GARDEN ISLAND LITTLE PENGUIN POPULATION ESTIMATE

Submarine Rotational Force-West, Priority Infrastructure Works

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This Garden Island little penguin population estimate for the Submarine Rotational Force-West, Priority Infrastructure Works, Garden Island, Western Australia (EPBC 2024/10031) has been developed in partnership with the technical expertise of Dr Belinda Cannell, University of Western Australia. We acknowledge the subject matter expertise provided towards the production of this report.

EXECUTIVE SUMMARY

RPS AAP Consulting Pty Ltd (RPS) and the University of Western Australia (UWA) were commissioned to provide this *Garden Island Little Penguin Population Estimate* on behalf of Department of Defence for the Submarine Rotational Force-West (SRF-West), Priority Infrastructure Works project (the Action). The primary objective is to present a report prepared by a **suitably qualified seabird conservation ecologist** that establishes the **baseline population** of **little penguins** detailing how it was derived from relevant historical population data and why it is suitable for comparison to data collected after **commencement of the Action** as per Condition 9 of Notification of approval decision (EPBC 2014/10031).

The Careening Bay colony of little penguins first established around 1986, following the construction of a series of rock walls for HMAS *Stirling*. Approximately 10–15 pairs of little penguins were regularly observed inhabiting the rock wall by 1986 (Wykes et al. 1999). Up to 41 breeding pairs and a further 24 nests with evidence of prospecting or breeding activity were observed within Area C over a three-year period from 2001 (Cannell 2004). In 2011, the Garden Island colony declined by approximately 20% from the previously recorded peak level, likely due to a marine heatwave (Cannell et al. 2023; B. Cannell pers. comm.).

Between 2021–2024 during Defence commissioned monitoring between Moresby Wharf and Colpoys Point, there was significant variation in the number of breeding adults, ranging from 156 to at least 226 individuals (noting Moresby Wharf was not monitored in 2021 or 2022) (Cannell 2025). For the purposes of setting a baseline population size, 156 breeding adults stands as the minimum population size that can be compared to population size estimates during and for six years post construction of the Action (Cannell 2025).

The estimated number of breeding adults is derived from the number of known and likely active nests, as each nest contains two adults and was used as an index of population size. Note, the total population size is not known, as the number of non-breeding adults (i.e. individuals taking a sabbatical from breeding in any one year), immature and juvenile birds in the population is not known and cannot be easily measured.

Seabird populations, including the little penguin, are variable and change in response to intrinsic (e.g. reproduction, mortality) and extrinsic (e.g. sea temperature, bait fish abundance, water quality, disturbance) factors. It is reasonable to expect there will continue to be variation in population size of similar scale into the future due to those intrinsic and extrinsic factors, as observed between 2021–2024. The establishment and persistence of the colony on Garden Island, despite some level of human and vessel traffic disturbance within Careening Bay and Cockburn Sound more broadly, is a testament to the penguins' adaptability and resilience to low-level disturbance (Cannell 2024).

The baseline population size range (156–226 breeding adults) will be used for comparison with monitoring data collected using comparable methods after commencement of the Action. Population estimates gained from ongoing monitoring of little penguins after commencement of the Action will be considered in relation to the success of implemented management and mitigation measures, as well as a range of environmental variables collected each year, to enable any measurable effects on the little penguin population due to SRF-West to be distinguished from effects that may be due to natural variation and other pressures on the population.

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1 BACKGROUND

RPS AAP Consulting Pty Ltd (RPS) and the University of Western Australia (UWA) were commissioned to provide a baseline population estimate of little penguins on Garden Island on behalf of Department of Defence (Defence) for the Submarine Rotational Force-West (SRF-West), Priority Infrastructure Works project (the Action). The primary objective of this report is to present a population estimate prepared by a **suitably qualified seabird conservation ecologist** that establishes the **baseline population** of **little penguins** detailing how it was derived from relevant historical population data and why it is suitable for comparison to data collected after **commencement of the Action** as per Condition 9 of Notification of approval decision (EPBC 2014/10031).

The little penguin *Eudyptula minor* is listed as a Marine species under s248 of the *Environment Protection and Biodiversity Conservation Act 1999*. The global conservation status of the species is considered as Least Concern with a stable population trend, but with the caveat that 60 per cent of all known colonies have unknown trends (BirdLife International 2025).

Garden Island, located ~40 kilometres (km) south of Perth, is a 11 km^2 nearshore island connected to the mainland via a 4.2 km causeway. The island is home to a colony of little penguin, which together with Penguin Island represent the northwestern most breeding colonies for the species. The Garden Island colony was established sometime following the construction of a rock wall in 1975 in Careening Bay for HMAS Stirling (*Stirling*).

The little penguin population size on Garden Island has increased slowly over time from zero before the early 1980's, to 10–15 pairs by 1986 (Wykes et al. 1999) and at least 41 pairs in Area C by 2001 (Cannell 2004). However, in 2011, the colony is estimated to have declined by approximately 20% from the previously recorded peak level, coinciding with a marine heatwave (Cannell et al. 2023; B. Cannell pers. comm.). The establishment and persistence of the colony on Garden Island, with some level of human and vessel traffic disturbance within Careening Bay and Cockburn Sound more broadly, reflects the penguin's adaptability and resilience to low-level disturbance (Cannell 2024).

Current nest sites on Garden Island encompass the artificial rock walls along the shoreline of Careening Bay, amongst concrete rubble and slabs, and occasionally under sturdy vegetation i.e. *Spinifex longifolius* grass (Areas A–F Figure 1-1). Little penguins also breed in a small number of nest boxes placed under *M. lanceolata* trees within Areas C and F (Figure 1-1). Nest sites are most numerous within Area C, while scattered nesting sites occur in Areas A, D–F (Figure 1-1). These nest sites are not all used simultaneously. Instead, little penguins establish nest sites throughout Careening Bay that are used periodically for breeding activity with penguins breeding asynchronously (Cannell 2022; 2024; 2025). Additionally, the location of a nest site may occasionally change from one breeding attempt to the next, more likely between rather than within years, dependent on a range of factors including breeding success, habitat availability, proximity to mates (B. Cannell pers. comm.; Wienecke 1993; Sutherland & Dann 2012).

Figure 1-1 Little penguin *Eudyptula minor* known or potential nesting sites (2021–2024) within Careening Bay, Garden Island

2 POPULATION MONITORING SUMMARY

Population monitoring of the Garden Island little penguin colony, commenced by Dr Belinda Cannell, began in 2001 to support academic research and has focused on a range of little penguin ecology aspects. This monitoring was conducted at various frequencies until 2020, was absent in some years, and included only a portion of what we now recognise as the total breeding colony (see Table 2-1, Figure 1-1). The data arising from this monitoring is the intellectual property (IP) of Dr Belinda Cannell.

