visitors have less time in Victoria and would be less willing to travel if they are not certain of seeing penguins.

Table 2 : Hypothetical scenarios for decreased visitation

Scenario	Features	Impact on visitation
Scenario 1 Small population decline	Climate change causes population decline, but penguin parade continues every night.	Negligible change. Domestic and international tourism continues.
Scenario 2 Large reduction in population	Population declines significantly, causing penguin sightings to become sporadic during winter months	Park closure to the public for winter months. International visitation suffers significant decline (50%) as tours remove penguins from itinerary. Domestic visitation declines during winter months only (30%).
Scenario 3 Extreme reduction in population	Population declines dramatically, causing sporadic penguin sightings year-round and rare sightings during winter months	International visitation collapses (90%) and domestic visitation dramatically reduced (80%). Viability of tourism threatened.

Source: MJA analysis

MJA stresses that this is a consequence analysis only, in which the likelihoods of scenarios are not assessed. A likelihood analysis of the scenarios described in Table 2 is beyond the scope of this project, but may be considered for further work. The consequences are themselves considered realistic as broad scenarios, but are not based on detailed analysis. Furthermore, these scenarios are hypothetical and are not projections. More rigorous scenario work involving consumer surveys could be considered for further work. Sensitivity analysis of these scenarios is found in the Attachment.

### 2.3. Economic flow-on

Visitor expenditure figures do not provide a measure of the total economic impact of tourism attributable to public open space; there are additional flow-on or multiplier effects. To calculate these we insert the figure of \$35 m from Table 1 derived above into the non-linear input-output (NLIO) model designed by Professor John Mangan from the University of Queensland's Economic Policy Modelling Centre.<sup>25</sup>

Primarily the model estimates four economic impact measures (gross output, value-added, factor income and employment), the results of which are summarised in Table 3.

Table 3 : Economic impact of visitors to the penguin parade

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	35.2	14.7	17.0	31.7	66.9
Value added (\$ m)	24.9	7.2	8.1	15.3	40.2
Factor income (\$ m)	16.5	2.8	3.5	6.4	22.9
Employment (FTEs)	74	22	30	62	136

Source: MJA estimates.

The annual economic impact of penguin visitation therefore has:

- a total gross output effect of \$66.9 m - made up of a direct effect of \$35.2 m and a flow-on (indirect) effect of \$31.7 m. Gross output refers to the value of increased production from penguin related tourism;
- a total value-added effect of \$40.7 m - made up of a direct effect of \$24.9 m and a flow-on (indirect) effect of \$15.3 . Value-added is the measure usually preferred when measuring economic impact. It measures the added value placed on intermediate products from the productive process;
- a factor income effect of \$22.9 m - made up of a direct effect of \$16.5 m and a flow-on (indirect) effect of \$6.4 m. Factor income refers to the share of value-added which is directly paid to individuals or firms in the form of wages or profits; and
- an employment effect of 136 Full -Time Equivalentents (FTEs) - made up of 74 FTEs directly employed and 62 FTEs indirectly employed.

<sup>25</sup> Further information on the NLIO model and the estimation undertaken in this study can be found in Attachment 1.

### 3. Results: Economic Impact of Reduced Tourism

The final task in this report is to quantify the economic impact on the Bass Coast Shire of a reduction in tourism associated with the penguin parade due to climate change. The change in economic activity is modelled on the three hypothetical scenarios outlined in Table 2.

#### 3.1. Scenario 1

Scenario 1 describes a situation in which climate change has a negligible impact on penguin numbers at the parade, causing no notable change in tourism. This is consistent with the experience of the last 25 years as penguin numbers have fluctuate within that time period without discernable impact on visitation.

Table 4 outlines this scenario.

Table 4 : No change in economic impact (Scenario 1)

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	35.2	14.7	17.0	31.7	66.9
Value added (\$ m)	24.9	7.2	8.1	15.3	40.2
Factor income (\$ m)	16.5	2.8	3.5	6.4	22.9
Employment (FTEs)	74	22	30	62	136

Source: MJA estimates.

