Population estimate of the Little Penguin colony on Penguin Island during September to November 2023

A report for City of Rockingham

Dr Belinda Cannell

University of Western Australia

April 2024

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1. Executive Summary

The Little Penguins on Penguin Island have been studied over the last three decades. Since 2010, many fewer penguins have been attempting to breed in the nestboxes, which have been monitored for nearly 30 years. A marine heatwave in late 2010/early 2011 and generally warmer sea surface temperatures (SST) in the local coastal waters in most years since is thought to be associated with an overall reduction in prey availability, and years of poorer breeding outcomes for the penguins.

Little Penguins are very faithful to a colony, returning to the colony each year to breed. They also return to the colony where they hatched, and are faithful to an arrival beach. Mark-recapture studies conducted on four arrival beaches on Penguin Island, in conjunction with counts of penguins arriving on beaches around the island, have been conducted six times since 2007. The population has exhibited a declining trend, and has decreased 94% since the highest estimate in 2008. An estimated **114 (± 29 SE),** 95% CI: 69-188, **individual** penguins were present on the whole island between September to November 2023, when the mark-recapture study was conducted. It is possible that the reduced estimate is due to penguins taking a break from breeding and/or a population decline.

The population decline can be due to multiple factors: 1) fewer penguins participating in breeding across multiple years, which results in fewer chicks available to recruit back into the population, 2) a reduction in breeding success across multiple years, which results in fewer chicks available to recruit back into the population, 3) a reduction in the survival of fledglings, which results in fewer two to three year old adults returning to the colony and 4) changes in the mortality rate of the adults.

A range of factors are linked to population decline. These include: reduced food availability; increasing terrestrial temperatures, which can cause mortality of both chicks and adults from hyperthermia; penguins being able to access their nest sites, which can be affected by storm damage, overgrowth of plants and anthropogenic changes to arrival sites; recreational watercraft injury; and predation.

Given the range of factors involved in the decline of the penguins, it is imperative that any management strategies developed be aligned in both the state and local government agencies to ensure that the recreational needs of the people are matched with the conservation needs of the Little Penguins from Penguin Island. Furthermore, to avoid serious impact on the penguin population, it will be necessary to consider the implications of additional structures, such as boat ramps and other infrastructure, within the penguins' home range using robust methods such as

decision-support tools. Previous tracking studies have identified that the penguins' home range extends from Cockburn Sound to Geographe Bay, and is dependent on where they nest on the island.

2. Introduction

Little Penguins on Penguin Island have been studied over the last three decades. These seabirds are recognised as key bioindicators for coastal marine environment health as they are relatively easily studied and hence changes in specific parameters can be readily determined. In 2003, it was identified that the penguins from Penguin Island were under threat (Department of Conservation and Land Management, 2003). Moreover, they are key performance indicators for the Shoalwater Islands Marine Park (Department of Environment and Conservation, 2007)

However, since 2010, many fewer penguins have been attempting to breed in the nestboxes, which have been monitored for nearly 30 years (Cannell *et al.* 2023a). Even though the breeding success has been variable since 2010 (Cannell *et al.* 2023a), the years of poorer breeding success have been associated with lower annual abundance of baitfish in the penguins' foraging areas (Moss pers. comm)[1]. The overall reduction in prey availability is thought to be associated with a marine heatwave in late 2010/early 2011 (Cannell *et al.* 2012, Cannell *et al.* 2023a) and generally warmer sea surface temperatures (SST) in the local coastal waters in most years since (Cannell *et al.* 2023a). It was thus surprising fewer penguins attempted to breed in 2016, when SST were below average, compared to 2014, when the SST were warmer (Cannell *et al.* 2023a).

In addition to the reduced breeding participation and varied success since 2010, penguins incubating eggs were often at sea for much longer than the average three to five days (Chiaradia & Kerry 1999), as determined by tracking studies. Many of those tracked penguins travelled more than 150 km south to forage in Geographe Bay and beyond (Cannell 2014, 2015, 2016, 2017, 2018, 2019). This southwest region is thus important for breeding penguins on Penguin Island. It comes as no surprise then that penguins are less likely to even lay eggs when baitfish availability in the southwest region is reduced (Cannell *et al.* 2023a), which suggests that this region is also important for pre-breeding penguins. Thus, recent studies, in part supported by the City of Rockingham, have identified that

[1]It is noted that it would be preferable to have measures of abundance, as derived from commercial fishing data. However, DPIRD are unable to supply data for a fishing block*species if there are less than three commercial fishers. Thus Moss, who is a commercial baitfisher within penguin foraging habitat, has supplied the "anecdotal" evidence, which was based on his commercial catches.

changes in the marine ecosystem have impacted the penguins. In essence, this coastal marine system has not supported a high proportion of breeding penguins.

