Natural history and management of the Shoalwater Islands and Marine Park

Proceedings of a seminar, 22 July 2015, Point Peron Camp School.

Department of Parks and Wildlife

urban nature

Department of Parks and Wildlife
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: (08) 9442 0300
Fax: (08) 9386 6399

www.dpaw.wa.gov.au

This publication was prepared by the Urban Nature program

Questions regarding the use of this material should be directed to:
Kate Brown, Ecologist
Swan Region/Regional & Fire Management Services
Department of Parks and Wildlife
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: 9422 0321
Email: kate.brown@dpaw.wa.gov.au

The recommended reference for this publication is:
Department of Parks and Wildlife (2015) *Natural history and management of the Shoalwater Islands and Marine Park: proceedings of a seminar, 22 July 2015, Point Peron Camp School*, Department of Parks and Wildlife, Perth.

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Cover image: Bridled terns, Penguin Island April 2015. Photo K Brown.

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Acknowledgments

We thank the Point Peron Camp School for their outstanding venue, catering and organisational assistance.

Preface

Stretching from Cape Peron to Point Becher, the Shoalwater Islands Marine Park, only 40km south of the city of Perth, supports a diversity of marine life and protects a small chain of islands known as the Shoalwater Islands. The vegetation and flora on the islands provide critical habitat for migratory seabirds and marine mammals.

On 22 July 2015 at Point Peron Camp School over 50 people attended a seminar on the natural history and management of the Shoalwater Islands and Marine Park. The seminar was hosted by the Department of Parks and Wildlife Urban Nature program.

Program

Natural History and Management of the Shoalwater Islands and Marine Park Wednesday, 22nd July 2015, Point Peron Camp School		
9.00am	**Arrive and cup of tea**	
9.15 -9.50	History and management of the Shoalwater Islands	Terry Goodlich, Parks and Wildlife Swan Region
9.50-10.25	Change over time on the Shoalwater Islands	Elizabeth Rippey, Honorary Research Fellow, UWA
10.25 -10.45	Morning tea	
10.45-11.20	Seabird responses to a changing ocean climate	Nic Dunlop, Conservation Council of WA
11.20-11.55	Seabird research on Penguin Island, an insight into bridled terns' demographic	Aurelie Labbe, Murdoch University
12.00-100pm	Lunch	
1.00-1.35	Conservation ecology and human disturbance of Australian sea lions (*Neophoca cinerea*) in Western Australia	Sylvia Osterrieder, Curtain University
1.35 -2.10	Artificial nests as a climate adaptation tool: buffering climate change impacts on the little penguin (Eudyptula minor)	Erin Clitheroe, Parks and Wildlife Swan Region
2.10-2.45	Impacts of feral predators on island ecosystems	Nic Dunlop, Conservation Council of WA
2.45-2.55	Afternoon tea	
2.55-3.30	Control and eradication of black rats (*Rattus rattus*) on Penguin Island, Western Australia, December 2012 – July 2013	Karl Brennan, Parks and Wildlife Swan Region
3.30-4.00	Restoration of plant communities and critical habitat on Penguin Island	Kate Brown, Parks and Wildlife Swan Region
	CLOSE	

1 History and Management of the Shoalwater Islands

Terry Goodlich

Department of Parks and Wildlife, Swan Region

As a child I grew up within the Shoalwater area of Rockingham. I have worked for the Department of Parks and Wildlife for over 30 years and have been a ranger for most of those years. In 1989 I was transferred from Walpole Nornalup National Park to Perth where I lived on Penguin Island with my family for the first two of 20 years. I was closely involved in the development and management of Shoalwater Islands and the metropolitan marine parks. My primary focus of the talk today will about Penguin Island, the surrounding islands and its connection with the Shoalwater Islands Marine Park.

Penguin Island has been an iconic part of the Rockingham scene since early settlement. First known to the local Aboriginal peoples (though no evidence of settlement or use has been found), and then to European settlers, whalers and sealers were also known to use Penguin Island. In 1830, the ship 'Rockingham', bearing settlers for the Peel region, was blown ashore during a storm near Mangles Bay. The town site of Rockingham was surveyed in 1847, and the locality prospered with the development of a railway and jetty to ship timber from the Jarrahdale area in 1872. Development of the port of Fremantle in 1897 saw Rockingham dwindle to a seasonal holiday or retirement destination, and generations of Perth children will have fond memories of summers spent at Rockingham and swimming lessons in the calm blue waters.

Shoalwater Bay faces Penguin Island, which lies 600m offshore. Penguin Island is part of a chain of limestone islands and rocky outcrops, which now form the Shoalwater Islands Marine Park. Penguin Island, at 12.5ha, is the largest of the islands (the total land mass of the Shoalwater Islands is 16ha), and is joined to the mainland by a sandbar.

The earliest 'resident 'of the Island was Paul Seaforth McKenzie, a somewhat eccentric mining engineer who took up residence on Penguin Island in 1918, having squatted there intermittently since 1914. Styling himself 'King of Penguin Island', McKenzie constructed a timber residence for himself which was known as the Manor

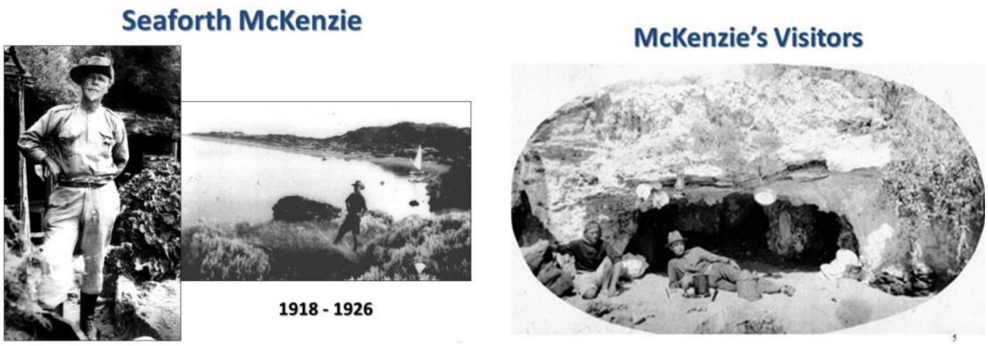


Figure 1: Seaforth McKenzie the self-styled 'King of Penguin Island' and his guests.

House, and excavated some of the numerous limestone caves ('Fairhaven' and 'Tudor Hall') as accommodation for guests. The caves were lined with hessian to stop the drift of sand from the roof of the caves, and kerosene lamps were suspended on hooks. McKenzie dug a well for fresh water, planted exotic species such as figs and ran a small shop from one of the caves. Visitors were invited to stay by permission of the ‘King’, and many stories abound of the parties, poetry readings, balls and ceremonies conducted on Penguin Island during McKenzie’s ‘reign’. After leaving Penguin Island in 1926, McKenzie built a house and ran a business on the mainland, before returning to his family in New Zealand, explaining a 42 year absence due to ‘amnesia’.

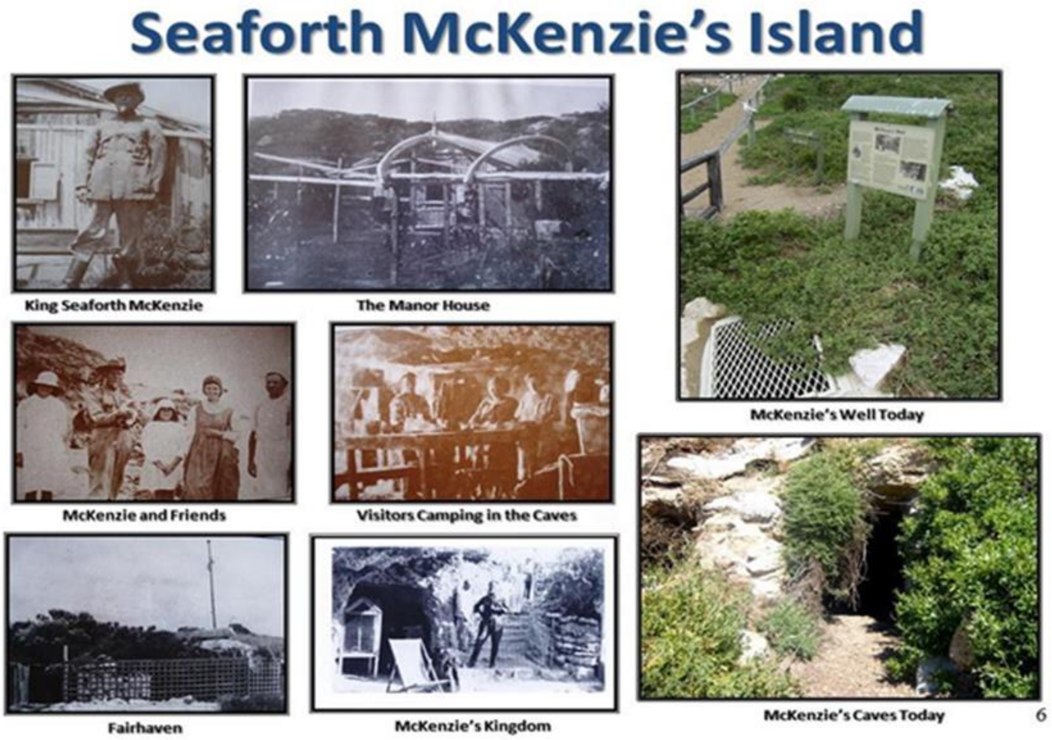


Figure 2: Historical photos of Seaforth McKenzie’s nine years on the island and the areas today.

Following Seaforth McKenzie’s tenure on the Island, several other leaseholders operated private enterprises on Penguin Island, including camping. One lease from 1950–1972 encompassed the central area where most of the management facilities and jetty are located today. A second lessee from 1972–1987 had a broader leasehold which included most of the southern portion of the island. Photographs taken from the end of these leases shows the severe erosion and numerous walk-trails crisscrossing the island. During World War II, Penguin Island formed part of the defence of the Perth area, when search lights were emplaced on the island. One long-time resident of the area related a story from that

Figure 3: Penguin Island leaseholds 1950–1972 (short dashed line) and (1972–1987 (long dashed line) and the buildings and facilities.

period when, at Christmas, a procession of ‘three wise men’ progressed across the sand bar on camels, using the searchlights as the star of the East, to bring gifts to baby Jesus.

In the 1950’s, holidays for Perth families were very popular, with access made easier by the acquisition of two ex-army DUCKW amphibious vehicles and ferries for transport. The remains of one of these vehicles are still visible at low tide buried by sand on the beach south of the jetty. Despite the terms of the leases gazetting Penguin Island as ‘camping only’, many buildings were haphazardly constructed from timber and asbestos (cheap and plentiful), as well as construction of septic tank systems and rubbish pits, shallowly buried in the sandy soil. Numerous walk trails crisscrossed the island, threatening bird nesting sites and little penguin (*Eudyptula minor*) habitats. Many day trippers also accessed the island by walking the shallow sand bar connecting Penguin Island to the mainland.

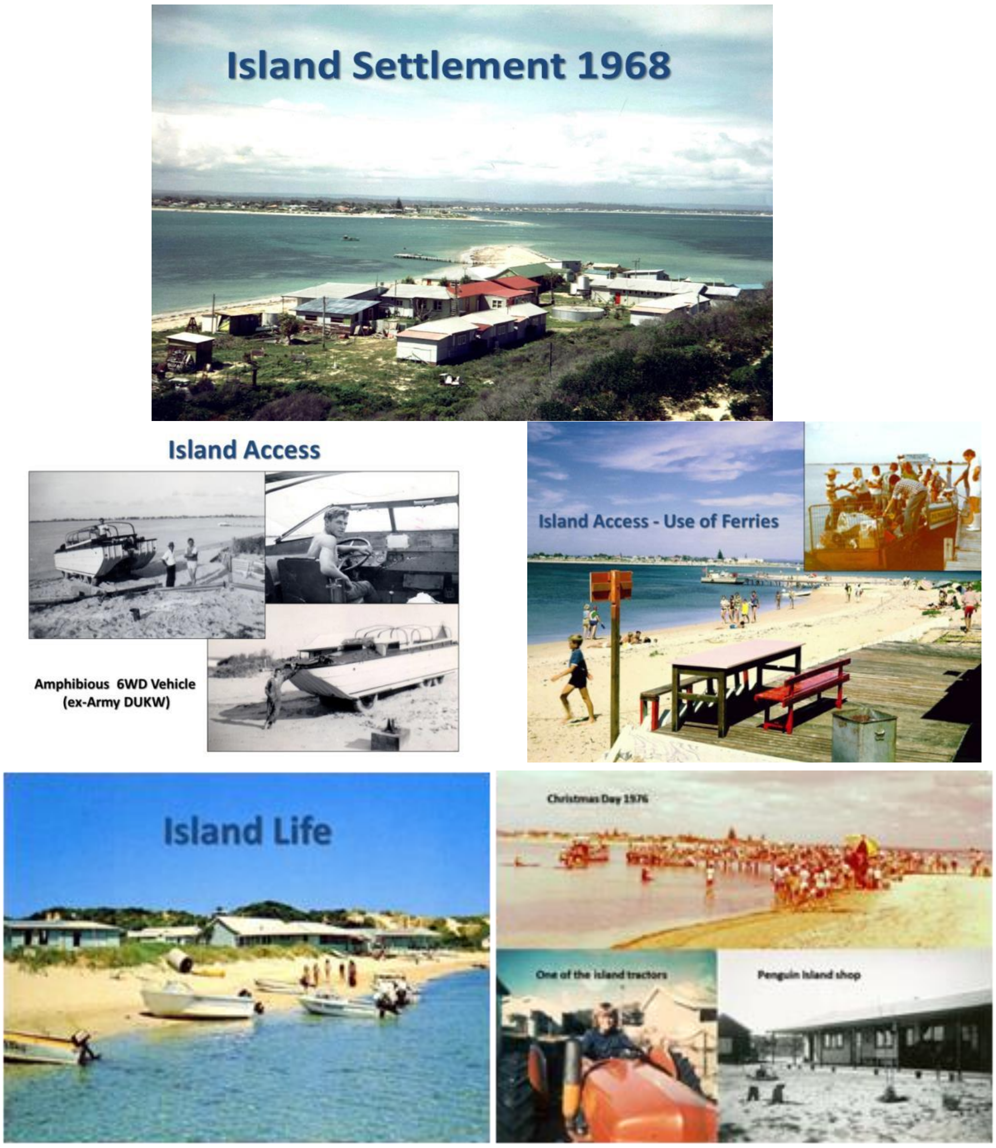


Figure 4: Penguin Island as a holiday destination in the 1960s and 1970s. My family and I occupied the small blue shack on the far left of the Island Life picture some years later in 1989.