#### 3.2. Scenario 2

Table 5 shows the economic impact associated with Scenario 2, in which tourism to the Bass Coast Shire associated with penguin visitation declines significantly (domestic visitation decreases by 30 per cent, and international visitation by 50 per cent). When compared with the current economic impact, there is a decrease in total gross output of \$28m per year, total value-added is reduced by \$17m, and reduced total employment (direct and indirect) of 66 FTE. (These differences are summarised in Table 8.)

Table 5: Significant change in economic impact (Scenario 2)

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	20.7	8.2	9.4	17.6	38.3
Value added (\$ m)	13.9	4.0	4.5	8.5	22.4
Factor income (\$ m)	9.2	1.6	1.9	3.5	12.7
Employment (FTEs)	41	12	17	29	70

Source: MJA estimates.

### 3.3. Scenario 3

Table 6 summarises the economic impact associated with Scenario 3, modelling a dramatic hypothetical decline in both domestic visitation (80 per cent) and international visitation (90 per cent). This reflects a decline in penguin sightings at the parade resulting in some nights of zero penguin sightings year-round. The viability of the parade would clearly be in question under this scenario.

When compared with the current economic impact (shown in Table 4), under Scenario 3 there would be a decrease in total gross output of \$58m per year, total value-added would decline by \$35m, and total employment (direct and indirect) would decline by an estimated 119 full-time equivalent employees. (These differences are summarised in Table 8.)

Table 6: Dramatic change in economic impact (Scenario 3)

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	5.1	2.1	2.5	4.6	9.7
Value added (\$ m)	3.5	0.9	1.2	2.1	5.6
Factor income (\$ m)	2.3	0.4	0.5	0.9	3.2
Employment (FTEs)	10	3	5	8	18

Source: MJA estimates.

### 3.4 Conclusions

The differing economic impacts of the three scenarios are summarised in Table 7. Differences in economic impacts compared with the status quo (Scenario 1) are shown in Table 8.

Table 7: Economic impacts summary table, scenarios 1-3

	Direct Demand			Flow-on			Total Demand		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Gross output (\$ m)	35.2	20.7	5.1	31.7	17.6	4.6	66.9	38.3	9.7
Value added (\$ m)	24.9	13.9	3.5	15.3	8.5	2.1	40.2	22.4	5.6
Factor income (\$ m)	16.5	9.2	2.3	6.4	3.5	0.9	22.9	12.7	3.2
Employment (FTEs)	74	41	10	62	29	8	136	70	18

Source: MJA estimates.

As can be seen in Table 7 and Table 8, Scenario 2 involves a sizeable decrease in economic activity once tourism is notably affected by penguin population decline. This involves a decline in direct economic output of \$14.5m per year, and with flow-on, a decrease in total gross output of \$28.6m per year. The decrease in direct value-added associated with Scenario 2 is \$11m per year, and with flow-on, \$18m per year. Total employment loss (direct and indirect) is estimated at 66 full time jobs.

Scenario 3, involving more extreme penguin population decline, is modelled to have more dramatic impacts on associated tourism. This involves a decline in direct economic output of \$30m per year, and with flow-on, a decrease in total gross output of \$57m per year. The decrease in direct value-added associated with Scenario 3 is \$21.4m per year, and with flow-on, \$34.6m per year. Total employment loss (direct and indirect) is estimated at 118 full-time jobs.

Table 8: Economic impacts difference table, scenarios 1-3

	Direct Demand			Flow-on			Total Demand		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Gross output (\$ m)	35.2	-14.5	-30.1	31.7	-14.1	-27.1	66.9	-28.6	-57.2
Value added (\$ m)	24.9	-11.0	-21.4	15.3	-6.8	-13.2	40.2	-17.8	-34.6
Factor income (\$ m)	16.5	-7.3	-14.2	6.4	-2.9	-5.5	22.9	-10.2	-19.7
Employment (FTEs)	74	-33	-64	62	-33	-54	136	-66	-118

Source: MJA estimates. Differences are relative to S1

MJA stresses that these scenarios are purely hypothetical. They have been compiled in the absence of detailed understanding of the likely impacts of climate change on the penguin population and without survey analysis of visitor preferences relating to penguin tourism.

Further work in these areas could establish a more robust understanding of the regional economic impacts of climate change on the Phillip Island Little Penguin colony.