Little Penguins are very faithful to a colony, returning to the colony each year to breed. So annual adult survival is important for population growth of Little Penguins. However, Little Penguins return to their natal colony, i.e. the colony at which they hatched, and do so when they are approximately two to three years old to start breeding (Dann & Cullen, 1990; Dann, 1992). So, both chick production and survival of the juveniles over that two to three year period are also important for population growth, perhaps more so than adult survival (Sandvik et a. 2012). Since 2007, when population estimates began, the population of penguins using the island from September-November (during the typical latter half of the breeding season), has declined by 80% (Cannell *et al.* 2023a) and was estimated at 309 **individual** penguins (95% CI=251-381) in 2019. This was despite both highest breeding success ever recorded in 2016 (Cannell *et al.* 2023a) coinciding with increased baitfish presence, healthy stocks of baitfish seen by local commercial fishers in late 2018-early 2019 (Moss pers. comm), and cooler than average SST in the first half of 2019 (Cannell *et al.* 2023a).

Since the 2019 estimate, the annual breeding success has been both below and above average (LPWG meeting minutes). Despite this, breeding participation has remained low, and there appeared to be limited evidence of the penguins on the island in July 2023 (LPWG meeting notes). This was unusual, given that there is often a peak of breeding in June (Wienecke 1993, Wienecke *et al.* 1995, Cannell *et al.* 2023a and b). Proposed changes in the infrastructure on the island, and in Cockburn Sound where some of the penguins on Penguin Island forage, could potentially impact the penguins if not managed appropriately.

3. Purpose and Aims

The overall purpose of this project is to understand the size of the current population to help refine the management required both on the island and in the marine environment.

The aims of this study were to determine:

1) the population of Little Penguins during September to November 2023, and

2) if the population is in decline.

4. Methodology

4.1 Study Area

Penguin Island (32°18'S, 115°41'E) is a 12.5 ha limestone island that lies 600 m offshore, approximately 50 km south of Perth, Western Australia (Fig. 1). Both the northern and southern ends of the island are limestone plateaux that reach 10-12 m above sea level (Chape 1984). Sand beaches surround the eastern and central western sections of the island.

Fig. 1. Location of Penguin Island, Western Australia, indicated by the red dot, is approximately 50 km south of Perth (green dot) and 600 m offshore.

4.2 Field Methods

Definition of Population Sampled

Penguins breed asynchronously on Penguin Island, with eggs laid from April to December (Wooller *et al.* 1991). Peak numbers of eggs generally are laid in June and September (Dunlop *et al.* 1988, Cannell *et al.* 2023a and b), although the timing and number of peaks does vary with year (Cannell *et al.* 2023b). The asynchronous breeding means that on any given night in the breeding season, the birds coming ashore could be prebreeding adults involved in courtship or prelaying attendance, partners of penguins incubating eggs or guarding chicks, or have post-guard phase chicks. Courtship generally occurs about one month before egg lay and lasts for five to six days (Chiaradia & Kerry 1999) and prelaying attendance at the nest site occurs one to two weeks before egg lay. Eggs are incubated for five to six weeks, chicks are guarded for two to three weeks after hatching, and chicks fledge at approximately eight weeks of age. During incubation, the penguins take turns to forage at sea, and on Penguin Island, the observed maximum duration of a single incubation foraging trip has been 20 days (Cannell unpub.data). During the guard phase, the penguins alternate between guarding the chicks and foraging for one to two days. After this guard phase, both parents forage every day. After each foraging trip, the penguins return in the evening to their nest site, and use an arrival beach which they have a high site fidelity to i.e. a penguin caught at one arrival beach will not be caught at another arrival beach (Cannell *et al.* 2011, Cannell *et al.* 2023a). As the beach captures coincided with breeding, and encompassed a seven-week block, we were likely to catch penguins that were involved in two to three of these breeding stages. In addition to breeding birds, both juveniles and non-breeding adults could be caught (Dann & Cullen 1990; Sutherland & Dann 2012). However, as only a few chicks are marked at fledging and juveniles are similar in appearance to adults, it is not possible to identify any unmarked bird as either a juvenile (1-2 years old), or an adult (≥3 years old). Thus, the population sampled during the mark-recapture is composed of breeding adults and potential breeders.