In 1987, the private lease was terminated and management of Penguin Island was handed to the then Department of Conservation and Land Management (CALM) who began the laborious task of removal of buildings and rehabilitation of the degraded environment, along with environmental studies and research to improve management of the fragile coastal ecosystem for the future. Penguin Island was gazetted as a Conservation Park with the Conservation Commission in 2002, and is now encompassed by the Shoalwater Islands Marine Park. Both the marine park and Penguin Island are managed by separate management plans, and within the 6,654ha there are four separate zones:

- general use
- sanctuary zones (5.8%);
- special purpose (scientific reference)
- special purpose (wildlife conservation) – the total of the two separate special purpose zones equates to 9% of the total marine park area.

The reason for the creation and separation of the park into zones is in recognition of the unique attributes of the environment and flora and fauna; not only is the area home to the largest population of little penguins on the west coast, the marine park and islands are home to many species of seabirds (both resident and migratory) for feeding, roosting and breeding. It is also home to the unique and threatened Australian sea lion (*Neophoca cinerea*) and as noted in the System 6 report (1983), the region has special significance for conservation, recreation and education.

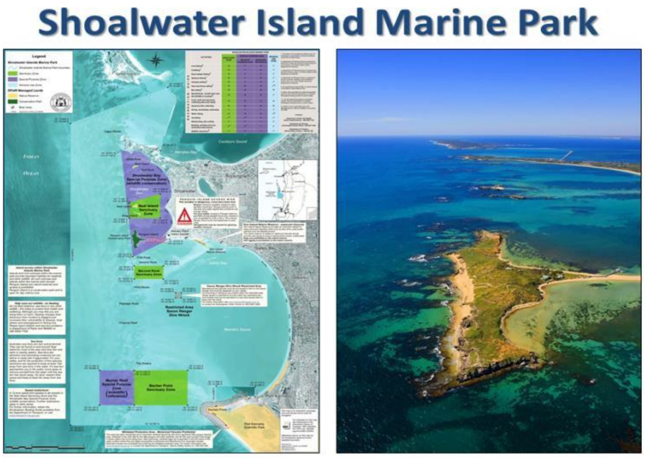


Figure 5: The Shoalwater Island Marine Park comprises 6,654ha. The map shows the different management zones. The park boundary and general use zone is pale blue, purple denotes special purpose- scientific reference or wildlife conservation and areas shaded green are sanctuary zones. The aerial photo shows the chain of islands in Shoalwater Bay looking north from Penguin Island. Garden Island at the top of the photo is outside the boundary of the marine park.

Habitual use and ready access meant that traditionally, Penguin Island was accessible year round, which presented the first of many challenges in the rehabilitation and management of the Island. The resident Penguin and seabird populations were under extreme pressure due to the degraded environment and continual disturbance (everyone who went to Penguin Island hoped to see penguins….). Introduction of non-native species of plants and animals (particularly mice, rats and feral pigeons) placed additional risks to the environment and native fauna. Much time and effort and consultation went into the preparation and development of the *Shoalwater Islands Management Plan (1992–2002)* and the definition of clear goals and guidelines for ongoing management and sustainability of the area. These management goals can be summarised as:

- conservation of the biological, physical, cultural and landscape values
- facilitation of recreation in a manner consistent and compatible with the conservation and other values
- promotion and informed appreciation of the natural and cultural values
- better management and understanding of the natural and cultural environments and the impacts of visitor use through monitoring, research and continuous quality improvement.

In the 25 years since CALM (now Department of Parks and Wildlife) assumed responsibility for the Shoalwater and Penguin Island, much has been achieved. Management strategies include:

- closure of the island during little penguin breeding season (June – September)
- creation of sanctuary zones on Penguin Island and within the marine park
- rehabilitation of denuded and degraded areas of the island with native flora
- closure of walk-trails and construction of designated board walks (north and south) and steps to preserve habitat and fauna nesting sites
- installation of composting toilet systems
- construction of the Penguin Experience Island Discovery Centre to provide opportunities to view little penguins in a managed environment
- construction of designated picnic site and retaining wall on the eastern beach area
- construction of the Penguin Island research and management facility in conjunction with private sponsors
- upgraded power system (solar panel array)
- construction of upgraded jetty and dock facilities.

Many of these activities required careful research and planning to implement. Although very close to the mainland, Penguin Island remains problematical in access for removal of bulky items, such as the hazardous waste created by removal of the many asbestos buildings constructed by the private lessees. There is no infrastructure such as roads on Penguin Island, hence the demolition and removal was very labour intensive; and final removal and disposal on the mainland was further hampered by access to the shallow waters of the island and prevailing weather conditions. Unique solutions had to be developed and collaborative projects such as with the Australian Army, who devised a series of linked pontoons with outboard motors to move bulk rubbish and waste back to the mainland. A similar project with the Australian Navy created a novel solution to the problem by using a helicopter to remove large items such as the elderly and outdated diesel generator from Penguin Island. This mode of transport has also been utilized to deliver timber and materials for the construction of boardwalks and facilities.

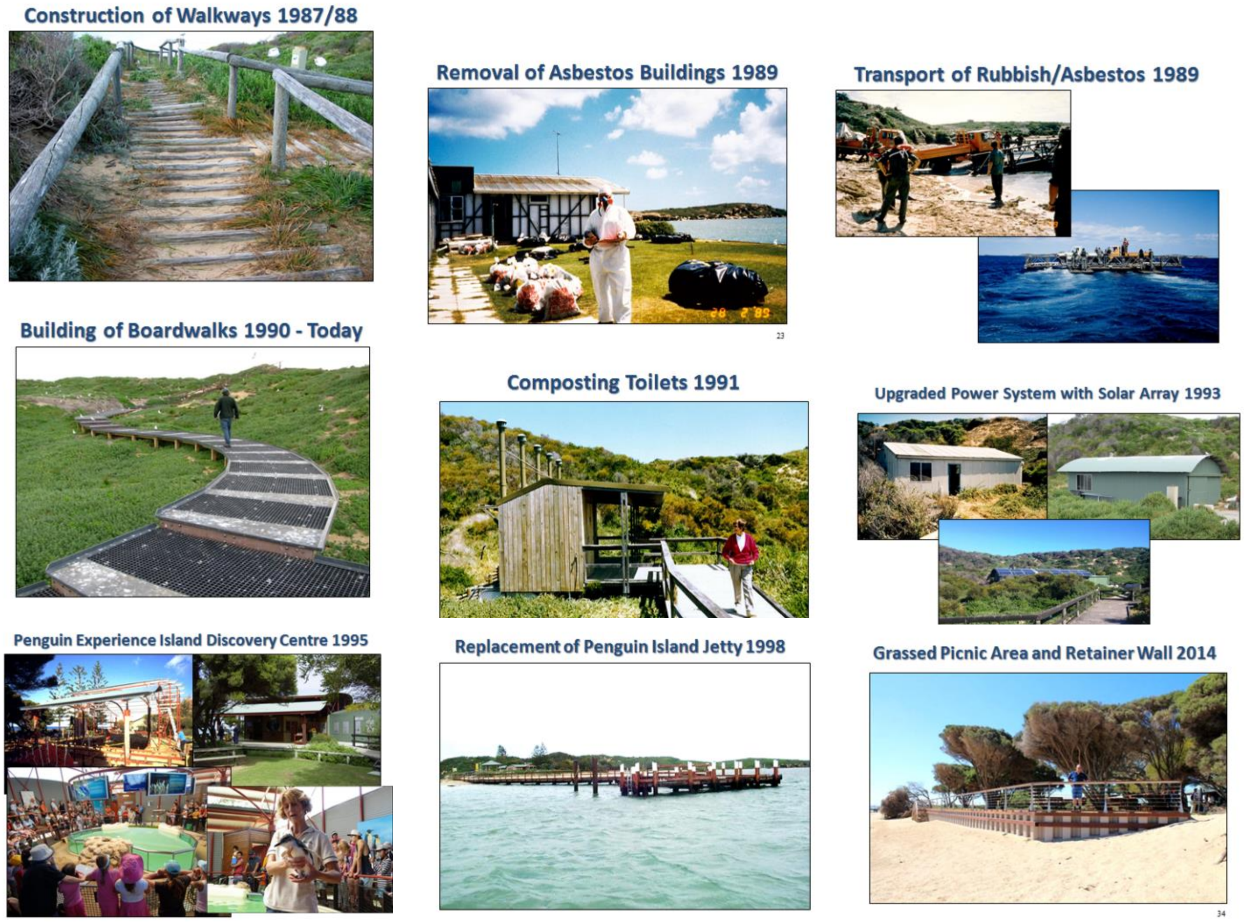


Figure 6: Major infrastructure projects, Penguin Island.

Construction of the Penguin Experience Island Discovery Centre which opened in 1995 was another landmark achievement for Penguin Island. Funded jointly by a Commonwealth grant, CALM capital funding and a contribution by Kodak Australia for interpretive displays, the centre is home to a captive colony of little penguins, which have been rehabilitated from illness and injury, but are unable to be released into the wild. It serves a dual purpose of providing an opportunity for visitors to view little penguins in a near-native habitat, whilst also providing an opportunity to communicate conservation values of the area. Funds raised from entry to the centre are also used to provide revenue for maintenance, upkeep and environmental management of the area.

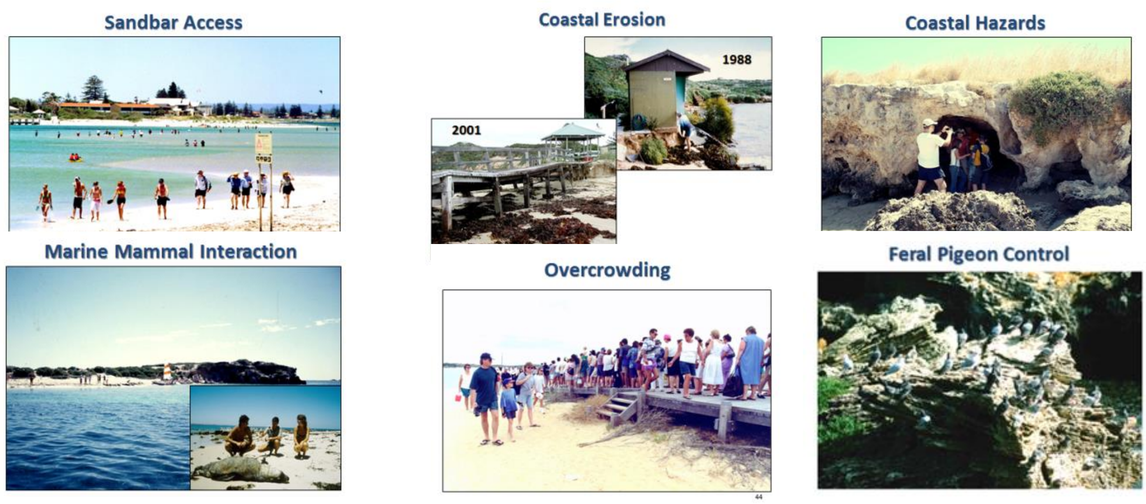
Figure 7: The facility provides accommodation and workspace for staff and visiting researchers.

The Research and Management facility, which opened in 1996, was another innovative collaboration between CALM and The Western Mining Corporation. The facility provides accommodation and workspace for island rangers and other CALM staff; as well as accommodation for researchers and scientists involved in study of the environment, flora and fauna.

Penguin Island and the Shoalwater Islands Marine Park remain a popular destination for local and international tourism. It is a drawcard for Perth and local tourism operators, and directly employs 43 staff, between Rockingham Wild Encounters, who hold an ‘E’ class license for exclusive operation of the Penguin Island ferries and tour vessels; and several other enterprises that hold ‘T’ class licenses to operate sea kayak tours. Revenue raised from these licenses is valued for its contribution to the ongoing management and upkeep of the island and marine park facilities.

Penguin Island is open to visitors for 38 weeks each year, and in the 2014–15 season received 138,000 visitors, and is increasing by approximately 16% per annum. Research divulges that 90% of these visitors visit Penguin Island to see little penguins and also to spend time with family and friends, staying on the island for anything between two and eight hours per visit. Of the 12.5ha of land comprising Penguin Island, only 2ha is actually designated for recreation in the form of picnic area, beaches and boardwalks. It is possible that overcrowding may detract from visitor enjoyment, as well as providing risk to the fragile environmental ecosystem.

Parks and Wildlife is currently focusing on these issues to consider and develop ongoing strategies for the management and sustainability of Penguin Island and the Shoalwater Islands Marine Park. Visitor risk issues and visitor safety are paramount concerns. There are well publicised and documented risks associated with visitors who choose to ignore the dangers associated with accessing Penguin Island via the sandbar. Recent tragedies have highlighted sandbar access as one of the most pressing concerns. Until as recently as 2008, one of the private enterprises operated marine mammal interaction within the boundaries of the marine park, where visitor could swim with sea lions; however this is no longer permissible due to the unacceptable risk posed by shark attacks and other associated visitor risks.