## **Attachment 1: Economic Impact Analysis – Technical Document**

### **The Economic Significance of Penguin Related Tourism on the Victorian Economy and the Sensitivity to Biophysical Changes**

#### **Economic modelling**

Economic modelling may proceed from a number of perspectives. One approach is to examine the value of a project or enterprise in terms of its alternative, ie an opportunity-cost approach. This view of modelling sees resources as effectively fixed, or at least slow-moving, and evaluates specific projects in a marginal way. For example, the real value of the decision to invest in additional tourist infrastructure would only be the additional gains from its operations over and above those gains that would flow from the alternative use of those funds on some other projects. Taken to extremes, this general equilibrium approach would only see a positive economic value from exogenous spending if it represented the most efficient use of these scarce resources in comparison to other potential uses.

At the other extreme, a partial equilibrium approach would attempt to value the economic contribution of spending on penguin-related tourism in isolation from other potential activities. That is, if a decision has been made to use funds in this way, what are its net economic benefits? Traditional Input Output (IO) analysis takes this standpoint. In other words it is not primarily interested in establishing efficient resource allocation but rather, the impact of each specific project in isolation and without the constraints of having to compete for scarce resources.

While this may seem a more direct way of attempting to provide economic measurement, the traditional IO method has a number of weaknesses. The main one is that, once a decision is made to consider a project in isolation, those factors that operate in the real world such as the competition among other economic agents for scarce materials, are not considered. For example, constraints on economic activity such as supply imbalances, lack of demand for the product or non-linearities in economic production are not assumed to exist. In other words, the output from a traditional IO analysis gives the best (or maximum) result from an economic activity on the assumption that there are no barriers in the rest of the economy that may constrain that maximum result from occurring. For small, localised projects that have no great impact on the economy this may be a reasonable assumption. For larger projects or projects that take place in a booming economy, these assumptions can be highly misleading.

Modifying traditional IO by the introduction of non-linear assumptions goes a long way to reducing a number of these constraints and for projects regarding such activities as penguin-related tourism, probably offers the best way of economic evaluation.

#### **Non-linear input output models<sup>26</sup>**

The Non-linear input output model (NLIO) seeks to remove one of the major limitations of standard input-output analysis by removing the assumption of linear coefficients for the household sector and allowing marginal income coefficients adjustment. This is because, as is widely known, the household sector is the dominant component of multiplier effects in an

---

<sup>26</sup> The description of the non-linear model properties is taken from CEPM model descriptions (West 2003).

input-output table. As a result, using marginal income coefficients for the household sector will provide a more accurate, and empirically more valid, estimate of the multiplier effects, which in turn, provides results closer to those of a computable general equilibrium (CGE) model. The transactions flows in the input-output table can be expressed in matrix equation form as:

$$T(\hat{X}^{-1})X + Y = X$$

That is, for each industry, total industry sales equals intermediate sales to other industries for further processing plus sales to final users, where T is the matrix of intermediate transactions, X is the column vector of sector total outputs and Y is the column vector of aggregate final demands. This can be rewritten as:

$$AX + Y = X$$

Where A is the matrix of direct coefficients which represents the amounts of inputs requires from sector i per unit of output of sector j. Thus, for a given direct coefficient matrix, it is possible to solve the set of simultaneous equations to find the new sector production levels X which will be required to satisfy a potential or actual change in the levels of sector final demands Y. By rearranging and converting to differences, this equation can be rewritten as:

$$\Delta X = (I - A)^{-1} \Delta Y$$

where  $(I - A)^{-1}$  is termed the total requirements table, Leontief inverse matrix or general solution, and represent the direct and indirect change in the output of each sector in response to a change in the final demand of each sector.  $\Delta Y$  can incorporate any element of final demand expenditure, including household expenditure, government expenditure and capital expenditure.

This model is a linear model in which the A matrix represents a (constant) matrix of average input propensities. Normally, the A matrix endogenises the household sector<sup>27</sup> so that household consumption-induced effects can be measured. This is referred to as the type II model; the alternative type I model is where households are treated as exogenous to local economic activity. Generally speaking, the consumption-induced effects are the largest component of the total multipliers. This is because consumer driven consumption (and income) to a large extent dominates local economic activity.