Beach Counts

Counts of arriving penguins were conducted on a single night in July and November at 15 sites around Penguin Island (Fig. 2). Four of the sites were also used for the beach captures for the mark-recapture study. Using all these sites, the majority of available landfall sites around the island were surveyed. Cliffs located at both the north and south end of the island (Fig. 2) prevented penguins from landing in these areas.

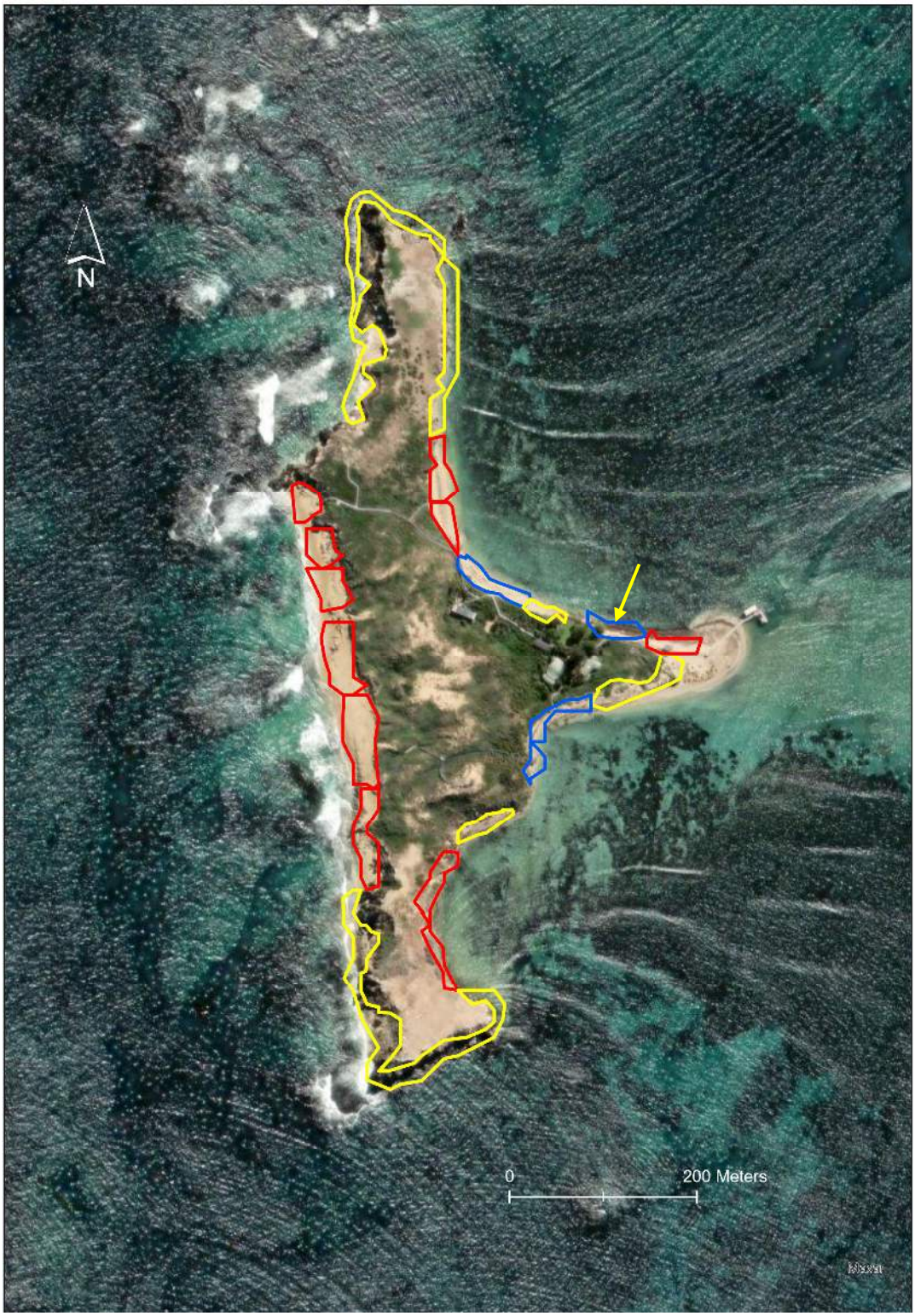

Fig. 2. The extent of the beaches covered by the RAN volunteers (red and blue polygons) counting Little Penguins arriving on one night each in July and November in 2023, using night vision goggles. The beaches covered by the blue polygons were also used for the beach captures from September-November 2023. The yellow polygons represent areas that the penguins have not been observed to use as arrival areas. The yellow polygons at the northern and southern ends cover 10-12 m high cliffs. The yellow arrow indicates a new arrival site.