The population monitoring program funded by the Department of Defence that was used to provide an estimate of the current baseline population size for little penguins on Garden Island began in 2021, expanded in scope (spatial and temporal) from the Dr Cannell's earlier research program and involved counting known and likely active penguin nests on a fortnightly basis in the following locations:

- Areas C, D, E and F (2021–2024), and
- Area B (2023–2024, Figure 1-1).

Area B was added to the monitoring program in 2023 after underweight chicks were found on the road adjacent to Moresby Wharf in 2022, in a previously unmonitored location. A reconnaissance survey in Area A was completed in 2023 to understand the importance of this area to little penguins. A total of 13 potential sites, including three with nesting material, were identified in Area A, however no further quantitative surveys were completed in Area A until April 2025.

Area A was added to the monitoring program in 2025 for completeness and to help inform evidence-based decision making related to potential impacts, mitigation and adaptive management for Defence activities in this location. The monitoring data from Area A, however, cannot be included in the current population estimate as it currently only spans several months. A summary of the various monitoring efforts (research and Defence monitoring) since 2001 in all areas is presented in Table 2-1.

The contemporary four-year baseline monitoring program dataset (2021–2024) will be directly comparable to data collected during- and post-construction of the SRF-West Action due to consistency in monitoring methods in the before and after periods (i.e. sites, methods, data quality assurance and replication of sampling).

Table 2-1 Summary of colony monitoring duration, frequency and location on Garden Island

Area	Period and frequency of monitoring
A	Reconnaissance in 2023 detected evidence of nesting. Monitored fortnightly since April 2025 for Defence.
B	Monitored fortnightly since late 2022 for Defence.
C	Monitoring completed fortnightly from 2001 to 2004 then monthly from 2004 and 2020 for research. Monthly monitoring of nest boxes installed in 2003 and 2004 for research. Data is the IP of Dr Cannell. Area C monitored fortnightly since 2021 for Defence.
D	Up to twice per annum from 2005 – 2016 for research. Before the ongoing Defence program, monitoring in this area had not been undertaken for five years. Data is the IP of Dr Cannell. Area D monitored fortnightly since 2021 for Defence.
E	Up to twice per annum from 2005 – 2016 for research. Before the ongoing Defence program, monitoring in this area had not been undertaken for five years. Data is the IP of Dr Cannell. Area E monitored fortnightly since 2021 for Defence.
F	Up to twice per annum from 2005 – 2016 for research. Before the ongoing Defence program, monitoring in this area had not been undertaken for five years. Data is the IP of Dr Cannell. Area F monitored fortnightly since 2021 for Defence.

3 CURRENT POPULATION ESTIMATE

Since 2021, monitoring of the little penguin colony (Areas B–F) has occurred on a fortnightly basis, per the methods developed described in DBCA (2019), RPS (2020) and Cannell (2022, 2024). Fortnightly visits are deemed to be the ideal frequency to increase the probability of observing chicks close to fledging (between 6–8 weeks of age) and increasing the probability of accurately identifying breeding outcomes (DBCA 2019). Furthermore, fortnightly monitoring during the moult period provides a sufficient window of opportunity for moulting penguins to be observed. Surveying more frequently than fortnightly is not necessary and risks disturbing the penguins.

The total baseline population size (including all age classes) cannot be provided, as the number of non-breeding adults (i.e. individuals taking a sabbatical from breeding in any one year), immature and juvenile birds in the population is not known and cannot be easily measured. To estimate the baseline population size of the little penguin population, the number of breeding adults recorded in Areas B–F from 2021–2024 was used as an index of population size and is derived from the number of known (confirmed) and likely active breeding adults (indirect evidence of nesting), as each nest contains two adults (Cannell 2025 – Appendix A).

The number of active nests and breeding adults in Areas B–F between 2021–2024 are presented in Table 3-1 and Figure 3-1. For the purposes of setting the baseline population size, 156 individuals stands as the minimum and at least 226 individuals as the maximum baseline population recorded between 2021–2024 (Cannell 2025).

During the baseline period, the number of active nests (and breeding adults) varied substantially, likely in response to a range of intrinsic factors and natural pressures such as sea surface temperature, prey availability and a significant red fox *Vulpes vulpes* predation event in 2023 (see Section 4.1).

Table 3-1 Number of active little penguin nests, including known and likely breeding, in Areas B to F from 2021–2024. The number of breeding adults is presented in parentheses (Cannell 2025).

Area	Nest Category	2021	2022	2023	2024
Areas C to F	Known breeding	68	95	64	71
Areas C to F	Likely breeding	17	18	11	13
Area B	Known breeding	NA	NA	2	4
Area B	Likely breeding	NA	NA	1	1
Total nests (breeding individuals)		**85 (170)**	**113 (226)**	**78 (156)**	**89 (178)**

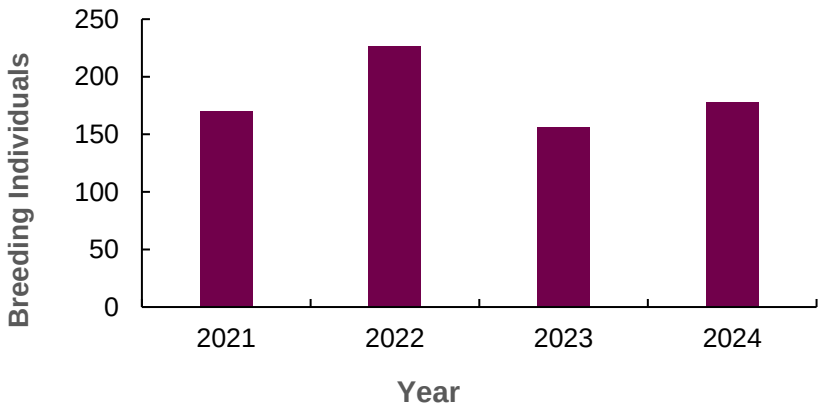

Figure 3-1 Number of breeding adult little penguins recorded between 2021 and 2024 between Areas B and F (Cannell 2025).