Total inputs are equal to intermediate inputs plus primary inputs (labour and capital). In the conventional input-output model, the inputs purchased by each sector are a function only of the level of output of that sector. The input function is assumed linear and homogeneous of degree one, which implies constant returns to scale and no substitution between inputs. A more reasonable assumption is to allow substitution between primary factors. If there is an expansion in economic activity, say due to a development project, employers will attempt to increase output without corresponding proportional increases in employment numbers, particularly in the short term, e.g. construction projects, where there are economies of scale in getting the existing workforce to work longer hours rather than employ additional persons. This occurs for two reasons.

First, there is evidence in Australia that labour productivity (output per employee) is increasing over time. Secondly, as companies strive to reduce costs and satisfy the micro-economic reform processes imposed on all states by the National Competition Policy, there is evidence

<sup>27</sup> That is, household income varies with the level of intersectoral activity.

of a shift in primary factor use from labour to capital. This implies that the conventional input-output model has a tendency to overestimate impacts, in particular the income and employment impacts. Therefore, a more realistic approach to modelling impacts is to replace the average expenditure propensities for labour income by employers with marginal input propensities. In other words, the household income row in the A matrix, which are average input coefficients, should be replaced by income elasticities of demand. Note that, as in the CGE model, the linear coefficients assumption between intermediate inputs, and also total primary inputs, and total inputs is retained.

One problem associated with this approach is that the solution procedure is now more complex. Now the income impacts will be a function of  $\Delta X$  but the income coefficients are included in the A matrix which determines  $\Delta X$ . Therefore the equation set becomes recursive;  $\Delta X$  depends on A and A depends on  $\Delta X$ . Solving the input-output equation therefore requires an iterative procedure, a common method being the Gauss-Seidel method.

The income and employment flow-ons from the initial impact also need to be modified. In the conventional input-output model, income and employment flow-ons are calculated as linear functions of the output flow-ons, but in the revised model the parameters relating income to output are no longer constant. The impact on household income needs to be calculated as the difference between the base (i.e. before impact) income levels and the post impact income levels. It can be shown that this is equivalent to using the matrix equation:

$$\Delta \text{Inc} = \hat{X}_0^{-1} (\Delta \hat{X}) \hat{L} U_0$$

where U is a vector of household income flows and L is a vector of sectoral household income elasticities of demand. The zero subscript denotes the base level values and the hat denotes a diagonal matrix formed from the elements of the corresponding vector. This equation simply states that, for each sector, the change in household income payments equals the proportional change in output times the base level income payments multiplied by the income elasticity of demand. These income elasticities of demand can be shown to be equal to:

$$I_j = \eta_{WX} + \eta_{EX}$$

where  $\eta_{WX}$  is the elasticity of wage rate with respect to output, and  $\eta_{EX}$  is the elasticity of labour demand with respect to output; that is, they are made up of two components, the wage price component and the labour productivity component.

Similarly, the change in sectoral employment can be calculated as the change in the sectoral wage bill times the wage rate:

$$\Delta \text{Emp} = \hat{H}_0^{-1} \hat{P}_0^{-1} \Delta \text{Inc}$$

where H is a vector of average household income coefficients and P is a vector of coefficients representing average output per employee.

There are several implications arising from the use of this model, compared to the conventional input-output model. Firstly, while the output multipliers and impacts should not be significantly different between the two models, we would expect the income and employment impacts to be smaller in the marginal coefficient model. This is because many industries, especially those which are more capital intensive and can implement further



productivity gains, can increase output, particularly in the short run<sup>28</sup>, without corresponding proportional increases in employment and hence income payments.

Secondly, unlike the conventional input-output model in which the multiplier value is the same for all multiples of the initial shock, the multiplier values from the marginal coefficient model vary with the size of the initial impact. Thus larger changes in final demand will tend to be associated with smaller multipliers than small changes in final demand. Therefore, the differential impacts of the marginal coefficient model are not additive, unlike the conventional (linear) Leontief model and CGE model.

Overall, within the confines of a static model, the major improvements brought by the non-linear model are to improve the overall accuracy of the factor income and employment impact projections.