To assist in correctly observing and identifying the penguins, Royal Australian Navy (RAN) Night Vision Goggles were used by RAN volunteers. Using these, each counter was able to clearly see penguins within at least a 40 m radius. The counts were conducted around the first quarter moon phase, from sunset to two hours after Civil Twilight[2]. Both the number of penguins arriving in each group and the time of arrival were noted.

Mark-recapture study

Penguins were caught at each of four arrival sites, one site per night, over four consecutive nights. Each set of four nights is hereafter referred to as a session. The arrival sites used had previously been identified as having the greatest number of penguins arriving on any night (Cannell *et al.* 2011). However, one of the sites had not been used in 2019, and so was swapped for a new arrival site on the eastern side of the island that has only recently been used (Fig. 2) The captures were repeated on four occasions from September to November 2023 (Table 1).

Table 1. The dates of each Mark-recapture session on Penguin Island in 2023

Capture Session	Date
1	24/9/23-27/9/23
2	7/10/23-10/10/23
3	23/10/23-26/10/23
4	4/11/23-7/11/23

To catch the penguins, low fences were erected along either side of the major landfall site, with a corral at the centre of the landfall site (Fig. 3) Arriving penguins were herded into the corral, the corral was closed off and the penguins were removed. The corral was then re-opened as penguins continue to arrive for several hours, either in groups or alone (Klomp *et al.* 1991, Cannell unpubl. data). Each group of captured penguins was taken to an adjacent area that was 10-30 m from the corral area and not directly visible from the landfall site. Here the penguins were weighed in a bag to the nearest 10 g using Salter 2 kg*10 g scales. They were scanned for subcutaneous transponders with a Portable Reader (Iso Max IV, scanning distance up to 30 cm). If the penguins did not have a transponder, they were marked with one, and both maximum beak depth and length were

[2] The instant in the evening when the sun is at a depression angle of 6° below an ideal horizon (http://www.ga.gov.au/earth-monitoring/geodesy/astronomical-information/astronomical-definitions.html)

measured (to determine sex of the bird). The penguins were returned to an area between the landfall and measuring sites. The entire process of corralling newly arrived penguins, then weighing, scanning and marking unmarked penguins from each newly arrived group continued for a minimum of two hours from first capture.

Fig. 3. A typical fence and corral assemblage used to capture Little Penguins on Penguin Island. Note that the arrow indicates an extra piece of fence that is used as a gate, thus closing of the corral once the penguins have moved into it

Mark-recapture analyses

I used a Multi-State Open Robust Design analysis (Kendall *et al.* 2019) for a single season to determine the population estimate for 2023. The modelled parameters include the probability of entering the colony for the first time in a given session (*pent*), the probability of capture (*p)* for those that are present in a given session, and the probability of persisting at the colony from one session to another (ϕ). I included models where the probability of capture was constant between sessions, or varied with time (when both *pent* and *p* were session dependent we set $p_1 = p_2$ because p_1 cannot be estimated separately). The probability of entry either varied with time or was the same for each session. As it takes approximately 13 weeks from egg lay to chick fledge, we assumed that once a penguin had been captured in the colony it is reasonable to expect it will be caught again, unless it is not a breeding penguin. However, given the asynchronous nature of the penguins' breeding, the probability of a penguin being captured within the four sessions is dependent on when its clutch was laid. Thus I modelled the probability of remaining within the colony (i.e. ϕ) to be constant over the four sessions, to vary over time, or to be dependent on when it arrived (e.g. a penguin will be less

likely to depart shortly after its egg is laid than shortly before its chick fledges). I also considered models where there were arrivals but no departures, only departures but no arrivals, or no arrivals or departures (the population was closed) over the four sampling sessions.

Model selection was based on Akaike's information criterion corrected for small sample sizes (AIC_c) (Burnham & Anderson 2002) and model averaging was used to address model selection uncertainty. I used the median *c*-hat procedure in Program MARK (White & Burnham 1999) to estimate the overdispersion parameter, *c*, for the global model. When *c*>1, the median *c*-hat estimate was used to adjust the AIC model selection metric (and report $QAIC_c$). The models were constructed and run in program MARK version 10.1 (White & Burnham 1999).