3.1 Suitability of baseline data and monitoring for comparison

While estimates of little penguin population size can be variable among years and survey methods, colony-wide surveys provide a benchmark for understanding changes in the population as they estimate the population size of the entire colony and correct for spatial and temporal variation in colony attendance (Sutherland & Dann 2014). This baseline population estimate range of 156–226 breeding adult little penguins in Areas B–F on Garden Island, is suitable for direct comparison to data collected from the same areas after commencement of the Action, because all future monitoring will be conducted using consistent and repeatable methods, at the same sites and with appropriate frequency of sampling. Monitoring data from Area A will be presented separately in future population estimates from 2025 onwards. Natural variation in population size between years and over short timescales (varying both up and down) will continue in the future as the little penguins respond to a range of natural pressures (e.g. Wienecke 1993; Sutherland & Dann 2014). For this reason, it isn't appropriate to select a single population size for future comparison, rather the range presented over the four-year baseline period is more informative.

As noted earlier, prior to 2021 monitoring of the Garden Island little penguin population was conducted by Dr Belinda Cannell for research purposes, with a lower frequency, was absent in some years and included only a portion of the total colony being monitored with a consistent frequency (i.e. Figure 1-1; Table 2-1). In addition, the data from this research program are the IP of Dr Cannell and not publicly available. For these reasons, the earlier monitoring data (prior to 2021) should not be relied on to inform an estimate of the baseline population size for comparison by Defence to data collected after the commencement of the Action. Therefore, the data from the 2021–2024 baseline monitoring program provides contemporary, consistent (and relevant) historical baseline population data that can be used to derive a little penguin population estimate on Garden Island and that is suitable for comparison to data collected after commencement of the Action.

Noting the limitations in interpreting the earlier research monitoring data outlined above, it can be useful to compare the average number of nests from Area C only from 2001–2020, to the number of nests recorded in Area C from 2021–2024. The historical unpublished research data from monthly population monitoring in Area C alone, shows an average number of 78±10 S.D. nests from 2001–2020 (B. Cannell unpub. data). In comparison to this average, the number of nests in Area C alone between 2021–2024 monitored fortnightly, was lower (average = 42±8 S.D.), suggesting there may have been a population decline. However, it cannot be ruled out that this apparent decline in population size may also, at least in part, be due to adult penguins moving or recruiting to other nesting sites within the colony (B. Cannell pers. comm.). Reiterating that the average number of nests for Area C are derived from a subset of the totals provided in Table 3-1 and Figure 3-1.

4 DISCUSSION

There was large variation in the number of nests (78 to 113) and breeding adult little penguins (156 to 226) between 2021–2024 and it is reasonable to expect there will continue to be variation of similar scale into the future due to a range of intrinsic factors and environmental pressures. The variation observed in the breeding population data over the monitored period may be driven by multiple factors, specifically:

1. Fewer penguins participating in breeding in some years
2. A reduction in breeding success in any one year, which results in fewer chicks available to recruit back into the population two to three years later
3. A reduction in the survival of fledglings, which results in fewer two- to three-year-old birds recruiting back into the colony as breeding adults
4. Changes in the mortality rate of the adults (Cannell 2025).

The potential influence of a range of pressures on little penguin body condition, breeding success, mortality and flow on effects on the Garden Island population size is discussed below.

4.1 Influences on population size

Penguins are among the most threatened group of seabirds worldwide with 11 species listed on the International Union for the Conservation of Nature (IUCN) Red List as Near Threatened (2), Vulnerable (4), Endangered (4) or Critically Endangered (1) (IUCN 2025). While the global little penguin population is considered Least Concern (stable), many Australian populations are threatened, and sites with or without active conservation measures have experienced severe declines to the extent that some colonies no longer exist (Dann 1994; Stevenson and Woehler 2007; BirdLife International 2020; Cannell 2020; Greenwell et al. 2022). The threats to little penguin colonies are numerous but vary depending on location (e.g. Dann 1991; Cannell et al. 2015; Colombelli-Negrel 2015; Cannell 2022).

Oceanographic change has the potential to drive a mismatch between plankton and the small pelagic fish on which penguin prey (Hinder et al. 2013). Reductions in prey abundance is a major threat to little penguin populations (Cannell et al. 2016; Chiaradia 2013). Changes in the abundance of major prey can lead to dramatic changes in their diet composition and trophic interactions, resulting in malnourishment, increased mortality and decreased breeding success (Dann et al. 2000; Chiaradia et al. 2010; Cannell et al. 2015; Cannell et al. 2024).

Between July and September 2021, 27 dead penguins were found along the Western Australian coastline (B. Cannell unpub. data in Cannell 2023). Thirteen of these penguins were found on the foreshores of Cockburn Sound or Garden Island and of those nine were emaciated (B. Cannell unpub. data) suggesting a lack of prey within the home range of little penguins in the winter and early spring of 2021 (Cannell 2023). This was evident in the number and timing of clutches laid on Garden Island and breeding success. For example, few clutches (n=17) were laid between March and August, and of those only 24% were successful (i.e. at least one chick survived to fledging). Conversely, 53 clutches were laid from September to December and 55% were successful (Cannell 2023).

In 2022, there was a high abundance of larval sandy sprat *Hyperlophus vittatus* in Cockburn Sound (Yeoh et al. 2025 in Cannell 2023), one of the species consumed by the little penguins. 2022 had greatest relative number of breeding individuals on Garden Island during the baseline period (i.e. at least 226 individuals, Cannell 2025). In 2022, at least 63% of all known breeding attempts were successful and double clutching (where breeding pairs laid a second clutch in the same year) was recorded in 13 nests, suggesting sufficient prey resources were available throughout the year (Cannell 2024).

On Philip Island in Victoria, land-based anthropogenic threats have been largely eliminated, and penguins are not limited by the area available for breeding (Dann 1992). Despite this, the population size of the colony between 1984–2012 was shown to vary among years (Sutherland & Dann 2014). The primary factor regulating little penguin population size on Phillip Island is thought to be factors at sea; specifically, density-dependent prey availability during the penguin breeding season (Dann & Norman 2006).

In 1995, 1,926 little penguins of all ages (but with predominance of adults) were reported dead along the Victorian and South Australian coastline (Dann et al. 2000). Of those found in Victoria, 131 were penguins were banded at Phillip Island; 26 had been banded at Rabbit Island and six at the St Kilda colony (Dann et al. 2000), demonstrating penguins were being affected over an expansive area. 29 individuals were

autopsied and 26 were found to have died from starvation (Dann et al. 2000). Around the same period, substantially fewer penguins were recorded at the Philip Penguin Parade between May and August 1995 with reductions also recorded at the St Kilda colony between May and October 1995 (J. Cullen, unpub.; Dann et al. 2000). The decline in penguins coincided with the onset of a pilchard mortality event of unprecedented magnitude (Dann et al. 2000).