Coastal erosion and hazards caused when fragile limestone structures collapse are also ongoing issues, as are control of introduced pests such as feral pigeons and rodents. Infrastructure on Penguin Island is also a serious issue – the composting toilets struggle to cope with high visitor numbers, and the manual nature of environmental concerns such as rubbish removal, transport of fuel for the generator, water supply, maintenance of jetties, buildings and boardwalks in the corrosive marine environment is resource intensive. The potential for fire and subsequent control is also a management issue. Parks and Wildlife has developed comprehensive plans for ongoing maintenance and assessment of the facilities and the environment such as the coastal caves and cliffs. Ongoing research is assisting with environmental management issues, and Parks and Wildlife works closely with other government, non-government and private stakeholders such as universities and tourism operators to develop balance and sustainability in their approach to managing this special and fragile area for future generations.

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2 Change over time on the Shoalwater islands

Elizabeth Rippey

Honorary Research Fellow, UWA

Changes in the populations of plants and birds together with rehabilitation efforts on Seal Island around 2000 are discussed in this report. Changes to the coastlines of the islands are also mentioned. It is helpful to consider the Shoalwater Islands as part of the chain of islands off the coast of Perth (Figure 1) as they share characteristics with the other small islands, Carnac, Dyer and Green islands.

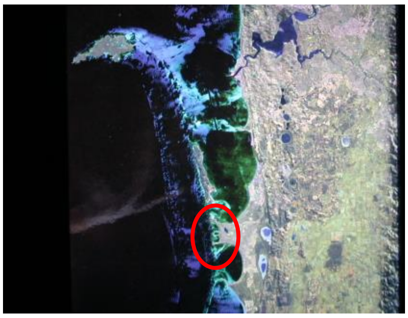

Figure 1: Chain of islands off Perth. Shoalwater circled in red. Landsat image produced by Landgate.

Changing coastline

Figure 2: Cave collapse at north end of Penguin Island 2000.

The Shoalwater coastline is extremely dynamic, with shifting sandbars and sand islands and erosion of the limestone of the islands causing frequent cave and cliff collapses which reduce the size of the islands. Between 1999 and 2003 a large cave at the north end of Penguin Island collapsed (Figure 2), two substantial cliff collapses occurred on Seal Island and one on Bird Island.

Vegetation and birds

In 1950 much of Penguin Island was bare, following decades of holidaymaking, guano collection on the southern promontory (N Dunlop pers. comm.) and grazing by rabbits. The rabbits disappeared in about 1952 probably due to myxomatosis, leaving 'hundreds of skeletons' (P Playford pers. comm.). Vegetation cover improved in the absence of rabbits, particularly after the government instituted management controls in 1987 and restricted tourist access (Figure 3).

1953 *1981* *1997* *2014*

Figure 3: Vegetation cover on Penguin Island.

Despite the improvement in vegetation cover, plant surveys in 1959 and 1997 showed a serious decline in the number of native species (Storr 1961, Rippey et. al. 1998).

Penguin Island lost five of 42 native species (12%), and the smaller islands on average lost two thirds of their native plant species, most of which were perennials including *Spinifex longifolius, Pittosporum ligustrifolium, Acanthocarpus preissii, Frankenia pauciflora* and *Olearia axillaris.*

The years 1997 to 2003 saw dramatic vegetation changes due to changes in the seabird populations nesting on the islands. The weed **Malva arborea* was also implicated in vegetation change, and was investigated.

Seabird populations

The population of pied cormorants (*Phalacrocorax varius)* has increased enormously, and pelicans (*Pelecanus conspicillatus)* have started nesting on the Shoalwater islands. Prior to about 1960 pied cormorants nested in small numbers on Carnac and on one or other of the Shoalwater islands. Between 1980 and 1990 up to 500 nests were recorded on both Carnac and Shoalwater islands. By 2000 there were 2600 nests on Carnac and 1300 nests spread across several of the Shoalwater islands. The images below show large colonies of cormorants on Carnac Island and their effects on the vegetation.

Pied cormorant colony May 2000. *NE promontory November 2001.* *Pied cormorants nesting on the NE promontory six months later, May 2002.*

Figure 4: The effect of the cormorant rookery on the vegetation of Carnac Island.

Pied cormorants and pelicans are the region's major guano producers. Extrapolating from South African statistics (Crawford & Shelton 1978), pied cormorants deposit 7–10 kg of guano per bird pa on land, so 1000 birds deposit several tons of guano per annum. This is a lethal dose of nutrients for most native plant species. *Nitraria billardierei* is an exception. Cormorants generally nest on *Nitraria*, but will spill out over adjoining vegetation if the colonies are too large, killing the plants with trampling and guano. They do not nest on bare ground so move to new sites each year. Native vegetation recovers over 5–6 years unless nesting is repeated or there is heavy competition from weeds. Cormorant numbers dropped to under 1000 pairs on Carnac by 2010, and 500 on the Shoalwater islands.

Pelicans started nesting on Penguin Island in 1998 and have continued to nest there for the past 17 years (Figure 5), undeterred by the denuded state of the rookery. The colony occasionally splits, and from 2001 has often nested on Seal Island.

Figure 5: Pelicans (left) nesting on the north end of Penguin Island, 1999. Pelicans (right) nesting on Penguin Island 2008. Note pied cormorants are nesting on Nitraria *in the foreground in both images.*

N

A new Weed

**Malva arborea* from Europe was noted on both Bird and Carnac islands in 1958/9. This large weed with purple flowers has since not only devastated the native plant cover on the plateaux of Seal and Shag islands, and Dyer and Green islets off Rottnest, but also eliminated the native white-flowered *Malva preissiana* from all seabird islands in the archipelago except Carnac and Shag islands. Both *Malva* species live for two years, but **M. arborea* germinates earlier, grows faster and taller and produces more seeds than *M. preissiana*. The two occasionally hybridise, as occurred on Bird Island in 1999 producing a beautiful but apparently sterile plant.

Figure 6: Shag Island May 2000. Tall *M. arborea *(left), small* M. preissiana *(right).*

Figure 7: Native M. preissiana.

Figure 8: Introduced *M. arborea.

Figure 9: Hybrid *M. arborea x M. preissiana.

Rehabilitation

Rehabilitation efforts on Seal Island 1997–2002 were not successful. We cut down **M arborea* and the population dropped from 10,000 to 3000 plants between 1998 and 2001. We also laid down weedmat and planted *M. preissiana* seedlings which survived and reproduced as long as we controlled **M. arborea*. We also planted *Carpobrotus virescens, Myoporum insulare* and *Rhagodia baccata*. The *Carpobrotus* flourished but *Myoporum* and *Rhagodia* succumbed probably because silver gulls pecked them. By September 2001 pelicans were nesting on the island and access was no longer possible. The sequence of events at Seal Island is pictured in the series of images below.

Figure 9: June 1999. Forest of young *M. arborea.

Figure 11: July 1999. Laying weedmat for M. preissiana *among chopped* *M.arborea.

Figure 12: Three months later Oct 1999. M. preissiana *flowering in weedmat surrounded by new* *M. arborea.

Figure 13: May 2000. Weedmats with M. preissiana *in their second year.*

Figure 14: May 2003 Seal Island with nesting pelicans (circled in red) and pied cormorants nesting on Nitraria *(circled in blue).*

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3 Seabird responses to a changing ocean climate

Nic Dunlop

Conservation Council of WA

Significant changes have been observed since 1900 in the distribution and abundance of populations of at least eight tropical seabird species off south-western Australia, south of the Houtman Abrolhos Islands. The observed changes have involved a southward shift in breeding distribution or the rapid growth of colonies located on or beyond previous limits. The rate of change appears to have accelerated over the last three decades.

The bridled tern (*Onychoprion anaethetus)* and brown noddy (*Anous stolidus)* meta-populations breeding off southwestern Australia have shown contrasting responses to changes in the regional ocean climate. Bridled terns have expanded their distribution southward, founding 40–50 frontier colonies up to 1 400 km from the edge of their historical range (pre-1900) at the Houtman Abrolhos islands. Some of these frontier colonies are amongst the largest recorded for this species anywhere.

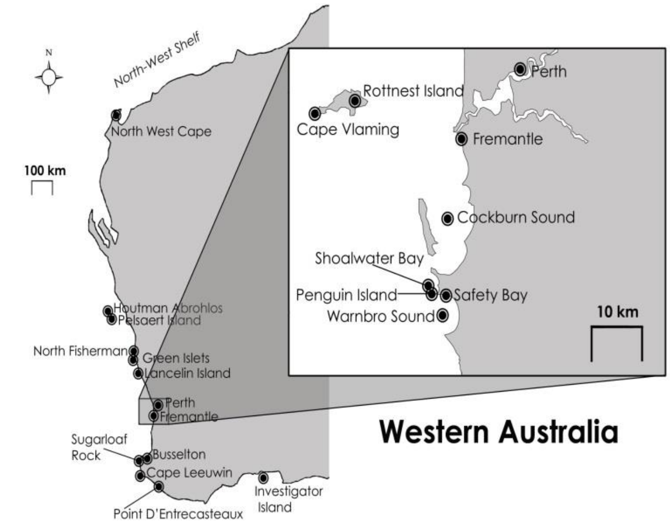

Figure1: Bridled tern and its expanded frontier colonies. A climate change winner.

Figure 2: Brown noddy, climate change struggler.

Conversely, the brown noddy's response to recurrent poor breeding performance at the Houtman Abrolhos has been limited dispersal and the establishment of only one frontier colony, at Lancelin Island, 280 km south of its stronghold on Pelseart Island. Egg-laying has started progressively later at the bridled tern frontier colony at Penguin Island, probably tracking a shift in the seasonal peak in sea temperature. The start of egg-laying in the brown noddy colony on Lancelin Island is significantly correlated with the long-term trend in the Southern Oscillation Index (SOI), with earlier breeding during La Niña periods when the Leeuwin Current is flowing strongly. The converse was the case in the bridled tern, which started breeding earlier during protracted El Niño periods. We present long-term trends in the timing of breeding of both species in relation to the El Niño Southern Oscillation.

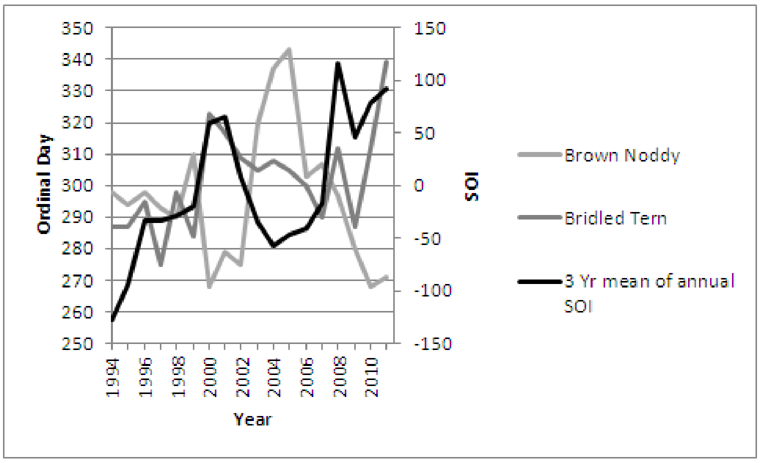

Figure 3: Relationship between first laying date and the Southern Oscillation Index (SOI). Brown noddies and bridled tern's have opposing responses. Sea temperatures influence marine productivity in the species' different foraging areas and therefore available resources for breeding.

We also review the foraging ecology of the two species off southwestern Australia and discuss the role that differences in foraging ecology between the two species may have in accounting for contrasting population responses to a changing ocean climate.

Table 1: Comparison of the foraging ecology between the bridled tern (left) and the brown noddy (right). The bridled tern's adaptable foraging ecology may contribute to its ability to exploit new opportunities and geographical areas.

ASPECT OF FORAGING ECOLOGY		
Foraging range	20-80 km	>100 km
Relationship with foraging predatory fish	Facultative, in the absence of competition from other dark terns	Near obligate with small, surface feeding tuna 
Prey types	Post larval fish and crustaceans and insects	Post larval fish and squid
Prey length	Multi-modal, high proportion under 10mm	Mean fish 51mm, squid 39mm
Prey diversity	20+ taxa	2-3 taxa
Prey shift within breeding season	In late chick-rearing period	none
Foraging habitat	Offshore on continental shelf	Oceanic, shelf edge, canyons and beyond
Water mass productivity	Oligotrophic	Upwelling

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4 Seabird research on Penguin Island, an insight into bridled tern’s demographic

Aurelie Labbe

PhD candidate, Murdoch University

Bridled terns (*Onychoprion anaethetus)* are a migratory species of marine bird that have a tropical to sub-tropical distribution around the world. Bridled terns have a wingspan of about a meter. They feed mostly on small fish and squid in offshore waters. Bridled terns only lay one egg per breeding season so they raise only one chick in summer when they breed on Penguin Island. However if the egg fails, or the chick dies early in the breeding season, then a couple may try to lay another egg. Bridled terns’ eggs are cryptic so they are camouflaged to avoid predation. Therefore they are very hard to see and they may be stepped on by people walking on limestone cliffs and inside the vegetation.

Eggs and very young bridled tern chicks are susceptible to predation by the king skink (*Egernia kingii*). Young bridled tern fledglings have a mottled pattern on their feathers during the first couple of years of their lives which makes them look very distinct from breeding adults.

Figure 1: Life stages of bridled terns: bridled tern egg (top-left), newly-hatched bridled tern chick (top-right), fledgling (bottom-left), adult bridled tern in breeding plumage (bottom-right).

Bridled terns on Penguin Island

Bridled terns on Penguin Island breed between October and April, during the summer when the ocean temperatures are warmer. They arrive from migration in late September and they start laying eggs in November. The chicks hatch after one month of incubation in December which coincides with the peak holiday season on Penguin Island. The chicks fledge in March and start leaving the island by the end of April flying north to the Celebes Sea. While they breed on Penguin Island, bridled terns feed around *Sargassum* rafts about 80km offshore on the continental shelf. There is an estimated 4,000 breeding pairs on Penguin Island.