Total Island Population Estimation

The total island population was estimated by combining the information from the mark-recapture study and cumulative beach counts of all beaches. This is based on the equation modified from Williams *et al.* (2002):

$$\hat{N}_t = \frac{\hat{N}_c}{\hat{\alpha}}$$

$$SE(\hat{N}_t) = \hat{N}_t \sqrt{[SE\ (\hat{N}_c)]^2 / \hat{N}_c^{\ 2} + [SE(\hat{\alpha})]^2 / \hat{\alpha}^2}$$

where $\hat{N}_c$ is the population estimate obtained from the capture-recapture study and $\hat{\alpha}$ is the fraction of area/population sampled by the mark-recapture study. The estimation of α uses the equation

$$\hat{\alpha} = \frac{x}{n}$$

$$SE(\hat{\alpha}) = \sqrt{\hat{\alpha}(1-\hat{\alpha})/n}$$

where *x* is the sum of the cumulative beach counts where the capture-recapture was done and *n* is the sum of all the cumulative beach counts on the whole island.

$SE(\hat{N}_c)$ is obtained from the Program Mark output

A Log-normal 95% confidence interval was calculated, with a lower limit of $\hat{N}^{L}_{total}=\hat{N}_{total}/C$ and upper limit of $\hat{N}^{U}_{total}= \hat{N}_{total}$ x C, where

$$C = \exp\left(1.96\sqrt{\ln\left(1+\left(\frac{SE\left(\hat{N}_{total}\right)}{\hat{N}_{total}}\right)^{2}\right)}\right)$$

5. Results

Beach counts

An average of 1±3 (Standard Deviation) penguins were counted coming ashore at each of the 15 sites over the two nights (Range: 0 - 14 penguins). The greatest number penguins arrived on a beach on the NE side of the island.

Mark-recapture analyses and island-wide population estimate

In 2023, 43 individual penguins were caught across the four sites over the four capture sessions. The model with the highest $QAIC_c$ weight and with 30% support was a fully open model, with new penguins (i.e. either unmarked or previously marked penguins not caught in previous sessions in 2023) arriving to the colony throughout the four sessions, an equal probability of capture in sessions one and two, and then in three and four, and a linear trend for remaining within the colony since it arrived (Table 2). The probability of new birds arriving to the colony was highest for the first session , i.e. in late September. However, in the first October session, there was slightly < 20% probability of new birds arriving. By late October and early November there was a negligible probability of new birds arriving (Fig. 5). The capture probability was 0.31 (± 0.10 SE), 95% CI: 0.15-0.53 for the first two sessions, and was higher in the third and fourth sessions, increasing to 0.45 (± 0.15 SE), 95% CI: 0.20-0.74. The probability of remaining in the colony after the first session was only 0.37 (± 0.16 SE), 95% CI 0.13-0.70, meaning that 63% of the penguins left after the first session. For those penguins arriving in the later sessions, they had a 100% probability of remaining for the rest of the sessions. The model-averaged population estimate for the nesting area accessed via the four beach capture sites was 75 (±17.55 SE) penguins. An estimated **114 (± 29 SE),** 95% CI: 69-188, **individual** penguins were present on the whole island between September to November 2023.

Table 2. Model selection results using multistate open robust design mark-recapture models to evaluate demographic parameters of Little Penguins on Penguin Island from September–November 2023. Parameters are p, probability of recapture; pent, probability of entering the colony for the first time in a given session; phi, the probability of persisting at the colony from one session to another. Structures are (.), constant; t, time within season; tsa, time since arrival; linear tsa, linear time since arrival trend. Median c-hat = 2.1