Following the pilchard mortality, egg-laying by penguins in the subsequent breeding season (1995–96) was about two weeks later than the long-term mean and 0.3 chicks were fledged per pair compared with the long-term mean of 1.0 (Dann et al. 2000). Dann et al. (2000) concluded that the increase in penguin mortality in northern Bass Strait and the significant reduction in breeding success were associated with the widespread pilchard mortality.

Increasing terrestrial temperatures in the spring and summer months can cause fatal hyperthermia in both chicks and adults (Cannell et al. 2011, Cannell et al. 2012, Cannell et al. 2016; Clitheroe 2021). This issue is likely to be less problematic on Garden Island, where penguins nest within burrows in rock walls that are close to the sea, as opposed to under vegetation or nest boxes like on Penguin Island where daily maximum temperatures are likely to be higher (BirdLife International 2020; Clitheroe 2021). Rapid changes in the marine and terrestrial environment have been associated with poorer breeding with penguins shown to catch less prey under warmer conditions (Cannell et al. 2012; Carroll et al. 2016).

In long-lived seabird species such as penguins, adult survival is of greatest importance for population growth rate, i.e. the trait with the greatest elasticity (Gadgil & Bossert 1970; Lebreton & Clobert 1991; Wooller et al. 1992; Sandvik et al. 2012). Where adult survival is directly reduced from events such as predation, starvation, or vessel strike, population-level changes may be observed in the immediate and longer term. The impact of the significant fox predation event on Garden Island in 2023 resulted in the immediate loss of 39 adult penguins (noting that immature, breeding or non-breeding birds cannot be distinguished). The full effect is likely to be observed over several years, due to lost breeding effort from those adult penguins that were killed and the loss of their offspring that would have otherwise recruited into the population in future years (Cannell 2025). While the probability of juvenile little penguin survival is relatively low (0.17–0.42) compared with adult survival (0.86) (Sidhu et al. 2007; Agnew et al. 2015), reduced recruitment (where a large number of individuals are affected relative to population size) into the population may have a measurable effect on the population.

In the Perth region, little penguins are threatened by a range of confirmed anthropogenic-induced pressures, but primarily watercraft injuries and invasive red foxes (Cannell et al. 2015; Cannell 2024). A study into mortality of penguins in the Perth region showed that a high proportion of deaths (approximately 26%, n=45) occurred due to watercraft strike (Cannell et al. 2015). Mortality was more likely due to small fast-moving watercraft rather than larger, slow-moving vessels (Cannell et al. 2015). Foxes were found to be the major contributor to penguin deaths in 2023, killing at least 39 individuals (Cannell 2024; Cannell 2025).

Potential anthropogenic pressures to little penguins that may arise from the Action include changes to ambient lighting that may disrupt natural behaviours, airborne and underwater noise, vibration, increased turbidity and resuspension of contaminated sediments, increased vehicle and personnel movement at night leading to disturbance, vessel strikes and leaks and spills. However, each of these potential impact and risk pathways have been assessed and appropriate mitigations included in the project design and implementation phase to ensure that acceptable environmental outcomes will be achieved during the SRF-West maritime and landside construction activities. Where appropriately mitigated and managed (per the Construction and Environmental Management Plan and Little Penguin Monitoring Plan), potential impacts and risks are expected to be short term in duration and spatial extent, leading to minor levels of behavioural disturbance only and are not expected to lead to population-level changes to little penguins (RPS 2024).

4.2 Ongoing monitoring program

Little penguin monitoring will be conducted throughout and following completion of the Action for the purpose of understanding the influence of anthropogenic pressure from SRF-West activities and environmental conditions on breeding success and population size (Cannell 2025). Noise and vibration monitoring will also be conducted during SRF-West Activities to inform adaptive management and prevent harmful levels from reaching penguin nesting sites, thereby reducing the risk of harm to little penguins. The little penguin monitoring program will continue from the baseline monitoring period and for six years following completion of construction to demonstrate that the baseline population size is not reduced below its baseline population size as a result of the Action, in accordance with the Conditions of approval (EPBC 2014/10031, Condition

10). However, as noted earlier, interannual variation in population size is normal and is expected to continue and this will need to be taken into consideration when assessing any potential impacts from SRF-West.

The environmental aspects of the monitoring program will investigate the influence of five environmental variables, with links to prey availability, on the breeding performance of the penguins (Cannell 2025). These data will be sourced from publicly available information via the Department of Water, Environment and Resources (DWER) Water Information database and the Bureau of Meteorology. These variables are:

- Salinity (PSU)
- Dissolved oxygen (mg/L)
- Sea surface temperature (°C)
- Turbidity (NTU)
- Rainfall (mm).

Generalised linear models (GLM) will be used to determine the variables that influence breeding activity (i.e. number of eggs laid each month and the success or failure of eggs hatching or chicks fledging) per Cannell (2022; 2024; 2025).

4.3 Conclusion

The baseline monitoring data demonstrates large variation in population size over a relatively a short period (four years) and it is reasonable to expect a similar level of interannual variation to continue due to a range of intrinsic (e.g. reproduction, mortality) and extrinsic factors (e.g. sea temperature, bait fish abundance, water quality, disturbance) influencing little penguin population size. For this reason, it is more informative to compare population size data from the ongoing monitoring program to a population size range, being 156–226 breeding adults, rather than a single number of adult breeding penguins recorded in any one year.

This estimate of little penguin population size is based on a well-structured baseline study that is to be followed by systematic, long-term data collection using comparable methods to account for inter- and intra-annual variation and the influence of environmental factors on breeding success and population size. The four-year, fortnightly little penguin baseline monitoring program (2021–2024) presents a contemporary, sufficient and applicable dataset of the number of known breeding and likely breeding attempts (with high confidence) on Garden Island on which to establish the baseline population size. These data are suitable for comparison to data collected after commencement of the Action (in accordance with EPBC 2024/10031, Condition 9).

The little penguin monitoring program will continue for the six years following the completion of construction to demonstrate that the little penguin population is not reduced below its baseline population size as a result of the Action (in accordance with EPBC 2024/10031, Condition 10).

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Appendix A
Population assessment of the little penguin colony, Garden Island, Western Australia 2021-2024 (Cannell 2025)

Population assessment of the little penguin colony on Garden Island, Western Australia, from 2021-2024

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1 EXECUTIVE SUMMARY

In Western Australia, little penguins (*Eudyptula minor*) are found on offshore islands, and their distribution extends from islands off the coast 50 km south of Perth through to the Recherché Archipelago.

Little penguins on Garden Island established in a rock wall that was constructed at Careening Bay in approximately 1975, and penguin presence was first noted in 1986 by Royal Australian Navy personnel who had consistently observed penguins in burrows.