Why are bridled terns important?

Generally, seabirds can be used as indicators of their environment because they are at the top of the food chain. Therefore anything that happens in the lower trophic levels, for example if a lot of small fish die because the ocean water is unusually hot, will be reflected in the seabird populations that feed on them. As a consequence, seabirds may die in large numbers or they may be unable to raise their chicks because there is not enough food to sustain them.

Furthermore, bridled terns are becoming more prominent in Western Australia. Over the years bridled terns have been found breeding further south. In 1843 they had never been recorded further south than the Houtman Abroholos Archipelago. In 1952 they were seen breeding on Penguin Island for the first time and in 2008 they were recorded in the Recherche Archipelago which is about 4,500km away from the Abroholos.

Bridled terns and rats/mice on Penguin Island

Black rats arrived on Penguin Island around 2012 and they predated on bridled terns to the extent that during the summer 2012/13 virtually all eggs and chicks were killed on Penguin Island. Rats also occasionally preyed on adult bridled terns and if they did not die straight away, most of the birds died from injuries later.

Now that rats appear to have been eradicated from Penguin Island, the mice population has boomed and is also causing some damage to the bridled tern population by preying on eggs and small chicks.

Bridled terns are ground nesting birds so they are generally vulnerable to predation.

Figure 2: A house mouse sitting on top of a nest tube over a bridled tern incubating a young chick.

My PhD research project

My main research question is “Are older parents better at raising their chicks than younger parents?”

This has been shown to be the case for a number of seabird species but not for bridled terns. To investigate this question I am looking at a number of parameters such as breeding success, chick growth rates, diet and the impact of plastic pollution on bridled terns.

To do this I have installed 50 artificial nest tubes on the north end of Penguin Island and I have been trying to control weeds and reintroduce native plants to give a natural cover for bridled terns to use as nesting sites.

My thesis is due for submission in November 2016.

Figure 3: Example of a nest tube that has been used by a pair of bridled terns to nest and raise their chick.

5 Conservation ecology and human disturbance of Australian sea lions(*Neophoca cinerea*) in Western Australia

Sylvia Osterriedier

Curtin University and Victoria University

The Australian sea lion (*Neophoca cinerea*) is the only endemic pinniped species in Australia and has the smallest overall population of all Australian pinnipeds. Its current range extends from the Abrolhos Islands in Western Australia to The Pages in South Australia. In 2008, Australian sea lions were listed as endangered on the IUCN 'Red List' due to their relatively small and declining population, which was estimated at a total of 12,690 (estimate from 2013/14). The species' population is divided into mostly small and widely scattered colonies with several of these declining in numbers, putting smaller colonies at risk of local extinction.

Most of the extant breeding colonies of Australian sea lions are located in South Australia, with 84% of the total pup production, and by proxy 84% of the overall population, being presently confined to that state. The remaining 16% of the extant population is found in WA, with breeding locations along the south coast (approximately between the Recherche Archipelago and Albany) and the west coast (around Jurien Bay and Abrolhos Islands). Most breeding islands are small, with a pup production of less than 25 pups per breeding cycle. There are 81 known breeding sites (47 in SA, 34 in WA) with the largest eight breeding sites (all in SA) producing 61% of the total pups.

Australian sea lions have an unusual breeding cycle of 17–18 months (range: 16.0–19.9 months) which is unique amongst pinnipeds. Individual breeding sites for sea lions exhibit asynchronous breeding cycles, that is while the cycle period/length appears to be the same, breeding may occur at different times at different sites. Female Australian sea lions display high natal site fidelity, in that females return to their birth places to have their pups. Pupping, or birthing, takes place over an elongated period of about six months. Australian sea lions wean their pups after about 17 months, just before the successive pup is born.

In WA, there are six haul-out islands off the Perth metropolitan area only used by male Australia sea lions. Seal and Carnac Islands are used by the largest number of sea lions, with up to 28 and 45 sea lions respectively, recorded to be hauled out during the Perth peak season. During the breeding season, male sea lions migrate from the Perth metropolitan islands to the closest breeding islands approximately 250 km north at Jurien Bay. The fluctuations in numbers of sea lions hauling out off Perth inversely align with the breeding season in Jurien Bay. Small numbers of sea lions are found hauling out off Perth during the breeding season and reach maximum numbers during the non-breeding season. The total size of this population inhabiting the Perth waters is, however, unknown.

Population estimates in pinnipeds are usually based on pup counts, due to the lack of information on numbers of older sea lions foraging at any one time. Abundance estimates at non-breeding haul-out locations, however, cannot be based on pup counts. The ability to identify individuals is beneficial for mark-recapture based population estimates, especially when pup counts are not applicable. Furthermore, reliable methods for individual identification are advantageous for ecological studies of population demographics and movement patterns. Non-invasive identification is based on using natural marks which are unique to the individuals, like fur patterns (for example stripes in tigers (*Panthera tigris*) or zebras (*Equus sp.*), or spots in harbour seals (*Phoca vitulina*)) or the shape or outline of some part of the body, like the dolphin's dorsal fin. Australian sea lions do not have any obvious marks or fur pattern that can be used, thus in the past, invasive methods like tagging, microchipping or branding individuals have been used in this and similar species. These methods involve capturing, handling, potentially anaesthetising the animals and applying the mark. Each of these procedures can be risky for the animals and also comprise some danger for researchers themselves. Scars may also be useful to assist identification in pinnipeds, but often change over time, for example when animals moult. Lions (*Panthera leo*) and polar bears (*Ursus maritimus*) have successfully been identified using their whisker spot patterns. Australian sea lion whisker patterns appear to be similarly visible, as in lions and polar bears, and have aided in individual identification in a previous study in Hooker's sea lions (*Phocarctos hookeri*).

This study found that whisker spot patterns in the endangered Australian sea lion (Figure 1) contained enough information to reliably identify individuals in small populations, with 99 (± 1.5% SD) reliability in a population of 50 individuals. A semi-automatic software package, using a point-pattern matching algorithm called Chamfer distance transform, matched 90 of pairs of photographs correctly when photographs of captive Australian sea lions taken at 90° (lateral), without tilt, were compared. Photographs taken at different angles (70°, 90° and 110°) resulted in 48% correct matches. Visual comparisons of 90° photographs and plotted spot patterns of potential matches, that is re-sightings, using photographs of wild Australian sea lions were unfeasible in the trial conducted, due to the variation between photographs of the same individual over time. Environmental conditions and untrained sea lions appear to introduce too much variation for successful matching. Currently, a different algorithm, the Groth algorithm, based on matching triangles, is undergoing testing that may improve the matching success of photos taken at different angles. Opportunistic photographs of scars helped identify four sea lions on Seal and Carnac Islands, the main haul-out islands in the Perth metropolitan area, Western Australia. Two of these re-sighted individuals showed movement between the islands, and the other two were either sighted twice on Carnac or twice on Seal Island.

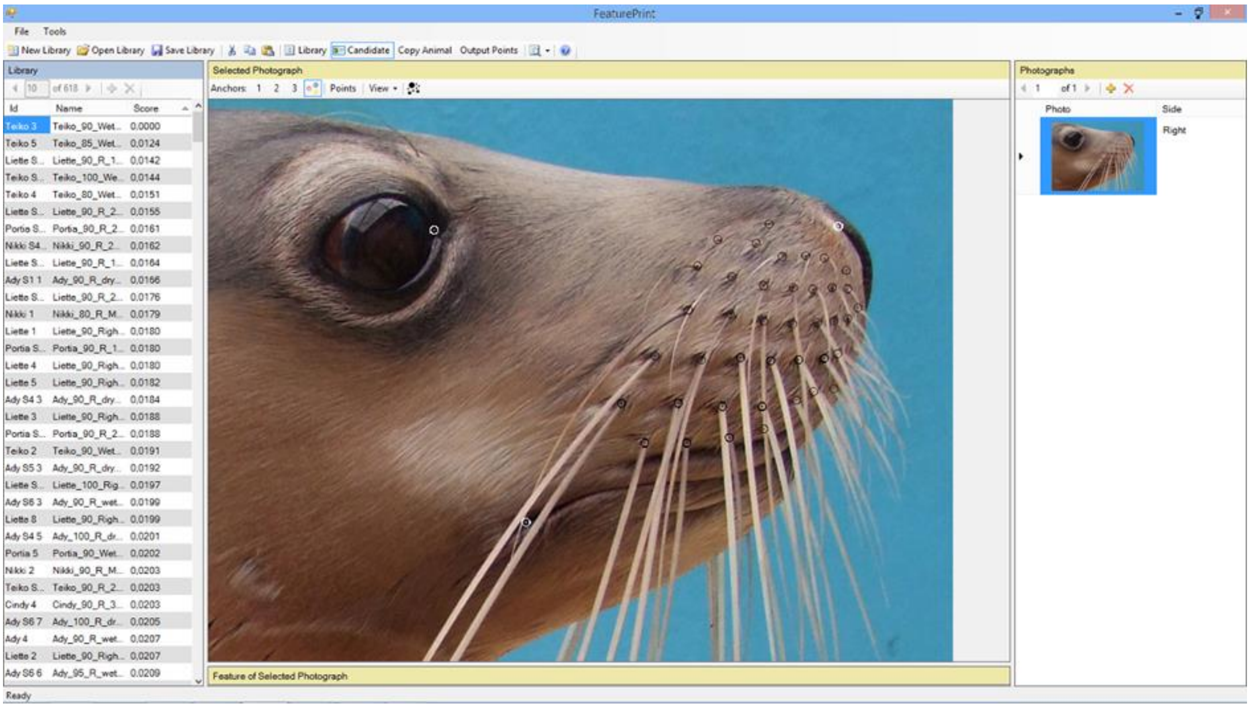

Figure 1: Adapted software interface to build a library and match whisker patterns using Chamfer distance transform. Whisker spots in the image are marked with black circles and reference points with white circles. The matching scores with other marked photographs are displayed on the left.

Estimating abundance and monitoring trends of a male-only sub-population based on count data needs to be carefully planned with a robust survey design. For an accurate estimate, it is important to consider daily haul-out patterns separately from the overall fluctuations due to the breeding cycle. To obtain more accurate trend estimates, recommendations have been made suggesting that counts should be conducted at times of least variance in numbers and when the maximum proportion of the population is hauled out. To achieve maximum reliability, effective surveys for accurate abundance and trend estimates must be designed based on known daily and seasonal patterns in haul-out behaviour.

We conducted 620 hourly counts on 78 days on Seal Island and 712 hourly counts on 88 days on Carnac Island. Due to accessibility, a remote-controlled camera was used for the majority of these counts on Carnac Island. Generalised additive models were applied to these hourly count data, conducted from 0800h–1600h. Numbers of sea lions followed 17–18 months fluctuations according to the breeding cycle (Figure 2). The numbers of sea lions hauling out varied between the locations in different seasons, but also between the two peaks. The numbers during the first peak were higher on Seal than on Carnac Island, but were relatively similar in the second peak season. The variation in sea lion numbers between different days was high, and numbers increased throughout the day which was usually only observed when overall numbers in the area were sufficient, that is during non-breeding season. Overall, numbers hauled out were associated with air temperature and tidal height, but not with wind speed. With rising air temperature up to about 21°C, the number of sea lions hauling out increased. Above 21°C, the effect of temperature remained relatively stable. With increasing tidal level, the numbers of sea lions hauling out decreased. The effect of tidal height was more pronounced on Seal than on Carnac Island, however, no significant interaction term was detected between tidal height and location.

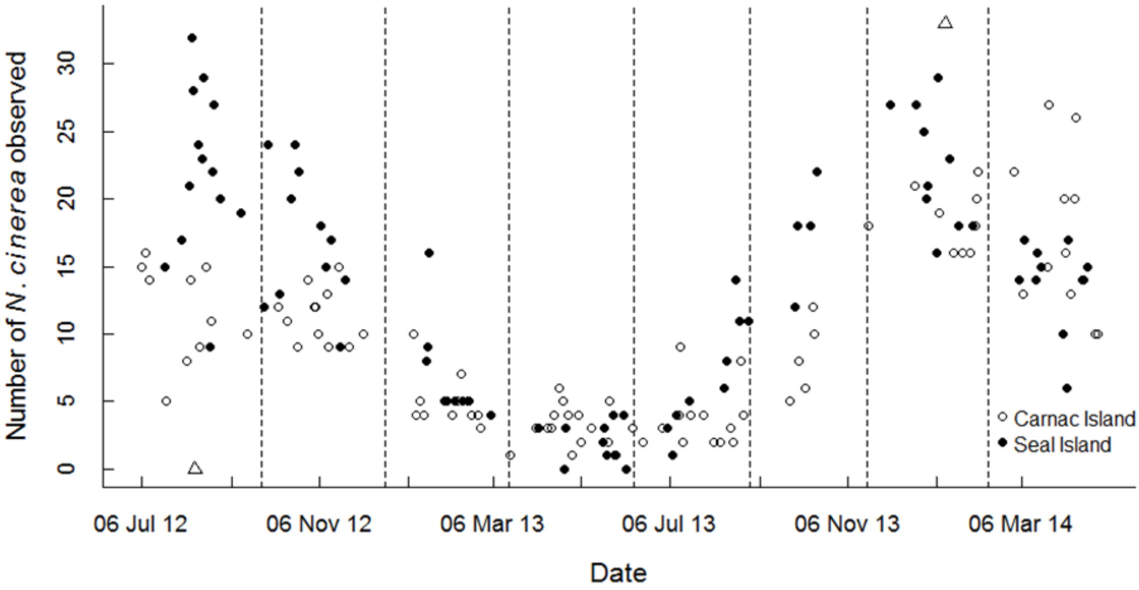

Figure 2: Maximum numbers of sea lions observed on Carnac (white dots) and Seal (black dots) Islands during 166 survey days between June 2012 and April 2014. Dashed lines mark the survey periods (survey intervals 1 to 8). The two white triangles present the exceptionally high and low observations on Carnac Island.