Model	QAICc	Delta QAICc	AICc Weights	Model Likelihood	Number Parameters	QDeviance	-2log(L)
p(t1=t2),pent(t),phi(linear tsa)	99.312	0	0.30138	1	4	90.6223	190.3069
p(t1=t2),pent(t),phi(.)	99.6971	0.3851	0.24859	0.8248	3	93.2903	195.9097
p(.),pent(t),phi(.)	100.7882	1.4762	0.14407	0.478	3	94.3814	198.201
p(t1=t2),pent(t) births only	101.411	2.099	0.10552	0.3501	2	97.211	204.1432
p(.),pent(t),phi(tsa)	102.6843	3.3723	0.05582	0.1852	5	91.6317	192.4265
p(.),pent(t),phi(linear tsa)	102.7843	3.4723	0.0531	0.1762	5	91.7317	192.6366
Closed Mt	103.9298	4.6178	0.02995	0.0994	4	95.2402	200.0044
p(t),phi(t), deaths only	104.7205	5.4085	0.02017	0.0669	6	91.2205	191.563
p(.),pent(t),phi(t)	104.9436	5.6316	0.01804	0.0599	6	91.4436	192.0315
p(t1=t2),pent(t),phi(tsa)	106.4185	7.1065	0.00863	0.0286	7	90.3822	189.8025
p(t1=t2),pent(t),phi(t)	107.2288	7.9168	0.00575	0.0191	7	91.1925	191.5042
p(t),pent(.25),phi(linear tsa)	107.8635	8.5515	0.00419	0.0139	5	96.8109	203.3029
p(.),pent(0.25),phi(linear tsa)	109.8799	10.5679	0.00153	0.0051	3	103.4731	217.2936
p(t),pent(0.25t),phi(.)	110.1707	10.8587	0.00132	0.0044	5	99.1181	208.1479
{p(.),pent(0.25),phi(tsa)}	112.0122	12.7002	0.00053	0.0018	4	103.3226	216.9774
{p(.),pent(0.25t),phi(.)}	112.0691	12.7571	0.00051	0.0017	2	107.8691	226.5251
{p(t),pent(0.25t),phi(t)}	112.6151	13.3031	0.00039	0.0013	7	96.5787	202.8154
{p(t),pent(0.25),phi(tsa)}	112.769	13.457	0.00036	0.0012	7	96.7326	203.1385
{p(.),pent(0.25t),phi(t)}	114.4798	15.1678	0.00015	0.0005	4	105.7901	222.1593

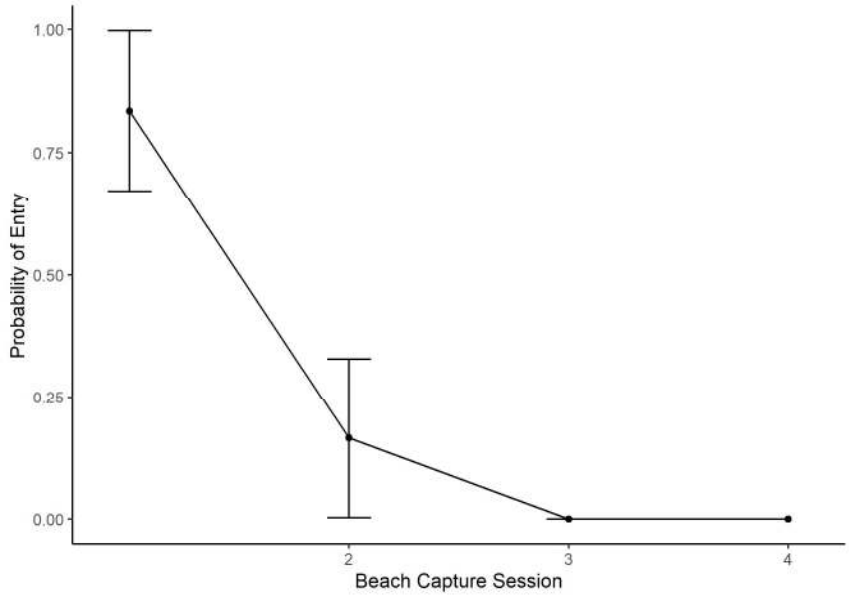

Fig. 5. The probability of Little Penguins entering the Penguin Island colony in beach capture sessions 1-4, 2023.

6. Discussion

Using a combination of Mark-Recapture analyses and the beach counts, the population of Little Penguins using the island between **September to November 2023** has reduced by approximately 64% from the estimates for a comparable time of year in 2019, by approximately 80% since 2017, by approximately 93% since 2007 and 94% since 2008 (Cannell *et al.* 2023a). It is pertinent to note that as the estimate is only for the penguins on the island from September to November, any penguins that bred earlier in the year, and whose parental duties were completed before the first capture session, were potentially not returning to the colony and thus **not included** in the estimate. This was evident in 2010, when the population estimate was considerably lower than in 2007, 2008 and 2011, and was due to a mismatch between timing of breeding and the mark-recapture program (Cannell *et al.* 2023a and b). However, in 2023, peak egg lay occurred across July/August (LPWG meeting notes). In 2017 and 2019, peak egg lay occurred in June, and eggs were laid in September (and October in 2017) (Cannell *et al.* 2023b). Breeding success was relatively high in 2023 (LPWG meeting notes) but was higher in 2019 and lower in 2017 and 2008 (Cannell *et al.* 2023a). Thus, any change in population estimates between recent years is comparable. Furthermore, as incubation and chick rearing covers approximately 13 weeks, then there was a good chance that any penguins laying eggs would be encountered during the breeding season. It can thus be assumed that the low population

estimate for September to November in 2023 is not due to failed breeding attempts, but to either a number of penguins choosing not to breed, i.e. taking a sabbatical from breeding and/or a declining population.