An estimate of the breeding population on Garden Island, from 2021 – 2024, was obtained using counts of nests with breeding activity in the Main colony in Careening Bay (south of Diamantina Pier and within the Slipway area), the rock walls between Diamantina Pier, Parkes and Oxley wharves and Colpoy's Point. The rock wall adjacent to Moresby Wharf was added into the Main colony monitoring area in January 2023.

Over the four years, the total number of breeding and likely breeding nests varied, from a minimum of 78 nests in 2023, to at least 113 nests in 2022 (noting Moresby Wharf was not monitored in all years). The population estimate increased from 2021 to 2022, decreased in 2023 and increased again in 2024, on par with the 2021 estimate. As each nest represents a breeding pair, then the population estimate of breeding adults on the island has ranged from 150 – 226 breeding individuals. Using the data for 2023 and 2024, only, when the nest sites on the west side of Moresby Wharf were additionally monitored, the number of breeding nests increased from 78 – 89 nests, i.e. 156 – 178 penguins.

When considering the Main colony alone, there has been interannual variability in the number of breeding attempts, with the total number of breeding nests in the Main colony only (not including the west side of Moresby Wharf) lower in each year from 2021 – 2024 (n = 42, 55, 35 and 37 nests for 2021 – 2024 respectively) compared to the historical average from 2005-2019 (78±10 nests).

The four-year baseline (2021 – 2024) adult breeding population estimates demonstrate large fluctuations due to a range of natural factors including a significant predation event. It will be necessary to monitor a range of environmental factors and breeding participation over a longer time period to determine if the population size variations are due to natural factors or impacts arising from the Action. However, a Construction Environmental Management Plan will be developed that includes a monitoring and adaptive management approach that aims to prevent significant levels of anthropogenic disturbance from being received at the nesting colonies, thereby reducing the potential for significant impact on little penguin breeding participation and breeding success.

2 INTRODUCTION

In Western Australia, little penguins (*Eudyptula minor*) are found on offshore islands, and their distribution extends from islands off the coast 50 km south of Perth through to the Recherché Archipelago, i.e. within the South-west Marine Bioregion. Within this region, little penguins were identified as a regional priority for conservation (Department of Sustainability, Environment, Water, Population and Communities 2012). The northern-most colonies are located in the Perth metropolitan region, on Penguin and Garden islands, and although historically they were also on Carnac Island, a recent survey was unable to locate any penguins (Clitheroe pers. comm). Little penguins are a listed marine species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The species is not listed as Threatened and Priority Fauna under the Western Australian *Biodiversity Conservation Act 2016* (BC Act). However, the conservation of little penguins under the BC Act is provided for, given that the objectives of the BC Act are "to conserve and protect biodiversity and biodiversity components in the State; and to promote the ecologically sustainable use of the biodiversity components in the State (s3)." Furthermore, little penguins in the Perth metropolitan region were assessed as having the highest relative threat and the highest conservation value of all marine fauna in the same region (Department of Conservation and Land Management 2003). Supporting this, a recent study investigating the risk of various fish species and iconic species in Cockburn Sound found that the penguins were at severe risk of impacts associated with climate change (Mitchell et al. 2025). Little penguins are also listed as a key performance indicator for the Shoalwater Islands Marine Park (Department of Environment and Conservation 2007).

Little penguins are a burrowing seabird, digging nests in soil, nesting under dense vegetation, in caves and under infrastructure (Dunlop et al. 1988). However, the loose sandy substrate on the islands off the Perth coast are too soft to support burrows, and hence they do not dig burrows on these islands. The Garden Island colony of little penguins established in a rock wall that was constructed at Careening Bay in approximately 1975, and penguin presence was first noted in 1986 by Royal Australian Navy personnel who had consistently observed penguins in burrows (Wykes et al. 1999). Prior to this, there were no records of penguins inhabiting Garden Island (Johnstone and Storr, 1998).

The little penguin Main colony (south of Diamantina Pier and within the Slipway) in the rock wall at Careening Bay has been monitored monthly since 2001. In 2003 – 2004, 12 nestboxes were installed under trees in the area between Diamantina Pier and the slipway, and these were included in the monitoring program. Nest sites in the rock walls in other areas have been monitored intermittently from 2005 – 2020, including between Diamantina Pier to Parkes Wharf, Parkes to Oxley wharves and Oxley Wharf to Colpoy's Point. At Colpoy's Point, additional areas monitored included rock walls, concrete slabs and other rubble, under large trees, and, since 2021, nestboxes sited in the area. Since 2021, all these sites have been monitored fortnightly.

The presence of penguins, the number of nests with breeding attempts, timing of breeding, breeding success and timing of moult have been determined as part of the monitoring (e.g. Cannell 2004, 2022 and 2024). Their core habitat and home range have also been established over multiple years (e.g. Cannell et al. 2014, Cannell 2022, Cannell 2024). From these data, it has been established that the penguins typically lay eggs in any month from April – November, and they forage within Cockburn Sound during both incubation and chick rearing (Cannell et al. 2014, Cannell 2022, Cannell 2024). There has been interannual variability in the number of breeding attempts, with the number of nests in the Main Colony only (not including west of Moresby Wharf) lower in each year from 2021 – 2024 (n = 42, 55, 35 and 37 nests for 2021 – 2024 respectively) compared to the historical average also from the Main colony only from 2005-2019 (78±10 nests; Cannell 2022, Cannell 2024). Note that these results were from monitoring of a subset of the total nests that were monitored between 2021 – 2024 in the Main colony, the rock walls between Diamantina Pier, Parkes and Oxley Wharves, and Colpoy's Point.

To estimate the population size of little penguins, several techniques can be used, including a count of nests (e.g. Bool et al. 2007), predictive habitat modelling (e.g. Rayner et al. 2007), extrapolation of burrow densities along line transects (e.g. Weerheim et al. 2003) or in randomised quadrats in different habitat types, mark-recapture models (Sutherland and Dann 2012, Cannell et al. 2024), counts of penguins returning ashore, or a combination of several techniques (e.g. Cannell et al. 2012, Sutherland and Dann 2014). However, not every method is suitable for a given colony. For example, in sparse colonies, line transects or randomised quadrats in different habitat types may overestimate

colony size. On Garden Island, it is not possible to use many of these techniques. For example, little penguins return to the colony in the evening, and the arrival sites are typically amongst the rock walls, making it extremely difficult to catch penguins as they make landfall. Hence, mark-recapture is not possible at this colony. There are large sections of the rock walls that are uninhabitable, either due to water inundation at high tide, or to the presence of large, open areas within the rock walls. As such,

predictive habitat modelling or extrapolation of burrow densities along line transects would overestimate the number of nest sites. Counts of penguins returning ashore, by itself, is not a suitable method for estimating the population. This is because of the asynchronous breeding of the penguins, meaning that on any evening, the returning penguins could be pre-breeding, in three different stages of breeding (incubating eggs, guarding chicks up to two to three weeks old, or raising older chicks), pre-moult penguins, or non-breeding adults or juveniles (i.e. two to three years old and not sexually mature).