The variability in numbers of sea lions hauling out within a day can affect the accuracy of abundance estimates significantly. As a result, it was suggested to conduct repeated counts on several days during the peak season around Perth. Counts should be conducted at Carnac and Seal Islands between 9–11 hours after sunrise, otherwise at a similar time of day across all survey days for comparable data between sites and years.

Anthropogenic activities have been shown to trigger disturbances in the animals. Short-term responses have been recorded in many marine mammals, including behavioural changes, for example disruption of foraging or resting behaviour, physiological responses like increased stress levels or suppressed immune system, and aggressive behaviours towards each other and also directed towards humans. Long-term impacts include habituation (such as animals become acclimated to human presence), avoidance of preferred habitat (for example for foraging or resting), and females potentially leaving their pups unattended which can increase pup mortality. Also, the risk of boat strikes increases with higher numbers of vessels in the water. All these impacts have led to the introduction of enforced regulations and voluntary codes of conduct at some haul-out and breeding sites to limit anthropogenic disturbance.

Australian sea lions are benthic foragers, hunting for prey that inhabit the seafloor. The majority of time on foraging trips is spent underwater (50–60%), exceeding their aerobic dive limits regularly. This means that sea lions are working hard to catch their prey, and need to rest between foraging trips. Disruption of their rest and recuperation may influence an individual’s energy budget as more energy is required if increased time is spent at higher activity or awareness levels. This would require sea lions to feed more during foraging trips and potentially increase trip length or increase the number of foraging trips, likely reducing time spent resting. If Australian sea lions leave their haul-out sites to forage in a tired or weakened state, they may present an easier target for predators. For sea lions in the Perth metropolitan area, it is therefore important to determine the influences that anthropogenic activities have on their behaviours.

Seal Island, a sanctuary zone without landing permission, and Carnac Island, where people are allowed on the beach, are easily accessible and highly frequented by humans, who regularly elicit responses from sea lions. Exposure and response levels varied between the islands and responses were related to all documented measures, including stimulus types (vessels and people), distances between the stimulus and the animals, and the stimulus activity. The majority of responses occurred at short ranges to sea lions, especially those elicited by people. The highest disturbance levels, aggressive and retreat behaviours, mainly occurred on Carnac Island, when people were viewing sea lions, an activity mostly carried out at close-range. To limit such disturbance-inducing proximity in sea lions, we suggested that the beach at Carnac Island be closed to human visitation and the minimum approach distance by vessels and people be increased by installing marker buoys at least 15 m off the shore.

This study increased the understanding of local Australian sea lions inhabiting the Perth metropolitan area, providing essential knowledge to improve their conservation and management.

6 Artificial nests as a climate adaptation tool: Buffering climate change impacts on the little penguin

Erin Clitheroe

Department of Parks and Wildlife, Swan Region

Penguin Island, situated in the Shoalwater Islands Marine Park, Western Australia, is home to a genetically distinct population of little penguins (*Eudyptula minor*). This population exists at the northern edge of this species' range and at its likely thermal limit. Penguin Island's population has been shown to respond negatively to elevated sea surface temperatures which cause reduced prey abundance, leading to speculation that future temperature increases will further depress already low reproductive success. In addition to changes in the marine environment, reduced rainfall and increased terrestrial temperatures associated with climate change are likely to alter the terrestrial habitat and vegetation used by the breeding population. Little penguins are burrow nesting seabirds however on Penguin Island, the sandy substrate is too soft in which to excavate stable burrows and penguins instead nest under dense vegetation, in rocky crevices or in artificial nest boxes. A reduction in vegetation extent may have negative impacts both on the thermal environment of the nest as well as soil stability.

The likely vulnerability of this population to the effects of ongoing climate change highlights its ecological importance for investigating the response of seabirds to climate change on land as well as at range margins. While the ability of this population to persist will be largely dependent on its ability to adapt to changes in food resources and availability, it may be possible to increase the resilience of the population to rapid environmental change through management of their terrestrial breeding habitat such as providing artificial nests. However this demands an understanding of nest habitat preference in order to ensure the continued efficacy of artificial nests as a climate change mitigation strategy for Penguin Island's little penguin population.

This project set out to answer the following questions:

1. How do physical characteristics influence nest microclimate?
2. How do microclimate and physical characteristics influence use and breeding success of penguin nests?
3. Can we improve nest box design to replicate optimal microclimate conditions of little penguin nests?

In order to test for associations between nest site characteristics, nest microclimate, nest use and reproductive outcomes, two major sets of data are being collected. The first data set consists of nest use and reproductive data. Reproductive performance of little penguins is being measured in birds nesting in both artificial nests and natural burrows in order to determine breeding success. Nests are monitored fortnightly for breeding activity over three breeding seasons. During each monitoring trip, the presence of adults, eggs and chicks will be noted and reproductive variables are recorded. From these data, three measures of breeding performance will be determined; (1) the number of chicks produced per pair; (2) the proportion of eggs that hatched; and (3) the overall breeding success, that is the proportion of total eggs laid that resulted in successful fledglings.

The second data set consists of nest characteristic and microclimate (temperature and humidity) data. The microclimate and a number of physical characteristics are measured for both used and unused, existing nest boxes and natural burrows, which are monitored fortnightly for use and breeding activity. Microclimate data (temperature and humidity) are collected with the use of temperature and humidity loggers which are placed in the rear of both natural and existing artificial nests.

In addition to this, three artificial nest designs will be placed *in situ* in three areas on Penguin Island in order to test the efficacy of each design as a method for reducing temperature and improving microclimate of artificial nests .

Figure 1: Nest box designs– design 1 (top left), design 2 (bottom left), design 3 (right).

Some preliminary data obtained from the temperature loggers to date are presented in the graphs below. Figure 2 outlines the temperature recorded inside 5 different nests over one day in early November. The temperatures recorded inside the exposed boxes (red lines) were observed to be much higher than those recorded for natural burrows (blue lines) or covered nest boxes (yellow lines). Figure 3 outlines the daily maximum temperature over 60 days in Spring. Maximum temperatures in exposed boxes (red lines) are much greater than those in the covered boxes (yellow line) or natural nests (blue lines). Temperature range recorded over the same period is also observed to be greater in the exposed boxes than the covered boxes or natural burrows (Figure 4). Penguins nesting in exposed boxes could not only be regularly experiencing temperature exceeding their thermal limit (35°C) but also expending energy on thermoregulation to cope with the higher temperature ranges.

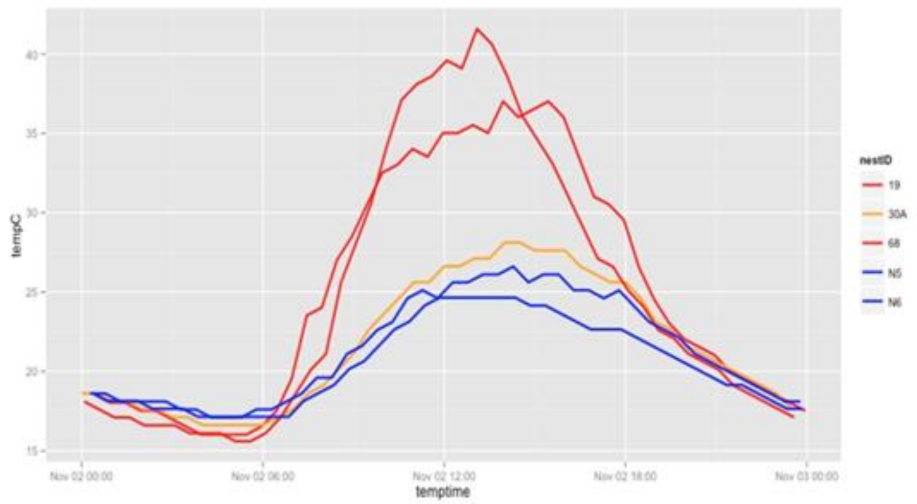

Figure 2: Temperature profile over one day in five different nests.

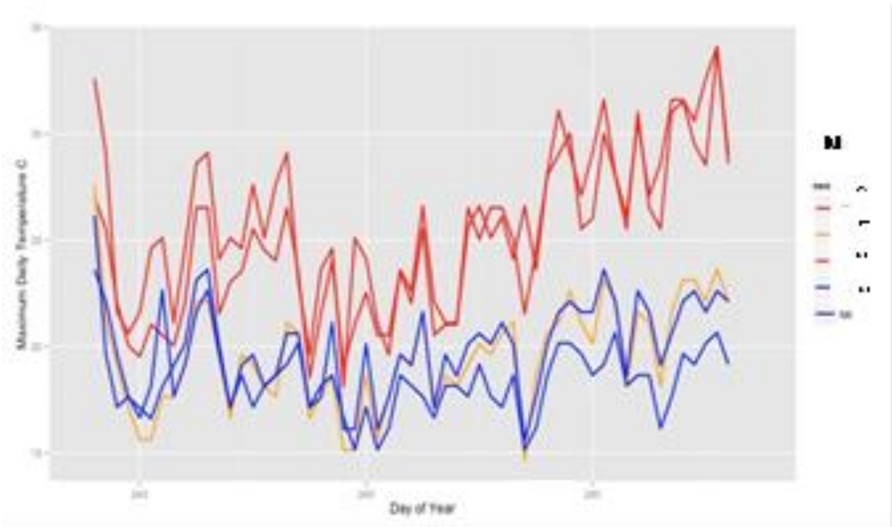

Figure 3: Daily maximum temperature over 60 days in five nests.

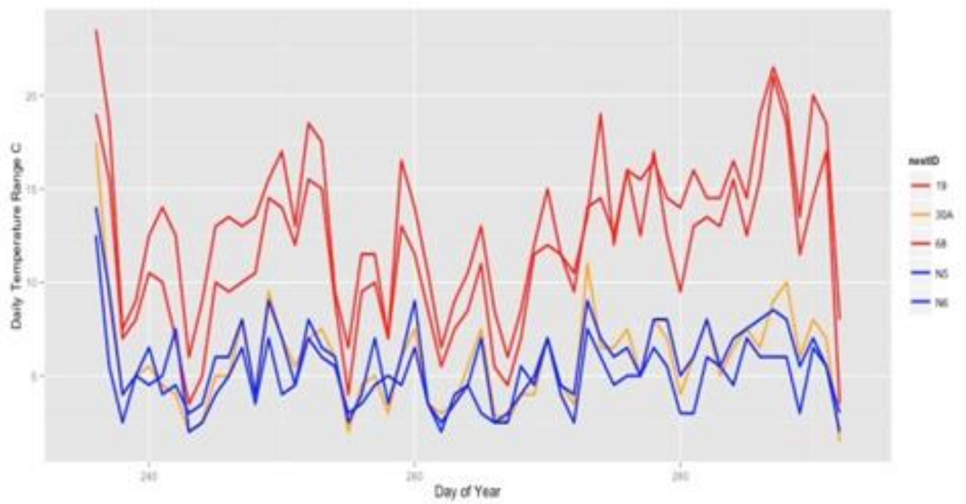

Figure 4: Daily temperature range over 60 days in five nests.

7 Impacts of feral predators on island ecosystems

Nic Dunlop

Conservation Council of WA

The large seabird colonies on Rat Island in the Houtman Abrolhos group were extirpated by the combined impacts of introduced black rat (**Rattus rattus*) and cat (**Felis catus*) as well as guano mining by the 1930s. Both introduced predators were eradicated following a baiting program conducted in 1991, with the last cat dying around 2000. The Rat Island Recovery Project was established to monitor the return of breeding seabirds after an absence of approximately 60 years. The seabird colonies began to re-establish within a decade of the eradication program and the number of species and breeding pairs on Rat Island increased dramatically in 2011 and 2012. The recovery of the seabird colonies presents a number of management issues on an island where human uses have developed in their absence. Management decisions will also need to be made about whether to enhance the recovery of important natural processes by facilitating the restoration of some of the conservation values lost from the terrestrial ecosystem on Rat Island.

Table 1: Rat Island Recovery Project records of breeding seabird numbers, colony areas and estimated colony densities on Rat Island from 2003 to 2013.

SEABIRD SPECIES	DATE ESTIMATED	AREA OCCUPIED (hectares)	ESTIMATED DENSITY (pairs / hectare	COLONY SIZE (Pairs on Rat Island)
Bridled Tern 2003	Dec-2003	-	-	6
Bridled Tern 2008	Dec-2008	-	-	50-100
Bridled Tern 2011	Feb - 2012	6.9	25	174
Bridled Tern 2012	Dec - 2012	8.4	25	210
Fairy Tern 2008	Dec - 2008	3.0	-	750
Sooty Tern 2011	Feb-2012	2.0	-	5000
Sooty Tern 2012	Dec-2012	29.52	2400	72324
Roseate Tern	Dec-2012	0.09	-	300
White-faced Storm-petrel 2012	Aug-2012	0.14	51	27
Caspian Tern 2012	Aug & Dec-2012	-	-	1
Pacific Gull 2012	Dec-2012	-	-	1
Silver Gull 2013	Apr-2013	1.35	44	60

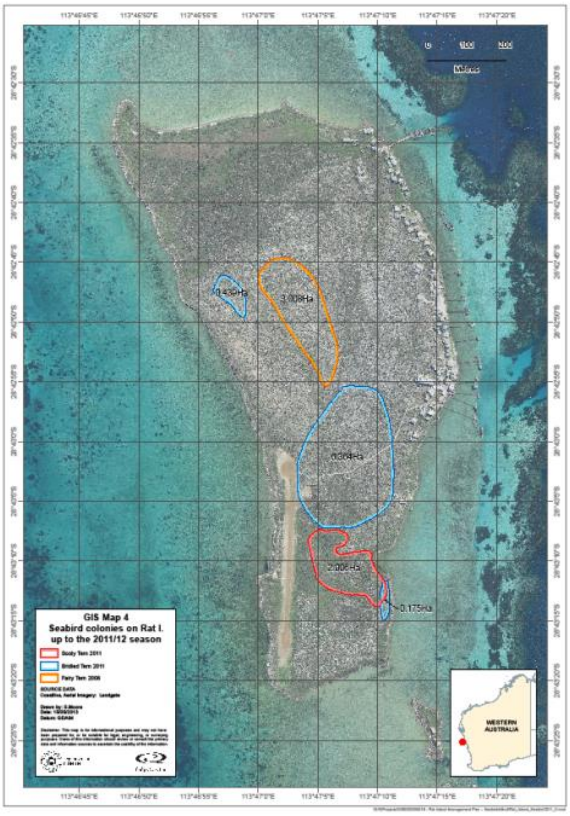

Figure 1: Seabird colonies up to the 2011–12 season.