What causes fewer penguins to participate in breeding? This will be driven by a poor body condition of potentially breeding adults due to reduced prey availability, disappearance of a mate (different to changing a mate when the previous partner is still alive - the divorce rate of Little Penguins is approx. 20-30% in cases (Johannesen *et al.* 2002, Saraux and Chiaradia 2022)), fewer chicks returning to their natal colony as breeding adults, or interrupted breeding attempts due to impacts on nest sites or arrival areas on the island. Furthermore, participation in breeding by the Little Penguins on Penguin Island has been found to be associated with the biomass of baitfish in the SW region (using the commercial catch per unit effort (CPUE) of baitfish as an index), combined with the mean strength of the Leeuwin Current over the year, the mean strength of the Leeuwin Current during the winter season, and the winter rainfall the year prior (Cannell *et al.* 2023a and b). The CPUE of baitfish in 2023 is not yet available, but the mean strength of the Leeuwin Current and the low winter rainfall in 2022 would indicate that there was a decreased likelihood of breeding participation in 2023.

Even though there were environmental variables that were associated with fewer penguins attempting to breed in 2023, it is also very likely that there has been a real population decline, especially given the downward trend observed since **2011** (Cannell *et al.* 2023a). This is highlighted with a reduced proportion of penguins attempting to breed in 2011 compared to 2017, and yet the population was lower in 2017 by 60% (Cannell *et al.* 2023a). The population decline can be due to multiple factors: 1) fewer penguins participating in breeding across multiple years, which results in fewer chicks available to recruit back into the population, 2) a reduction in breeding success across multiple years, which results in fewer chicks available to recruit back into the population, 3) a reduction in the survival of fledglings, which results in fewer two to three year old adults returning to the colony and 4) changes in the mortality rate of the adults. There is evidence to support that all these factors have influenced the population on Penguin Island.

Reduced food availability is implicated in reduced breeding success, reduced survival of fledglings and juveniles (i.e. up to two to three years of age), and increased mortality of adults. If food is scarce, then breeding penguins bring back less food to chicks, may take longer foraging trips to find food which leaves the chicks hungry for longer and affects their growth rate (Chiaradia and Nisbett 2006, Cannell unpubl. data), or may abandon the breeding attempt completely. Less prey means

fewer chicks surviving and thus fewer recruiting back to the colony when they are sexually mature adults two to three years later. However, breeding success can also be impacted by terrestrial temperatures, with chicks present on the island in the late spring and summer months potentially dying from hyperthermia. As our climate warms, there is an increasing probability of terrestrial temperatures negatively impacting chick survival. Breeding success is also influenced by penguin access to their nest sites. As mentioned, Little Penguins are very faithful to an arrival beach, and will not use another beach to get to their nest. Storm damage, overgrowth of plants and anthropogenic changes to arrival sites can all impact a penguin's ability to get back to its nest (Wienecke *et al.* 1995, Cannell 2001, Stevenson and Woehler 2007, Cannell pers. obs.).

For fledglings, mortality rate in their first year is higher than that of adults (e.g. at Phillip Island, the probability of surviving the first year is on 0.17- Sidhu *et al.* 2007), and the better body condition they have when they first leave the island (which is due to the parents feeding them well during chick rearing), the greater the chance they will survive. This is partly driven by their initially poor foraging skills (Cannell 1994), which is exacerbated by reduced prey availability. But climate effects on juvenile penguin survival operate for the first two to three years of their life due to indirect effects on prey (Cannell *et al.* 2023a). Therefore, even in the years when reproductive success and chick mass at departure is high, adverse conditions in the following years can result in decreased survival. There will be other threats to the juveniles, which remain at sea except to moult. It is not currently known where the fledglings and juveniles forage, nor where they go to moult. This is a critical missing piece of information. Unfortunately, the tags deployed on adults are considered either too large to remain on the inexperienced foraging youngsters for an extended period of time, or have limited battery capacity rendering them inefficient for appropriate data collection. With continued improvements in this technology, hopefully this lack of knowledge can be rectified soon.