### **The Victorian non-linear model**

An input-output table developed by using generation of regional input output models (GRIT) methods was modified to have non-linear properties by the use of the IO-8 software developed by Guy West from the Centre of Economic Policy Modelling at the University of Queensland.<sup>29</sup> The table was also updated to reflect latest Australian Bureau of Statistics Census (2006) employment data. In an essentially static model, the way in which non-linearities can be included is by the interaction of estimated elasticity coefficients upon the multipliers, particularly the employment and factor income multipliers.

### **Economic impact measures**

The primary economic impact measures used in this section are as follows:

- Gross Output (regional turnover) - refers to the gross value of increased production from an additional economic activity. Within this gross value is included the value of raw materials that, in most cases, have already been counted as part of gross output from earlier production. Therefore there is a tendency for gross output figures to include some double counting. As a result, more concentration is placed upon incremental (additional output created) or value-added. Nevertheless, the concept of gross output should not be abandoned because it is a good indicator of the level of turnover in the economy and hence a good measure of the total level of economic activity.
- Value-Added - refers to added or net output. Value-added is equivalent to the gross state / regional product as used by the Australian Bureau of Statistics. It is the measure usually preferred when measuring economic impact. It measures the added value placed on intermediate products (raw materials) from the productive process. It is made up of margins, wages, profits and transfers
- Factor Income - relates to the share of value-added (and gross output) which is directly paid to individuals or firms in the form of wages and/or profits. By definition it is a percentage of value-added and cannot exceed value-added.
- Jobs - relates (usually) to the amount of labour required for the level of production. Depending upon the type of activity, job numbers measure either the use of existing labour

<sup>28</sup> The term 'short run' here does not refer to any specific time period; rather it will vary from industry to industry. It is used here in the conventional economic sense to mean that the full adjustment from any shock has not had time to occur, i.e. the system has not yet returned to full, long run, equilibrium.

<sup>29</sup> Some assumptions had to be made concerning elasticity coefficients for some industries. Where exact data was not known, the Rest of Australia (minus NSW) estimates were used.

(continuing jobs) or hiring new staff. Full Time Equivalent (FTEs) employment refers to the number of full time person-years of employment generated by a particular project or event. This alleviates the overstating of the level of job growth due to the stimulus.

### Economic impact modelling

To determine the economic benefits that may accrue to the economy of Victoria as a result of tourism on Phillip Island, data supplied was applied to a non-linear input output model of Victoria. The impacting sectors chosen are shown in Table 1 and international tourism is modelled as additions to exports.

Table A1 Tourism - Allocation of Impacting Sector

Impacting Sector	Percentage Contribution
Retail and Wholesale Trade	35%
Transport	12%
Personnel Services	20%
Restaurants and Cafes	12%
Finance	10
Miscellaneous	11

Percentage weights estimated from Bureau of Tourism Research and CEPM (2003).

On the basis of this assumption and the arguments used above the results obtained were:

Table A2(a) Annual Impacts of Phillip Island Tourism Domestic Lower Scenario (\$m)

	Final Demand	Industry Effects	Consumption Effects	Total	Flow-on
Gross Output	11.5	4.9	5.3	21.6	10.2
Value added	8.3	2.4	2.7	13.3	5.1
Factor Income	5.5	1.0	1.2	7.6	2.2
Employment supported**	24	7	10	41	17

Source: Victorian non-linear I-O table

- Gross output/turnover effects of \$21.6 million
- Additional GSP of \$13.3 million
- Additional factor income of \$7.6 million
- Support for 41 FTE jobs throughout the economy.

Table A2(b) Annual Impacts of Phillip Island Tourism (International) Lower Scenario (\$m)

	Final Demand	Industry Effects	Consumption Effects	Total	Flow-on
Gross Output	17.9	7.8	8.1	34.8	16.9
Value added	12.9	3.7	4.2	20.8	7.9
Factor Income	8.5	1.5	1.8	11.8	3.3
Employment supported**	38	11	16	64	27

Source: Victorian non-linear I-O table

- Gross output/turnover effects of \$34.8 million
- Additional GSP of \$20.8 million
- Additional factor income of \$11.8 million
- Support for 64 FTE jobs throughout the economy.