This report details the estimate of the breeding population on Garden Island, from 2021 – 2024, obtained using counts of nests (*sensu* Bool 2007) with breeding activity.

3 METHODS

3.1 Study species and site.

3.1.1 Study species

Annual cycle

Little penguins breed asynchronously, i.e. they do not all breed at the same time. On Garden Island, eggs are generally laid from April to November, though eggs have also been occasionally observed in March, and the penguins can lay two clutches in a year. Like all little penguins, generally two eggs are laid in each clutch, rarely is only one egg laid. The eggs are incubated for an average of 36 days (Stahel & Gales, 1987). Both parents share incubation, with the partners swapping every three to five days on average (Chiaradia & Kerry, 1999). Once the eggs hatch, the chicks are guarded constantly for two to three weeks. Both parents share the guard phase, and whilst one parent guards the chick/s in the nest, the other is foraging at sea. That parent then returns to the nest in the evening, feeds the chick/s, and the next day the parents swap roles. Following the guard phase (once chick/s are developed enough to maintain their body temperature), the parents alternate between long trips that last for several days, and short trips, lasting for one day (Saraux et al. 2011). The number of long trips they take is related to the mass of the adult (Saraux et al. 2011). Regardless of whether they are leaving for a long or short trip, the parents leave the nest before sunrise and return during the evening to feed the chick/s. Chicks are fully fledged and leave the nest at an average age of eight weeks, usually one sibling leaving at a time (Pryor & Wells, 2009).

It is possible for a pair of penguins to successfully raise chicks from two clutches within a year, i.e. a maximum of four chicks, providing the first clutch is laid in April/May. The interval between the departure of fledglings from a nest and the second clutch being laid ranges from one to four weeks (Cannell, 2004).

After breeding, the adult penguins typically moult between November and February, though have been observed moulting in March (Cannell unpubl. data). During this time, they replace all their feathers. This is a critical process which the penguins must undergo every year. The moult takes two to three weeks, during which the penguins are confined to land. As they are unable to feed during the moult, the penguins must build up their fat reserves prior to moult and can double their mass. Low body mass during moult can result in death from starvation.

Following the annual moult, the penguins depart the colony, returning only intermittently until eggs are laid. However, penguins are more likely to be at their nest site one, four and seven weeks before laying (Reilly & Cullen, 1981). As some of the penguins on Garden Island lay eggs in April, then increased visitation can occur as early as February. It is not known if the penguins remain within Cockburn Sound between post-moult departure and breeding.

Little penguins have a high site fidelity to the area where they were raised as chicks, to their breeding nests and to the arrival area back into the colony. Even though dispersal between colonies is more likely in a penguin's first year, compared to once penguins begin breeding (Reilly & Cullen, 1982; Agnew et al., 2016), less than 6% of the individuals select a new nesting colony (Dann, 1992).

Daily cycle

Little penguins leave the colony before dawn, with the departure travelling behaviour characterised by slow speeds and long periods of time on the surface of the water (Cannell unpubl. data). During the departure, the penguins often preen, an important activity for maintaining feather structure and waterproofing, thus decreasing the risk of hypothermia and improving efficiency of swimming (Stahel & Gales, 1987). The slow departure continues until approximately morning civil twilight. The penguins then travel to their foraging grounds. Travelling is characterised by shallow dives, within the top 1 m of the water column, with both the dive time and surface time between dives being of short duration (Cannell et al. 2020). Foraging areas are identified by areas of high penguin residence and sinuosity (i.e. curves and turns), often interspersed by slower travel between areas. During foraging, they can dive more than 100 times per hour (Ropert-Coudert et al., 2003; Cannell et al. 2020), searching for and feeding on prey. In between dives, they rest on the surface, replenishing important oxygen stores.

The return to the colony is typically in a straight line to an area offshore, where the penguins remain for up to an hour, "rafting", prior to landing at the colony. Their return to shore is then rapid and is

characterised by shallow dives, surfacing only to take a quick breath (Cannell pers. obs.). Eighty percent of the penguins arriving on Garden Island do so within 40 minutes after sunset, regardless of breeding stage, moon phase or weather patterns (Cannell, 2004). This is much earlier compared to the mean arrival times of penguins at Penguin Island (one to two hours after sunset) (Klomp & Wooller, 1991, Cannell pers. obs.) and Phillip Island (average of 81 min after sunset) (Rodríguez et al., 2016). At Garden Island, some penguins have been observed arriving even before sunset (Cannell pers. obs.) There are a few major arrival areas within the colony, with penguins using accessible arrival areas that are closest to the nests. The penguins are highly faithful to an arrival area however, and do not use other areas (Cannell et al., 2011).

Once the penguins have come ashore, usually in groups of at least two to three birds, they do not immediately make their way back to the nest. When they first arrive at the colony, the penguins tentatively alight the beach/rocks, often walking a few paces, stopping, looking and either continuing or rapidly returning to the water (Cannell pers. obs.). Noises and movement, even from waves, can trigger this return to the safety of the water. The penguins have been observed swimming back to deeper water in Careening Bay, or parallel to the shore, before attempting to land again. They can land and retreat several times before eventually making their way towards the nesting site (Cannell pers. obs.). Once onshore, the penguins spend up to at least 15-30 minutes between the shore and nesting sites, engaging in a variety of behaviours, including preening (Cannell, 2001). If the penguins do not return to the colony, they will remain at sea overnight. However, as the penguins rely on vision to catch their prey (Cannell & Cullen, 1998), they tend to do very little diving at night but remain on the surface of the water.

3.1.2 Study site

The little penguin colony is located on Garden Island, Western Australia (32°11'21.60" S 115°40'9.59" E). The study area included the nest boxes and burrows within the Main colony (south of Diamantina Pier and within the Slipway) in Careening Bay, the rock walls between Diamantina Pier, Parkes and Oxley wharves (referred to as Wharves), and Colpoy's Point. Examples of the rock walls are shown in Figs. 1 a and b, and location of all the areas studied in Fig. 2. Following reports of underweight chicks found on the road adjacent to Moresby Wharf (to the west of the slipway on the western edge of Moresby Harbour) in late 2022, the rock wall adjacent to this wharf was added into the Main colony monitoring area in January 2023 (Fig. 2).