Mortality in adult Little Penguins is generally low, with a survival probability of 0.86 for Penguin Island penguins (Tavecchia *et al.* 2016). However, climate effects on prey can impact adult mortality. Indeed, in 2011 and 2012, when SST were very high, more malnourished penguins were found dead compared to any other year since necropsies began in 2003 (Cannell *et al.* 2016, Cannell *et al.* 2023a). However, reduced food availability isn't the only cause of mortality in penguins. When terrestrial temperatures are ≥ 35°C, penguins can die of hyperthermia, and this can occur during the breeding season or during the moult period (Cannell *et al.* 2011, Cannell *et al.* 2016). Importantly, recreational watercraft injury has been shown to cause just over a quarter of all deaths of Perth's Little Penguins, and is the most prevalent cause of their mortality (Cannell *et al.* 2016). Furthermore,

penguins are more likely to be injured by watercraft in spring and summer when recreational boating activities are at their highest (Cannell *et al.* 2020). Predators can also impact adult survival, and low levels of predator attacks (5-15 birds killed per attack) can increase the risk of extinction of small colonies (100 birds) in 10-15 years if there were >20 attacks/50 years (Blamey *et al.* 2024). There are no dogs, foxes or cats on Penguin Island, which are all known to predate on adult Little Penguins (Cannell 2001 and references within). However, rats did become problematic on the island in the early 2010s, and there was evidence that they did predate on both chicks and adult penguins (Clitheroe pers. comm.). An intensive baiting program was conducted and the rats were removed, but this highlights the importance of management of feral predators on Penguin Island.

Given the range of factors involved in the decline of the penguins, it is imperative that any management strategies developed be aligned in both the state and local government agencies to ensure that the recreational needs of the people are matched with the conservation needs of the Little Penguins from Penguin Island. Furthermore, to avoid serious impact on the penguin population, it will be necessary to consider the implications of additional structures, such as boat ramps and other infrastructure, within the penguins' home range, using robust methods such as decision-support tools. Importantly, their home range extends from Cockburn Sound to Geographe Bay.

Changes in distribution on Penguin Island

The proportion of total penguins captured at each of the four capture sites varied between the years. Most remarkably, there were some occasions in 2023 when no penguins were caught at the two sites on the southern side of the island. Although this has not occurred in previous years, the number of penguins caught at these sites was much lower in 2017 and 2019 compared to previous years (Cannell *et al.* 2023a). Interestingly, the proportion of penguins returning at the site on the NE side of the island has not changed since 2017. Also, the proportion of penguins arriving at this arrival site and the new arrival site accounted for 90% or more of the penguins returning on any evening. Penguins that use the NE arrival beach are more likely to forage in Cockburn Sound during incubation and on the west side of Garden Island during chick rearing. Contrary to this, penguins that arrive at the beaches on the SE and SW side of the island forage in Geographe Bay, and beyond, during incubation, and in Warnbro Sound and Comet Bay during chick rearing (e.g. Cannell 2016, 2017, 2018). It is presumed that those arriving at the new arrival site will also be foraging in Cockburn Sound and on the west side of Garden Island. This highlights the importance of these

foraging areas for the penguins and may be pivotal in the maintenance of the population on Penguin Island (Cannell *et al.* 2023a).

Fortunately, more penguins have been using one of the arrival sites on the southern side of the island in 2024 than during this project (LPWG meeting notes). As such, there is hope that some penguins from this area of the island are still available for breeding in 2024 should conditions be favourable.

Conclusion

The population of Little Penguins on Penguin Island from September to November 2023 is estimated at **114** individuals. The decline reflects lower breeding participation and/or fewer penguins available to breed. However, Little Penguins are resilient, and the population can recover with appropriate environmental conditions and threat mitigation strategies. For this to occur, a concerted effort from all levels of the community is required to reduce all threatening processes that this colony is exposed to both on land and at sea, and spanning from Cockburn Sound to Geographe Bay. Every breeding attempt by a penguin pair is critical for the future of the population. Further work to determine the habitat used by fledglings and juveniles before they return to the island as sexually mature adults is also important.

Acknowledgements

I am indebted to Professor Bill Kendall (U. S. Geological Survey, Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University) who has patiently advised on the appropriate models used for the Mark-Recapture analyses.

This work could not have been accomplished without support from the Royal Australian Navy, who provided personnel and equipment for counting penguins coming ashore in the evening. I also thank the many volunteers who assisted during the Mark-recapture sessions.

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