Table A2(c) Annual Impacts of Phillip Island Tourism (Domestic) Medium Scenario (\$m)

	Final Demand	Industry Effects	Consumption Effects	Total	Flow-on
Gross Output	15.4	6.2	7.00	28.4	13.2
Value added	10.8	3.1	3.5	17.5	6.6
Factor Income	7.2	1.2	1.5	10.0	2.8
Employment supported**	32	10	12	54	22

Source: Victorian non-linear I-O table

- Gross output/turnover effects of \$28.4 million
- Additional GSP of \$17.5 million
- Additional factor Income of \$10.0 mMillion
- Support for 54 FTE jobs throughout the economy.

Table A2(d) Annual Impacts of Phillip Island Tourism (International) Medium Scenario (\$m)

	Final Demand	Industry Effects	Consumption Effects	Total	Flow-on
Gross Output	19.8	8.5	10.0	38.3	18.5
Value added	14.1	4.1	4.6	22.7	8.7
Factor Income	9.3	1.6	2.0	12.9	3.6
Employment supported**	42	12	18	72	40

Source: Victorian non-linear I-O table

- Gross output/turnover effects of \$38.34 million
- Additional GSP of \$22.7 million
- Additional factor income of \$12.92 million
- Support for 72 FTE jobs throughout the economy.

Table A2(e) Annual Impacts of Phillip Island Tourism (Domestic) High Scenario (\$m)

	Final Demand	Industry Effects	Consumption Effects	Total	Flow-on
Gross Output	20.6	8.7	9.2	37.7	17.9
Value added	14.4	4.1	4.7	23.2	8.8
Factor Income	9.5	1.7	2.0	13.2	3.7
Employment supported**	42	13.	17	72	30

Source: Victorian non-linear I-O table

- Gross output/turnover effects of \$37.7 million
- Additional GSP of \$23.2 million
- Additional factor income of \$13.2 million
- Support for 72 FTE jobs throughout the economy.

Table A2(f) Annual Impacts of Phillip Island Tourism (International), High Scenario (\$m)

	Final Demand	Industry Effects	Consumption Effects	Total	Flow-on
Gross Output	26.5	11.3	13.0	50.7	24.2
Value added	18.8	5.4	6.1	30.3	11.5
Factor Income	12.4	2.2	2.6	17.2	4.
Employment supported**	55	16	23	94	39

Source: Victorian non-linear I-O table

- Gross output/turnover effects of \$50.7 million
- Additional GSP of \$30.3 million
- Additional factor income of \$17.9 million
- Support for 94 FTE jobs throughout the economy.

### Comparisons with Tourism Victoria Study

It is hard to make direct comparisons with the results cited above for the Tourism Victoria study because the basis for the study and its methodology is not clear. One area for potential comparison is in the amount of gross output used to support one direct job.

Table A3: Comparison of gross output for direct employment

Gross Output per direct job	\$, 000s
Tourism Victoria (2005)	338,383
Victorian non-linear model (FTE) (domestic)*	525925
Victorian non-Linear model (FTE) (International**)	532500
Victorian non-linear model (adjusted for part time and casual jobs (Domestic-Medium Scenario)	368147

Initially it appears as if there is considerable disagreement between the job estimates, with the non-linear model predicting fewer jobs per million. However the non-linear estimates are for FTE jobs. It is believed that the Tourism Victoria estimates include part-time and casual jobs. After adjustment of the non-linear figures to include part-time and casual jobs, the comparison between the value of output per job costs from Tourism Victoria (\$338,383) and the Victorian non-linear model (\$368,147) is relatively close, particularly allowing for inflation between the dates.

### Scenario analysis

Table A4: Scenario 1 - Economic impact of visitors to the penguin parade

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	35.2	14.7	17	31.7	66.9
Value added (\$ m)	24.9	7.2	8.1	15.3	40.2
Factor income (\$ m)	16.5	2.8	3.5	6.4	22.9
Employment (FTEs)	74	22	30	62	136

Source: Victorian non-linear I-O table

Table A5: Scenario 2 - Economic impact of visitors to the penguin parade

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	20.7	8.2	9.4	17.6	38.3
Value added (\$ m)	13.9	4.0	4.5	8.5	22.4
Factor income (\$ m)	9.2	1.6	1.9	3.5	12.7
Employment (FTEs)	41	12	17	29	70