Some nest sites can become unusable due to changes in positioning of rocks (e.g. from storm damage), whilst adults may use new nest sites (e.g. they changed mates, or when juveniles return as sexually mature adults to breed). Therefore, it was necessary to identify and mark nest sites in the entire study area throughout the year to capture all nesting attempts.

Figure 1 a) Northern, and b) central section of rock wall in Main Colony, Garden Island, Western Australia

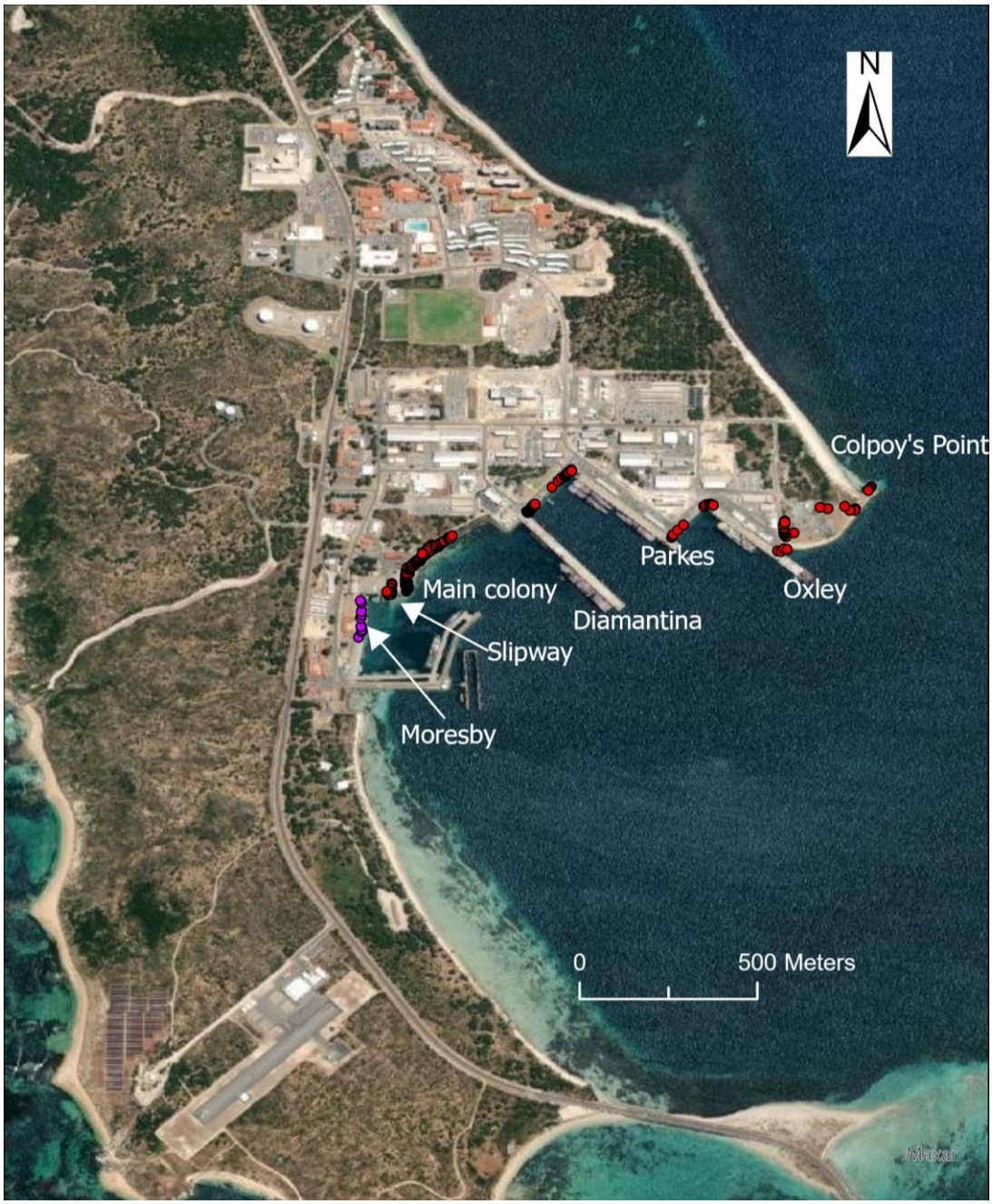

Figure 2. The location of monitored little penguin breeding sites on Garden Island, Western Australia. Red- Main colony (south of Diamantina Pier and within the Slipway), between Diamantina Pier, Parkes and Oxley wharves, and Colpoy's Point. Purple- nests along west Moresby Wharf, monitored since 2023.

3.2 Breeding assessment

The entire colony was monitored every fortnight in 2021 – 2024 (Moresby Wharf area was added in 2023 and 2024). Breeding was determined by checking all potential nest sites and nestboxes for any evidence of breeding. Nest contents were determined using a torch or a burrowscope, a lipstick camera housed in a long, flexible hose and wirelessly connected to a monitor (Fig. 3). However, it is not always possible to observe adults, eggs, or chicks even with a burrowscope. This is because the entire nest may not be able to be observed with a burrowscope. In such cases, indications of nesting activity were recorded, including the presence and colour of fresh or dried faeces, nesting material, chick down, ants or fleas, regurgitants, and/or penguin vocalisations. For each nest with a known breeding attempt, the final outcome, i.e. whether the eggs hatched, or whether the chicks fledged, is not always known. Hence, the nests are classed as having a known or unknown outcome. Additionally, for a few nests, the eggs and chicks may never have been observed. If one or more of the indications of nesting activity were noted on more than one monitoring date for a nest, then the nest was classed as having a likely breeding attempt.

Figure 3 Dr Cannell using a burrowscope to identify contents of a nest site at Garden Island, Western Australia.

3.3 Counts of the breeding population

The total number of unique nests with known breeding activity or likely breeding activity was determined for all the areas, excluding those in Moresby Wharf, for each year from March to February the following year. This is to ensure that all breeding attempts that occur later in the year (and hence the presence of chicks may not be observed or indicated until January or February) are counted. As it is not necessary to determine the month in which eggs were laid in nests with known breeding for this

survey, even those nests in which the lay month could not be determined were included in the counts (such nests were excluded from analyses in Cannell 2022, 2024 and 2025). The counts for 2023 and 2024 within Moresby Wharf are also added for comparison.

With only four annual counts for the breeding nests, it is not possible to perform a linear regression to determine if there is any statistically significant difference between the years.