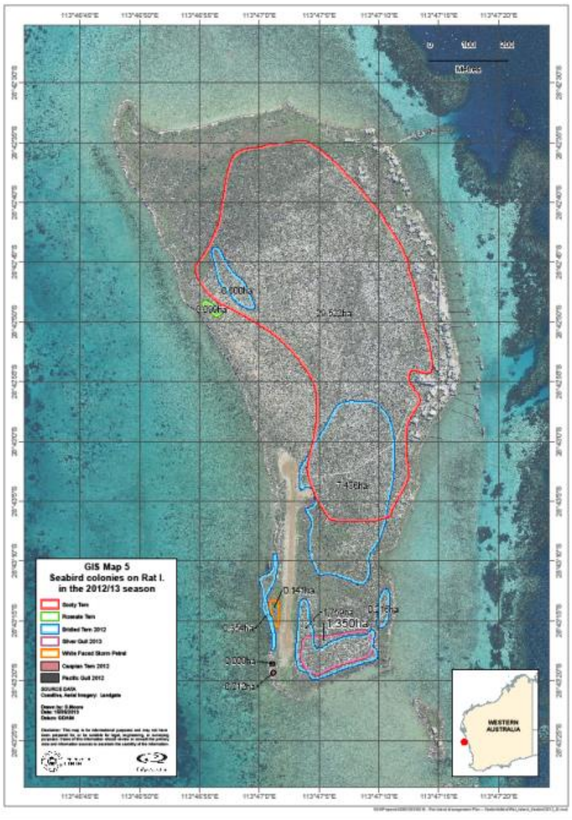

Figure 2: Seabird colonies in the 2012–13 season.

Figure 3: Transect-based density sampling (above), along with systematic day and night searches to locate and count nest sites, counts of birds flying over colonies (right), and mapping colony boundaries (above) were used to census the dramatic seabird recovery on Rat Island just over a decade after the last feral predator was eradicated.

References

Dunlop JN, Rippey, E, Bradshaw LE & Burbidge AA (2015) Recovery of seabird colonies on Rat Island (Houtman Abrolhos) following eradication of introduced predators *Journal of the Royal Society of Western Australia* 98, 29–36.

8 Control and eradication of black rats (**Rattus rattus*) on Penguin Island, Western Australia, December 2012 – December 2014

Karen Bettink

Department of Parks and Wildlife, Swan Region

Background

Penguin Island off the coast of Rockingham is a relatively small island of 12ha but is a hugely popular international tourist and recreation destination. It is also home to the largest and most northern breeding colony of little penguins (*Eudyptula minor*) in Western Australia, resident large colonies of breeding pelicans (*Pelecanus conspicillatus*), a range of migratory tern species (*Sterna* spp.) and Australian sea lions (*Neophoca cinerea*). As one of the few other mammals present on the island, pest house mice (**Mus musculus*) have been known to occur here for many years. However, in early 2011 secondary signs of invasive black rats (**Rattus rattus*) were observed, followed by confirmation of their presence on remote cameras in June 2012. The rat incursion was most likely a result of one or more stowaway individuals in construction materials or boats, or alternatively but less likely, by animals moving across shallow water on the sandbar at low tide.

Black rats are one of the most widespread and destructive invasive animals in the world, implicated in decline and extinction of small native mammals and seabirds on island environments. Black rats are known as ecosystem transformers, they directly prey on bird eggs, chicks and adults, consume seeds, vegetation and a range of invertebrates and other small vertebrates. Unlike house mice, black rats are considered a significant threat to nesting seabirds on Penguin Island, in particular the little penguin colony. An attempt to eradicate the black rat population was considered vital for the protection of the island's seabird colonies, as well as the protection of the island's conservation values.

Impacts on Penguin Island biodiversity

A range of impacts on the island's biodiversity were observed up until an eradication program commenced. In 2012, changes in food availability led to a marked decline in little penguin breeding, undoubtedly worsened by black rats predating on eggs, chicks and fledglings. Over the breeding period of migratory bridled terns, normally 2000 fledglings are reared on the island, however in 2012–13 only eight were recorded. Dorsum and tail injuries to King's skinks (*Egernia kingii)* were commonly observed. Rats were also observed consuming fruit, seeds and ringbarking vegetation, possibly with the aim of gaining water where none was available.

Figure 1: Typical injuries noted (left to right) to little penguin chicks, adult little penguins and bridled terns.

Methods

Planning for the eradication program, including obtaining necessary permits and ethics commenced in July 2012, was chiefly led by Parks and Wildlife Swan Coastal District staff with support from Science Division and Penguin Island staff members. Commonwealth approval was sought through the Australian Pesticides and Veterinary and Medicines Authority to use X-Verminator (active constituent brodifacoum 0.05g/kg) off-label in Australia. This formulation featured high dose brodaficoum lacking wax-based deterrents, designed for eradication programs often in island settings. The application included an Environmental Risk Assessment outlining the risk to non-target species and mitigation measures. Conditions on the permit granted (permit number PER13612) included a strict timeframe for checking and removal of rodent carcasses, considered important for minimising secondary poisoning by foraging birds of prey and reptiles. Animal Ethics Committee approval was required to undertake monitoring of fauna on the island. Once this was gained, a detailed schedule for baiting and monitoring was developed.

Baiting commenced in January 2013, following the timeline set out in the permit's conditions. Although this fell within the hottest periods of the year, it was deemed an optimal period for baiting as it represented the interval between most seabird nesting and when food resources for the rats on the island were at the lowest. To develop bait stations to maximise rat access but limit non-target species access, various bait station designs made up of 15L square PVC buckets were trialed across 32 days between December and January. The aim of these designs was to exploit ecophysiological differences between rats and non-target species. Ten remote cameras were used to monitor activity in stations containing non-toxic X-Verminator baits threaded onto metal pins. King's skinks were found to be particularly attracted to the baits but difficult to exclude owing to agility and climbing ability. However after testing a range of hole heights, diameters and sleeves, a final design of 50mm hole diameter, 70mm long PVC sleeves and buckets raised 20–30mm were deployed across the Island.

Figure 2: Bait station design showing raised 15L bucket with sleeves and black rat about to enter (left) and King's skink (right) attempting to enter raised station.

Baiting

Baiting was undertaken on a grid across the entire island with 20m intervals, following similar rat control programs on islands in eastern Australian states. From spatial assessment initially it was thought 270 stations would be adequate, however owing to the hilly diverse terrain, 350 stations were required to effectively cover the island (Figure 3). All stations and monitoring points were assigned grid references and recorded by differential GPS.

On low, rugged, inaccessible limestone cliffs and scree areas that were deemed unsafe and unsuitable to deploy bait stations normally, buckets were lowered by rope or placed into position by boat. In other inaccessible areas including thickets of *Nitraria* hand broadcasting of X-verminator pellet bait at nominal rates of 12kg/ha and 8kg/ha (two applications 10–12 days apart) was undertaken during periods of clear weather.

Baiting commenced on 14 January 2013, taking two full days to bait all stations. Subsets of bait stations were sampled every three days to record percentage classes of remaining bait which indicated bait uptake and rat activity. After five days, poisoned black rats and carcasses were observed.

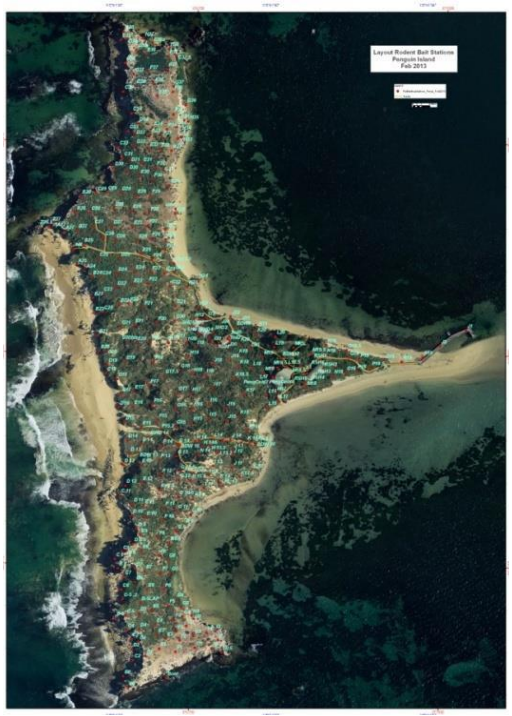

Figure 3: Map of entire island showing locations and label of bait stations.

All stations were rebaited after 10 days, which allowed sufficient time for dominant rats to consume lethal doses of bait. Several stations, sleeves and bait storage containers needed replacing after being chewed through by black rats. In several locations including north east caves, where it appeared there was bait station avoidance, sets of individual toxic and non-toxic bait blocks were wired together and hung from cave edges and Nitraria thickets off the ground to allow rats to consume baits while limiting skinks' access. Camera evidence and excessive chewing of bucket exteriors in late February indicated that a remaining set of very large/obese, sub-adult and juvenile rats had difficulty accessing holes in stations with sleeves, thus sleeves were removed, leading to an increase in King's skink mortality.

After originally proposing that 2–3 baitings of the entire island would be sufficient, five full baitings were required, likely due to the high population density of rats and complexity of habitats. The last full baiting of island was 28 March 2013. Baits were removed from most stations 15 April 2013, excluding key stations identified as high risk**.**

Monitoring

A range of monitoring was undertaken prior to and during the program. A rat carcass tethering trial with remote cameras was conducted to observe what, if any, native species are attracted to and predate the rodent carcasses, and therefore assess what impacts there may be from secondary poisoning once the baiting commenced.

Three permanent trapping transects (Sheffield cage traps and Elliot traps) were established across the island. Traps were opened at dusk to minimise reptile and buff-banded rail captures.

Thirteen remote cameras (Reconyx HC500/600) were initially deployed to monitor bait stations and lures. Lures were refreshed monthly and camera images downloaded and reviewed fortnightly for rat activity. Five of these were retained for longer-term monitoring beyond the eradication program.

Carcass tethering trial

The carcass tethering trial indicated that several species displayed interest in rodent (both rat and mice) carcasses, however only Australian ravens (*Corvus coronoides*) took entire mice, while King's skinks and other rats predated rat carcasses (Figure 4).

Figure 4: Images from remote cameras during carcass tethering trials showing a black rat predating the tethered rat carcass (right) and a silver gull pulling at a tethered rat's tail (left).

Carcass checks

During carcass checks, a total of 123 black rat carcasses were collected and disposed of in deep landfill off the island. In total, eight adult King's skink carcasses were retrieved; the majority in late February/March after sleeves were removed. The preliminary necropsy confirms death by haemorrhaging, likely a result of brodicaoum poisoning. An additional number of other skinks were successfully treated with vitamin K and released. Two feral pigeon carcasses were also retrieved, with cause of death unknown.

Trapping transects

Initial (pre-baiting) trapping saw 13 rats of various ages captured along with a small number of house mice (4) and a larger number of King's skinks (19). Subsequent trapping in April saw one adult female rat trapped, with several house mice and little penguins. Follow-up monitoring in July recorded no rats, but increased levels of house mice (17) and silver gulls (5).

Camera traps

Camera images during the first several weeks showed extreme levels of rat activity, including during daylight hours (Figure 5). “Events” were deemed as captures separated by at least 60 seconds. Adult rats initially dominated bait stations. This activity declined dramatically from January to late February. Nights of lower rat activity from February onwards saw increased activity of native species, including penguins and bridled terns. First records of other species occurred in mid to late March, including a small skink (*Morethia* spp.), marbled gecko (*Christinus marmoratus)* and willy wagtail (*Rhipidura leucophrys)*.