Source: Victorian non-linear I-O table

Table A6: Scenario 3 - Economic impact of visitors to the penguin parade

	Final demand	Flow-on (indirect) effects		Total flow-on	Total
		Industry	Consumption		
Gross output (\$ m)	5.1	2.1	2.5	4.6	9.7
Value added (\$ m)	3.5	0.9	1.2	2.1	5.6
Factor income (\$ m)	2.3	0.4	0.5	0.9	3.2
Employment (FTEs)	10	3	5	8	18

Source: Victorian non-linear I-O table

## **6 Conclusions and recommendations**

A number of recommendations for adaptation activities to protect the Phillip Island penguin population arise from this work, the effect of which will be to limit future changes in penguin populations to that envisaged in MJA's Scenario 1.

### **6.1 Potential effects, including loss of breeding habitat through inundation and erosion, of sea-level rise on distribution and abundance of penguins**

There will be some small loss (<< 1 %) of breeding habitat on the Summerland Peninsula due to sea level rise in the next 100 years but it is considered that breeding habitat is unlikely to be limited on the Peninsula in this period. However, there is likely to be some erosion in the vicinity of Whaleshead Creek and further east. Accordingly, there are some implications for the viewing of penguins at the Penguin Parade. It is anticipated that there will be some loss of productivity of inshore waters in Bass Strait, which may ultimately result in reduced food availability for penguins.

#### **Resilience building and recommendations for actions including future research**

- Removal of Marram Grass on the beach profile of Summerland, Cowrie & Shelly Beaches and Cat Bay (and replace with native species, e.g. Spinifex).
- Incorporate the "Future Coasts" data into the Phillip Island Nature Parks' GIS system to allow better determination and visualisation of areas on the Summerland Peninsula likely to be most affected by sea-level rise and storm surge (see Appendix 1 for more details of the "Future Coasts" project).
- Complete the purchasing of all private property in the Summerland Estate to allow the extension of penguin breeding areas further inland.
- Encourage the penguins to colonise the eastern side of the current breeding area at the Penguin Parade through active management (see Dann 1996) particularly by:
  - eradicating foxes from Phillip Island
  - improving access for penguins on the east side of the Parade
  - optimising vegetation type and cover for breeding penguins

### **6.2 Potential effects of decreasing rainfall and humidity on distribution and abundance of penguins**

It is predicted that there will be little appreciable direct impact of decreased rainfall and humidity on adult Little Penguins over the next century. However it seems likely that fire risk will increase and needs to be managed to ensure penguin survival is unaffected. In addition, if the availability of anchovies is reduced by decreased rainfall, then adult survival (and possibly breeding productivity) may be reduced.

#### **Resilience building and recommendations for actions including future research**

- Increase appropriate ground vegetation cover in penguin breeding habitat to reduce evaporation of soil moisture during periods of decreased rainfall and to reduce erosion after high rainfall events
- Investigate the role of burrow temperature and humidity in determining the breeding success of penguins, particularly hatching success and chick growth
- Honours project on relationship between burrow location and structure on nest temperature and humidity- commence June 2009. Project brief in Appendix 2.
- Reduce fire risk on Summerland Peninsula through:

- planting fire resistant local vegetation, particularly succulent species where appropriate,
- give high priority to fire response planning and training,
- ensure all power supply on Summerland Peninsula is underground.
- Establish if relationships exist between stream inflows (and temperature) into Port Phillip Bay and anchovy spawning and production.

### **6.3 Potential effects of ambient temperature rise on distribution and abundance of penguins**

Increasing temperatures in burrows during daylight are likely to increase adult and chick mortality and, based on a tripling of days greater than 35 °C and assuming a conservative linear function, will constitute c. 0.51% of annual adult mortality by 2070. Increasing burrow temperatures may also have a role in determining breeding success and this warrants investigation as does the scope for mitigation of burrow microclimates through vegetation management and artificial burrow design.

#### **Resilience building and recommendations for actions including future research**

- Increase appropriate ground vegetation cover in penguin breeding habitat to reduce internal temperatures of burrows on hot days
- Investigate the role of burrow temperature in determining the breeding success of penguins, particularly hatching success and design an artificial burrow with optimal microclimate (temperature & humidity) - see Section 2. A project to examine breeding success in relation to temperature in artificial burrows is currently in train (Chiaradia *et al.*) and a project brief for a study to look at temperature and humidity in natural burrows is given in Appendix 2.
- Compare breeding success and ambient temperatures of Little Penguins on northern (warmer) & southern (cooler) sides of the Summerland Peninsula between 1984 and 2008.