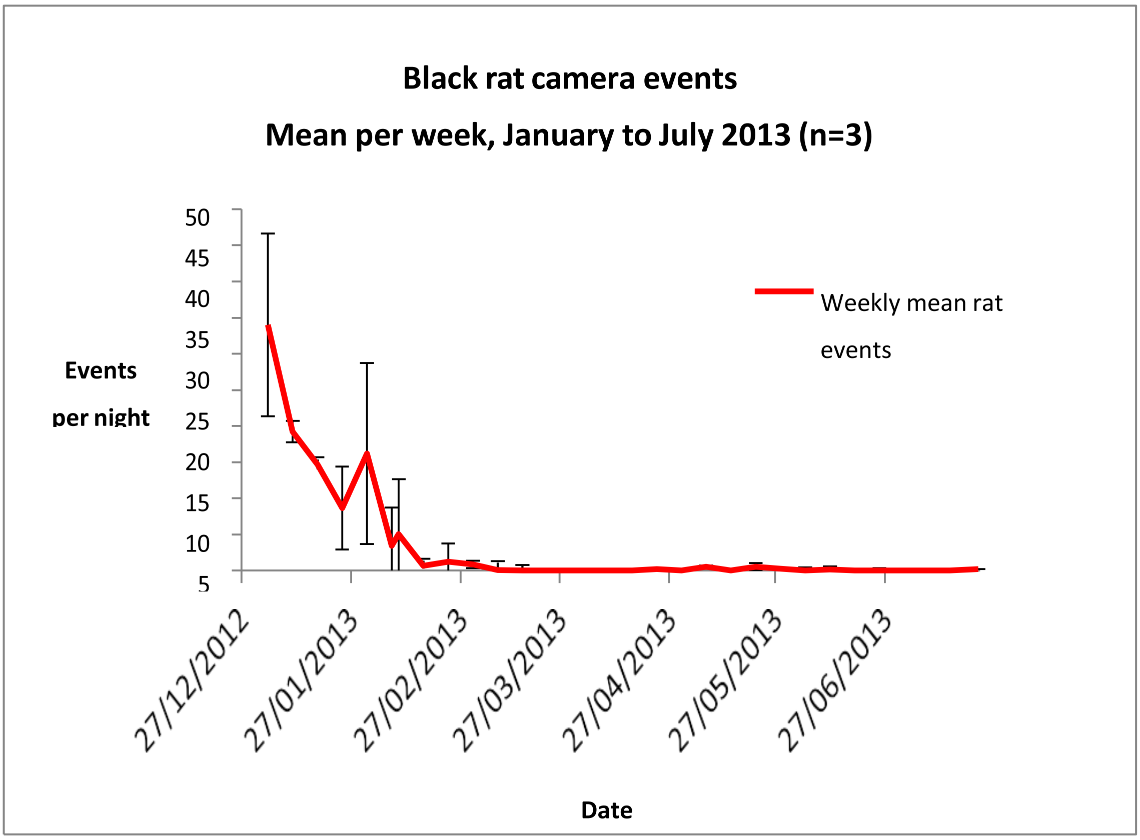

Figure 5: Rat activity recorded as mean number of events per night on remote camera over one week intervals from January to July 2013. Separate events were defined on intervals of one minute.

Discussion

The program was successful in dramatically reducing rat numbers from several thousand to only occasional sightings of single rats, including the last sighting in August 2013, which was targeted immediately with rebaiting.

Initial high number of rat captures in monitoring transects have given way to increased captures of house mice, an expected result after steep declines in rat abundance.

King’s skink captures were highest in January then declined in April until no captures were recorded in July, partly due to altering setting traps to after sunset, after which time the skinks became inactive, and partly due to slowing of skink activity with the onset of cooler weather. While King’s skink deaths from brodifacoum poisoning were recorded it is unlikely this was the main driver in changes in trapping rates.

Remote cameras were integral to developing bait stations that were effective in excluding most King’s skinks but allowing rats ready access.

Camera images for different stations over the weeks when rat activity (number of events) started to dramatically decline show native species’ activity increased. Species with increased activity included little penguins, bridled terns and buff-banded rails and the first record of *Morethia* sp., willy wagtail, brown honeyeater and marbled gecko occurred after March and April when rat activity was almost zero.

Adaptive management and team work have been central to overcoming challenges and achieving the goals of the program. A number of significant challenges included working in difficult and unstable limestone rocky terrain, inaccessible (except by boat) cliff edges, extreme heat (up to 42°), peak tourist visitation periods and minimising disturbance to vegetation and roosting and breeding seabirds (including large pelican roosts at southern and northern ends of the island). Coordinating the range of groups assisting was a significant task.

Despite this, non-target species impacts were effectively minimized and all operations were undertaken within animal ethics approval parameters. Elimination of the majority of rats has allowed terrestrial and sea birds to commence breeding while eggs and chicks are protected with the hope that populations will recover. As of October 2015, it has been two years since the last rat detection on the island, however to ensure the island remains free of invasive rats a set of key of recommendations have been made.

Monitoring and surveillance

Monitoring and surveillance for the rapid detection of rat outbreaks and/or new incursions is critical for rapid response.

Response to outbreaks

Responses to detections should be initiated immediately, and involve rebaiting stations in a radius of 100m. Monitoring effort should be increased in the area. Carcass collections will need to occur daily to weekly up until 100 days post-baiting.

Biosecurity

A biosecurity plan to ensure no invasive rats are able to be transported to the island should be developed as soon as possible, including quarantine of materials (particularly for construction) and changes to public mooring policies.

Use of lower toxicity bait (Pestoff® 20R)

Following initial use of X-Verminator (0.05g/kg brodifacoum) to control the high numbers of rats on the island, an alternative less potent rodent pellet bait (Pestoff® 20R with 0.025 g/kg brodifacom as the active constituent) was deployed in a remaining set of key stations in high risk areas near entry points and infrastructure.

This bait have been extensively used and it has proven efficacy in numerous island eradications globally.

Acknowledgements

I wish to thank the following people for their advice, support and particular efforts: Russell Palmer, Nic Dunlop, Aurelie Labbe, Grazyna Packowska, Julia Cullity, Robyn Prior, Nicole Godfrey and Erin Biggs, Jane, Mike Lohr.

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9 Restoring critical habitat on Penguin Island

Kate Brown[1], Aurelie Labbé[2] and Grazyna Paczkowska[1],
[1]*Department of Parks and Wildlife,* [2]*Murdoch University*

Introduction

Historically, the dynamic processes involved in shaping the vegetation on Penguin Island have included trampling and disturbance by seabirds. Dense colonies of nesting cormorants deposited guano and trampled woody shrubs that over time would be replaced by native succulent shrubs such as *Rhagodia baccata* and *Nitraria billarderi* and succulent creepers including *Tetragona implexicoma*, *Enchylaena tomentosa* and *Carpobrotus virescens*. Once the cormorants moved on woody shrubs would eventually re-establish cover until the birds returned to nest and the cycle would start over (Gilham 1961). Sometime after 1961 a large colony of silver gulls (*Larus novaehollandiae*) became established on Penguin Island. Currently large numbers of silver gulls nest on the island each year over the winter months causing extensive trampling, guano deposition and disturbance. In addition the birds are effective carriers of weed seed which are ejected from their crops in a viable form (Gilham 1956, Calvino-Cancela 2011) and in large areas where gulls nest, a cover of nitrogen loving exotic grasses and annuals has now replaced native shrublands. The transition from native shrubs and succulents to a cover of introduced annual grasses following establishment of large colonies of gulls has been reported for floras of small islands across the world (Hogg and Morton 1983, Ellis 2005, Otero et al. 2015).

The vegetation in north east section of Penguin Island has historically been important nesting habitat for bridled terns (*Onychoprion anaethetus)*. The birds return from Japan and Borneo in spring each year to nest and breed. Under bilateral migratory bird agreements with Japan (JAMBA), the Australian Government has undertaken to provide for the protection and conservation of migratory birds, including bridled terns, and their important habitats. In recent years silver gulls have moved into the area and the cover of native shrubs that was important nesting habitat for bridled terns has largely been replaced by a cover of weedy annual grasses in winter/spring and bare ground through summer. Native cover adjacent to the site is largely made up of only two species *Rhagodia baccata* and *Tetragona implexicoma.*

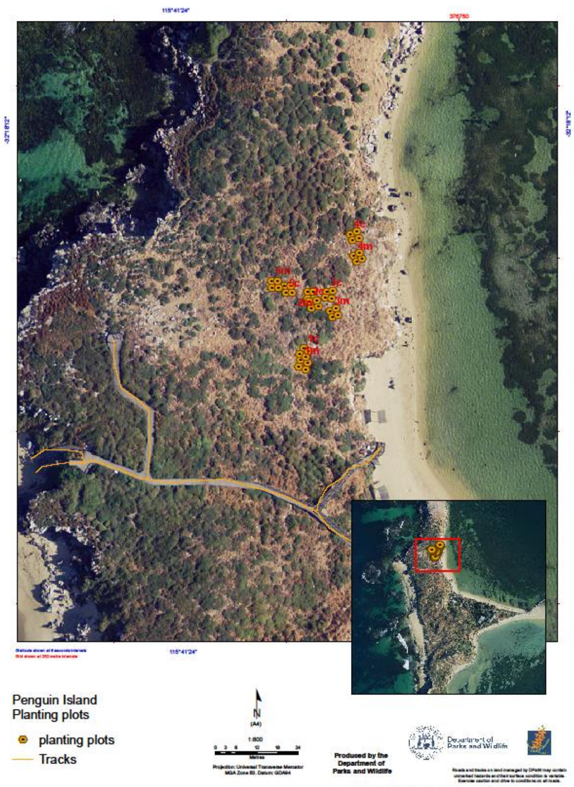

Figure 1: Location of study site.

Trials in 2014 revealed that silver gulls consistently pulled out tube stock across planted sites. By December 2014, of the 490 plants that went into the ground in June, only three survived. The results indicated that to re-establish vegetation cover at the site tubestock required protection from silver gulls until well established. Subsequently, in 2015, we trialled techniques to protect tube stock in the early stages of establishment. In addition brushing and direct seeding with *Rhagodia baccata* were investigated as methods of establishing native vegetation cover. We also investigated the capacity of soil stored seed to return vegetation cover if sites were weeded and protected from silver gulls. The objective of all treatments was to replace dense stands of annual weeds with a resilient native vegetation cover that provided bridled tern habitat.

Methods

In June 2015 five replicates of four different treatments were placed across the study site (Table 1). All treatments were protected with weld mesh cages. The cages were constructed from 3m x 2.4m sheets of weld mesh in the Mandurah Workshop.

Table 1: Treatment plots

Treatment	**Date**	**Size**	**Weeded**	**No. replicates**
Brushed with branchlets of *Rhagodia baccata* covered in ripe fruit	March 2015	1m x 1m	Yes	5
Control	March 2015	1m x 1m	Yes	5
Direct seeding with *Rhagodia baccata* fruit	June 2015	1m x 1m	Yes	5
Planting, no weed matting	June 2015	2m x 1m	no	5
Planting, weed matting	June 2015	2m x 1m	no	5

Figure 2: 1m x 1m trial plot brushed with Rhagodia baccata.

Brushed: Material for brush trials was collected off *Rhagodia* bushes with ripe fruit from across Penguin Island. The brush was collected and laid across plots on 19 March 2015 (Figure 2).

Control: Control sites were hand weeded, sites caged and germination of native seedlings recorded over the 10 month trial period. Plots were hand weeded each month.

Figure 3: Planting trials had paired weed matted (left) and unmatted plots under the same cage.

Planting: Five sites were planted in June with 40 tube stock, 20 in matted and 20 in unmatted, under a single cage. Sites were hand weeded before the matting went down and cover of planted natives and cover of weeds was recorded monthly for 10 months (Figure 3).

Direct seeding: Seed of *Rhagodia baccata* was collected from across Penguin Island in March 2015 and cleaned and stored in the Threatened Flora Seed Centre. In June 2015, 2.4 grams (~250 seed) were sown in each plot following hand weeding and caged. Cover of *Rhagodia* was recorded each month for 10 months. Plots were hand weeded each month.

Results and discussion

Germination in the brushed sites began in early winter and seed germination was prolific (Figure 4) with seedlings rapidly creating cover in the plots (Figures 5 & 6). By September average cover across the five plots was 73 (±10.0% SE) and significantly higher than direct seeded, 10.0 (± 3.4% SE) cover or control sites 3.5 (±3 0% SE) cover (Figure 4).

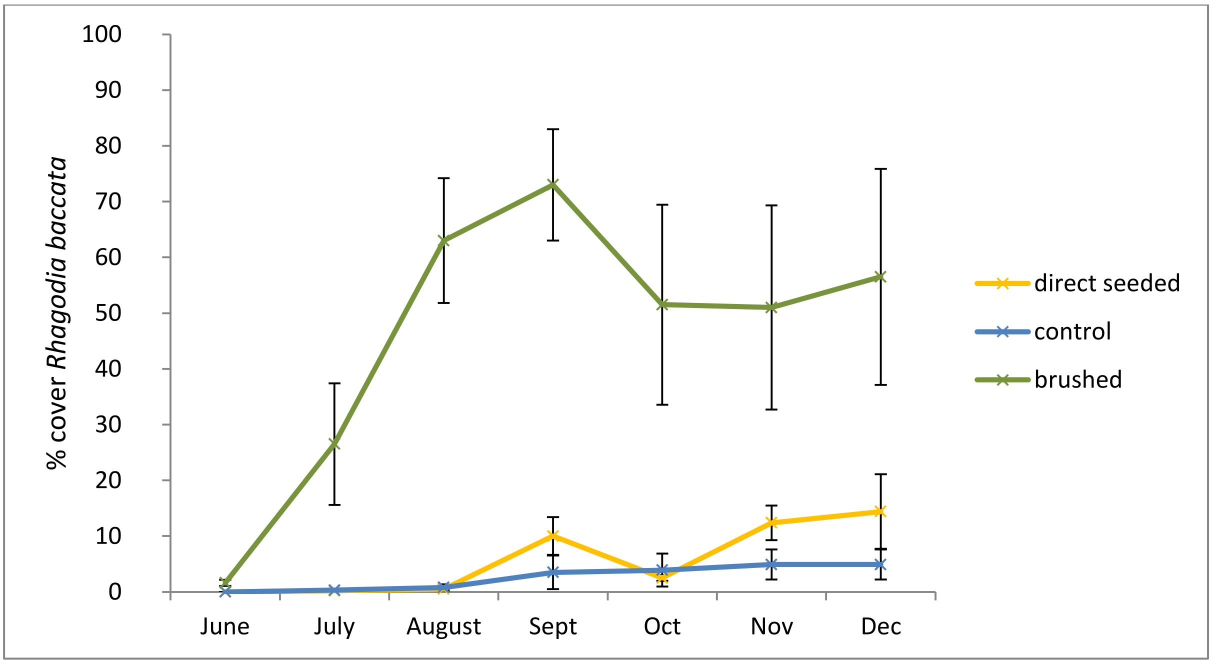

Figure 4: Average % cover Rhagodia baccata *June to December 2015 in treatment plots n=5.*

Figure 5: Rhagodia baccata *seedlings, brushed plot June.*

Figure 6: Rhagodia baccata *cover, brushed plot September.*

Figure 7: Rhagodia baccata *cover, direct seeded plot October.*

Direct seeding in June resulted in significantly lower cover than brushing and only a slightly higher cover of *Rhagodia* than controls (Figure 4 & 7). Germination of *Rhagodia* in the control sites indicates viable seed present in the soil seed bank across the restoration site. Very low numbers of another native, *Enchylaena tomentosa* (ruby saltbush) germinated in two control plots. Germinants in both control and direct seeded plots appeared in July, were very scattered across the plots, and resulted in comparatively low cover of *Rhagodia* by October (Figure 4 & 7**)**

By late October the dense stands of *Rhagodia baccata* in brushed sites appeared to be drought affected. Many seedlings had died and average cover across sites had dropped to 51.5 (± 17.9% SE) but cover was then relatively stable through to December.