### **6.4 Summary of potential impacts of oceanic changes on distribution and abundance on penguins**

Increasing sea-surface temperatures in Bass Strait may result in an earlier start to the breeding season, increases in breeding success and increases in first-year survival. Decreases have been predicted in adult survival, but more work is required to confirm the direction of this relationship. More productive breeding seasons and higher first-year survival should improve recruitment into the breeding population. Increased stratification of the water column may reduce productivity and, correspondingly, food availability for penguins but, conversely, increase foraging efficiency of Little Penguins.

#### **Resilience building and recommendations for actions including future research**

- Continue Phillip Island Nature Park's commitment to long-term studies of breeding, demography and foraging of Little Penguins. Long-term datasets are the key to documenting and understanding the response of species to climate change and the Little Penguin study at Phillip Island is one of the longest running studies of a marine species in Australia
- Model the impact of shortening or lengthening the breeding season has on productivity of penguins



- Investigate if the timing of breeding of penguins at Phillip Island has continued to track the autumn SSTs in Bass Strait following the apparent change in trend since 2000
- Review the linkages between SSTs in autumn and the timing and success of breeding in penguins, giving priority to those involving prey species
- Determine with more confidence the relationship between sea-surface temperatures and adult survival with more confidence
- Determine if there are any competitive interactions between fisheries and Phillip Island penguins. Building resilience to reductions in food availability for penguins could include reducing competition from fisheries
- Investigate the role of climate on fish recruitment (spawning and survival) in Bass Strait

### **6.5 Summary of potential impacts of wind, the southern oscillation index and ocean acidification on distribution and abundance on penguins**

Decreasing winds in the region are likely to reduce the recruitment of fish populations and hence the availability of food for penguins, with potential impacts on their survival and breeding success. It is unknown if wind direction and velocity directly affect penguin foraging success. Decreasing SOI may reduce adult survival and increase juvenile survival but the mechanisms are unknown for either. Increasing acidification may reduce food availability for penguins.

#### **Resilience building and recommendations for actions including future research**

- Develop a trophic model of the Bass Strait ecosystem to allow assessment of sensitivities to oceanic variables for higher predators and potential interactions.
- Determine the effects of wind on the foraging success of Little Penguins
- Analyse the relationships between SOI and survival of adult and first-year penguins

### **6.6 Summary of tourism-related issues for further research**

The impacts of climate change on the Little Penguin population of Phillip Island could have repercussions for the Phillip Island economy, and that of the Bass Coast Shire more broadly. The penguin population contributes to a strong and viable tourism industry on the Island. Of the more than 1000 businesses in the Shire, over half benefit directly from tourism. In 2007/08, a total of 491,780 people visited the Nature Park to see the penguin parade. Of these, 308,465 were international tourists spending a total of \$19.7 million, and 183,315 were Australian visitors spending a total of \$15.4 million.

#### **Tourism scenarios under climate change**

As noted, the impacts of climate change on the penguin population have not been detailed as yet. Nor has the impact on tourism of penguin population decline. Accordingly, three scenarios have been developed to hypothesise tourism decline, and the resulting economic impacts modelled. Scenario one models a small penguin population decline, with no notable change in economic impact. Scenario 2 involves significant population decline with similar economic impacts. And Scenario 3 models extreme population decline and associated visitation. These scenarios are summarised below.



dramatic impacts on associated tourism. This involves a decline in direct economic output of \$30m per year, and with flow-on, a decrease in total gross output of \$57m per year. The decrease in direct value added associated with Scenario 3 is \$21.4m per year, and with flow-on, \$34.6m per year. Total employment loss (direct and indirect) is estimated at 118 full time jobs.

MJA stresses that these scenarios are purely hypothetical. They have been compiled in the absence of detailed understanding of the likely impacts on penguin population of climate change and without survey analysis of visitor preferences relating to penguin tourism.

Further work in these areas could establish a more robust understanding of the regional economic impacts of climate change on the Phillip Island Little Penguin colony.