Sites planted with *Rhagodia baccata* and *Tetragona implexicoma* in June had 83 (±11.2% SE) average cover of natives by September. Average weed cover was also high by September, particularly in the sites with no weed matting 88% (± 0.0% SE) (Figure 8). The high cover of weeds in unmatted sites appears to have led to a decline in native cover to less than 48 (±6.1% SE) by December. In matted sites, where weed cover was much lower, natives maintained over 80% cover though to December (Figure 8).

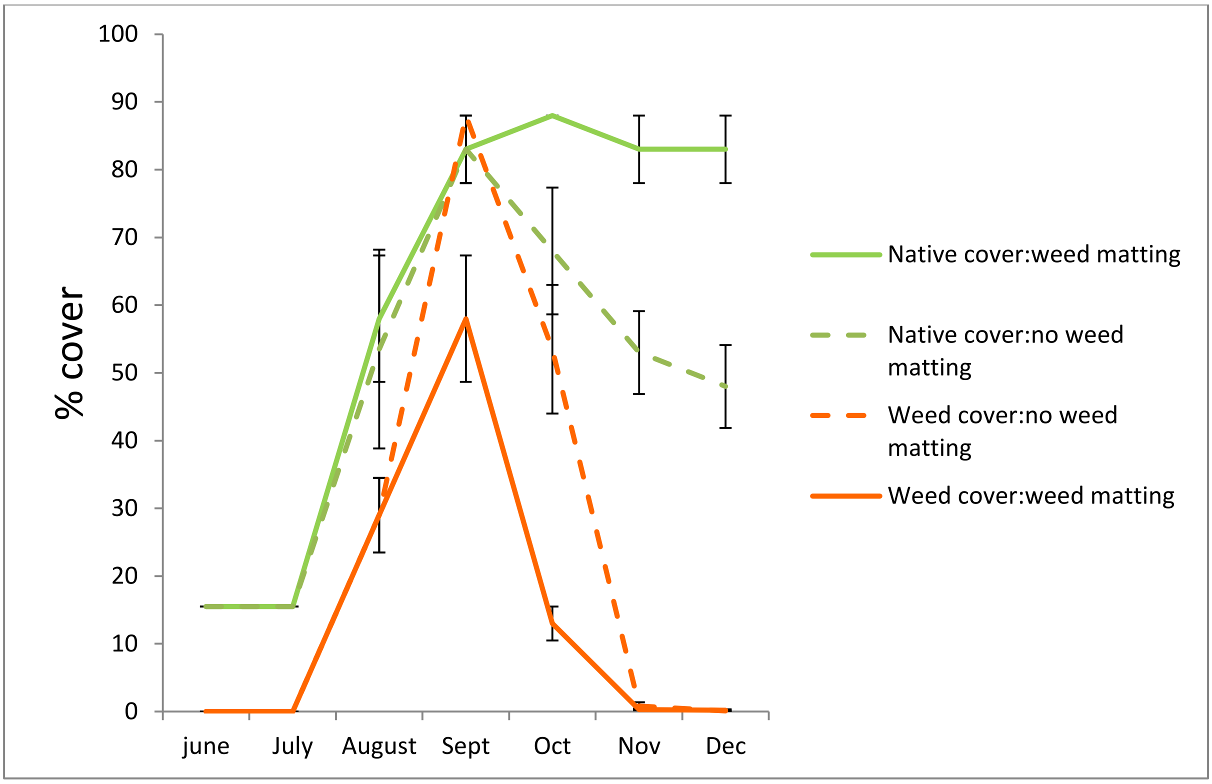

Figure 8: Average % cover of natives and weeds in matted and unmated plots June to December 2015.

Conclusions and recommendations

- Brushing using *Rhagodia baccata*, with no cost for plant material, was the most cost effective method of creating native cover.
- The rapid die-off of seedlings in September/October could be prevented by thinning seedlings out early in the season allowing the fewer remaining plants to develop adequate root systems and survive spring/summer drought.
- Brushing with other species including *Tetragona implexicoma* and *Enchylaena tomentosa* could be trialled.
- Native seedling germination in control sites indicates that there is a native soil seedbank present at the restoration site. Simply hand removing annual weeds early in the season and placing weld mesh cages over weeded sites to protect germinating seedling from gulls would be cost effective method of restoring native shrublands. Indications are it will be very slow in the first year. Follow up weeding will be required at least over the first year until a cover is established. A great project for volunteers.
- Direct seeding was not cost effective and did not create significantly more cover than controls.
- Planting and matting, while the most expensive option, created over 80% native cover through to December. It also allowed establishment of *Tetragona implexicoma*. Plants of this species were grown from cuttings. We have not been able to grow them from seed. The species creates a significant cover on Penguin Island and is important habitat for nesting seabirds including little penguins

(*Eudyptula minor*). When funding is available planting tubestock into weed matting and caging is a very effective method of establishing native cover.

- All these result are as of December 2015. Results following 2015/16 summer and removal of weld mesh cage in March 2016 are required before final management recommendations can be made.

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10 Re-introducing the Australian Hollyhock, (*Malva preissiana*) to Penguin Island

Kate Brown[1], Aurelie Labbé[2], Grazyna Paczkowska[1] and Leonie Monks[1]
[1]*Department of Parks and Wildlife,* [2]*Murdoch University*

Introduction

Malva preissiana or Australian hollyhock only occurs on offshore islands around the western and southern coasts of Australia. Its life cycle is linked to that of nesting seabirds and it grows specifically in their guano deposits. The habitat is nutrient rich, continually disturbed by seabird trampling and highly susceptible to weed invasion.

Figure 1: Malva preissiana *on Carnac Island.*

Competition from weeds including the introduced **Malva dendromorpha*, **M. pseudolavatera,* annual grasses including **Lolium* spp., **Bromus* spp. and from ice plant **Mesembryanthemum crystallinum,* has had a major impact on populations on islands along Perth's coast including the Shoalwater Islands. Over the last 20 years *M. preissiana* has gone extinct on Rottnest, Green, Bird, Seal, and Penguin islands. Carnac and Shag islands now support the only population of *M. preissiana* in the region (Figure 1). Over the last five years seed has been collected from the Carnac Island population and stored at the Department of Parks and Wildlife Threatened Flora Seed Centre.

Figure 2: Location of trial sites.

The type collection (the first collection of the species and the specimen for which the species is named) was from Penguin Island on 11th of November 1839 by German naturalist Ludwig Preiss. Unfortunately *M. preissiana* disappeared from Penguin Island sometime in the 1970s. There were many factors that may have led to the decline of the Penguin Island populations including increasing numbers of silver gulls (*Larus novaehollandiae*) and associated weed invasion, direct competition from the introduced **Malva dendromorpha*, establishment of large pelican (*Pelecanus conspicillatus)* rockeries and guano mining in the southern parts of the island.

Our project aimed to evaluate establishment techniques for the reintroduction of *M. preissiana* to Penguin Island. As well as being the type location, it is the most accessible of the Shoalwater Islands allowing for consistent monitoring and management of trial sites. Once techniques have been established through small scale trials, the aim is to investigate the feasibility of establishing self-sustaining populations on Penguin Island. The Australian hollyhock once formed an important component of the island's vegetation and this reintroduction is part of a larger restoration program for the island.

Methods

Figure 3: Direct sewing Malva preissiana *seed.*

In June 2014 10 pairs of 50 x 50cm trial plots were established in old pelican nesting sites at the northern end of the island (Figure 3Figure). All weeds were hand removed from one plot in each pair, in the other plot weeds were left in place. All plots were then direct seeded with *M. preissiana* from the Carnac Island collections. Each of the plots was sown with 48 seed. Half of these seed (24) had been pre-treated by nicking the seed coat using a scalpel prior to planting (this was done under laboratory conditions the week before planting and then the nicked seed was transported to the island in paper envelopes). The remaining seeds (24) were not nicked. Seed were sown by hand 3–4mm below the surface. Seedling germination and survival were monitored each month through to December 2015. Follow up weeding (in the weed treatments) was also carried out as each plot was monitored.

Results and discussion

Nicking and weeding had an initial germination rate of only around 6% (average of 2.8 seedlings) and no treatment, (not nicked, not weeded) a little over 2% or just over one seedling per plot (Figure 4). Plots were trampled by gulls and pelicans in the month after sowing and this impacted on germinating seedlings. Some plots were more disturbed than others and there was high variation in survival rates across replicates. By December 2014 an average of less than one plant per plot survived in the nicked and weeded plots and none in the untreated plot.

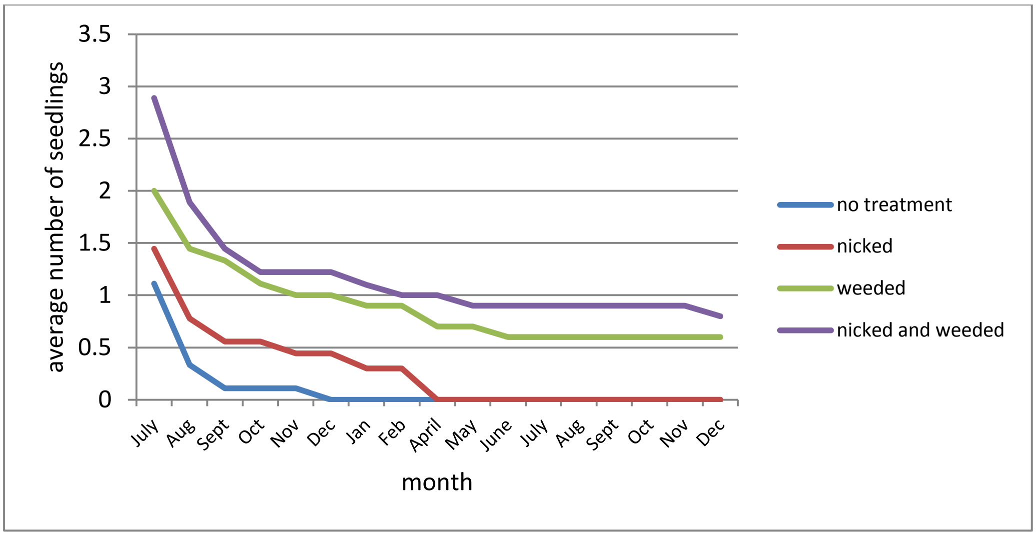

Figure 4: Average number of Malva preissiana *seedlings in 50cm x 50cm treatment plots (n=10) on Penguin Island over winter/spring/summer 2014 and 2015.*

While germination and establishment rates were not high, the trials provided information on survival rates of seed and establishment rates of reproductive individuals under natural conditions including trampling and disturbance by gulls and pelicans.

In addition, 60% of weeded plots and only 20% of unweeded plots contained flowering and fruiting individuals by December 2014. Removal of competition from weeds does appear to be important for establishment of populations (Figure 5). Of the plants that did survive most went onto flower and produce fruit. In addition a number of 50cm x 50cm plots were filled by a single individual (Figure 5). The decreasing number of plants per plot over time may partly be explained by competition from adjacent *M. preissiana* seedlings (self-thinning). Most plants that survived the 2014/15 summer and made it through to spring 2015 flowered and seeded prolifically (Figure 6).

Figure 5: Weeded (left) and unweeded plots (centre) and an individual in a 50cm x 50cm plot flowering in October 2014.

All fruit examined on plants in 2014 appeared to be heavily predated and on the December 2014 monitoring trip invertebrate samples were collected. They were identified as seed bug, *Oxycarenus arctatus*, also commonly known as the coon bug, a ladybird beetle in the genus *Telsimia*, most likely an undescribed species, and a beetle larvae. Heavy seed predation has been observed on populations of *M. preissiana* in most seasons. Some years though, for example 2014 on Carnac and 2015 on Penguin Island, little predation was evident.

Management implications

- The results indicate direct seeding combined with weed control is a useful technique for reintroducing *M. preissiana* to Penguin Island and that plants can go on to flower and set seed in the first year.
- Based on the results of these trials if 5000 seed are directly sewn across a 20m by 20m area where weeds are controlled, around 100 plants should become established, a figure close to the natural densities on Carnac Island.
- While nicking seed appeared to result in higher germination rates seed germinated without nicking. Nicking is an expensive pre-treatment. Sowing higher numbers of seed rather than nicking could be an option. If seed is limited other pre-treatments such as hot water could be investigated.
- Disturbance by trampling birds impacted on successful establishment. We did attempt to discourage seagulls using fishing line strung across the plots. This was unsuccessful. One option is to cage the sites. However given there was survival without caging and trampling is a part of the system and habitat, it is not a preferred option.

Conclusion

These trials have provided a management framework for the reintroduction *M. preissiana* to Penguin Island, an important part of the larger restoration plan for the island. The next phase of the project will involve acquiring resources to scale up the trials and through an adaptive management process, establish self-sustaining populations on the island.

Acknowledgements

Thanks to Melinda Moir for identification of invertebrates, Department of Parks and Wildlife staff on Penguin Island for ongoing support and field assistance and to Elizabeth Rippey for generously sharing her knowledge of the vegetation of Perth's islands.

Figure 6: Individual of Malva preissiana *flowering and setting seed 17 months after germination, October 2015 Penguin Island.*