4 RESULTS

Over the four years, the total number of breeding and likely breeding nests fluctuated, with the minimum of 78 nests (including those in Moresby Wharf) in 2023, to at least 113 nests in 2022 (noting Moresby Wharf was not monitored in all years). 2022 (Table 1). As each nest represents a breeding pair, then the population estimate of breeding adults on the island has ranged from 150 – 226 breeding individuals. With the nests at Moresby Wharf included, the lowest estimate is 156 individuals. However, the highest estimate cannot include numbers from Morseby Wharf, given there was no monitoring of this area in 2022. As such, the number of breeding individuals would likely be higher than the estimated 226 individuals.

Table 1 The total number of breeding nests (with or without known final outcome of each breeding attempt), likely breeding nests, and the sum of both, on Garden Island, Western Australia, each year from 2021 – 2024. Prior to 2023, the areas monitored included the Main colony in Careening Bay (the rock wall and nestboxes within the Small Boats Harbour and the rock wall in the Slipway area), the rock walls between Diamantina Pier, Parkes and Oxley Wharves, and Colpoy's Point. In 2023 and 2024, the total number of breeding and likely breeding nests in the Moresby Wharf were also determined.

Nest category	2021	2022	2023	2024
Known Breeding	68	95	64	71
Likely Breeding	17	18	11	13
Total	**85**	**113**	**75**	**84**
Known Breeding – Moresby Wharf	NA	NA	2	4
Likely Breeding – Moresby Wharf	NA	NA	1	1
Total including Moresby Wharf			**78**	**89**

5 DISCUSSION

This report has identified the number of adult breeding penguins on Garden Island in each year from 2021 – 2024 has ranged from 150 – 226 individuals (excluding Moresby Harbour nests). The estimate covers the entire breeding season, which can occur in any month from March – February. The estimate does not include non-breeding adults or juveniles.

The interannual variability observed in the breeding population is due to multiple factors: 1) fewer penguins participating in breeding, 2) a reduction in breeding success in any one year, which results in fewer chicks available to recruit back into the population two to three years later , 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.

In 2021, when there were an estimated 170 breeding individuals (i.e. 85 nests * 2, as a nest represents a pair pf penguins), the breeding season had begun in March, however, there was an unusual hiatus from June – August. High turbidity levels measured in Cockburn Sound coincided with fewer eggs being laid and hence fewer breeding penguins. The turbidity levels were associated with greater discharge from the Swan River into Cockburn Sound from May -October, with levels in July and August an order of magnitude greater than average (data from https://kumina.water.wa.gov.au/waterinformation/wir/reports/publish/616011/616011.htm), and a much higher than average winter rainfall (Cannell 2022). This resulted in increased tannin flowing into the Sound from the Swan River as well as water with higher chlorophyll levels, within which was a phytoplankton bloom (Pattiaratchi & Thomson, 2021). However, during spring, there were very high abundances of juvenile sandy sprat (*Hyperlophus vittatus*) in Cockburn Sound (Yeoh et al 2025), one of the species consumed by the little penguins in Cockburn Sound, but albeit infrequently (Cannell unpubl. data). This high abundance of sandy sprat were likely flushed from the Swan River, and fed on the planktonic organisms that would have been associated with the phytoplankton bloom (Tweedley et al. 2025). Coinciding with the increase in sandy sprat was a very unusual, synchronous breeding of the little penguins. The abundance of the juvenile sprats declined by summer of 2021, but there was a high abundance of larval, not juvenile, sandy sprat in winter 2022 (Yeoh et al. 2025). This was the year with the greatest relative number of breeding individuals on Garden Island, at least 226 individuals, between 2021 - 2024.

The lowest breeding population estimate was for 2023. There were at least 39 penguins that were killed by foxes in January to May 2023 (Cannell 2024), and the majority were at Colpoy's Point. The penguins killed were in various stages of moulting, or pre-breeding. It is not possible to determine what proportion of these penguins were juveniles, or non-breeding penguins. However, assuming that some of them would have started breeding in 2023, then this predation would have resulted in an immediate lower estimate of breeding penguins. As a worst-case scenario, if the adults killed represented one of a breeding pair, and assuming that they all would have attempted breeding in 2023, then that is at least 39 nests impacted. If each nest was to have produced between one to four chicks over a breeding season, then between 39 and 156 chicks would not have been produced. Even if a surviving mate found another partner the same year, breeding may not be as successful the first year a pair is together (Nisbet and Dann 2009). Regardless of how many chicks may not have been produced due to this predation event, the short-term impact will be observed in 2025 – 2026, when the juveniles would have been recruiting back into the population. There will also be a longer-term impact, based on the lost breeding effort over multiple years from those penguins that were killed, and those juveniles who themselves would have become breeding adults.

Despite the low numbers breeding, there was anecdotal evidence of large groups of penguins observed rafting offshore near the Magnetic Treatment Facility in Careening Bay in late 2023. This indicates that there were more penguins in the population that were likely to be taking a sabbatical from breeding.

Mortality in adult little penguins is generally low, e.g. an estimated 86% survival for Penguin Island penguins (Tavecchia *et al.* 2016). However, climate effects on prey can impact adult mortality. Indeed, in 2011 and 2012, when sea surface temperatures (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.* 2024). Elevated SSTs are not the only factor which influence prey abundance. Nutrient levels, particularly nitrogen levels, are also important as they are associated with primary productivity- the base of the food chain for many fish. Within the WA coastal ecosystem, nitrogen mostly comes from discharges (Mitchell *et al.* 2025) due to the low nutrients carried within the

Leeuwin Current. With the discharges being well managed in recent years, Cockburn Sound may have become too “clean” to support an abundant penguin prey stock. However, reduced food availability isn’t the only cause of mortality in penguins. 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). Thus, the population is likely to fluctuate temporally, dependent on a suite of factors associated with direct adult mortality and a reduction in the number of juveniles returning to the colony.

Environmental factors

To understand the influence of environmental conditions and prey availability on breeding success and population size for future monitoring and to separate these from any effects that may be due to the project, the influence of five environmental variables on the breeding performance of the penguins will be investigated. These data will be sourced from publicly available information via the DWER Water Information database and Bureau of Meteorology. These variables are:

- Salinity (PSU)
- Dissolved oxygen (mg/L)
- Sea surface temperature (°C)
- Turbidity (NTU)
- Rainfall (mm).

Limitations of study

It is also possible that a small percentage of nests deep within rock wall cavities are missed. Therefore, the population estimate represents a minimum number of penguins per year. Additionally, a population is not only composed of breeding adults, but also nonbreeding adults and juvenile penguins. The latter two groups of penguins will likely intermittently visit the colony, but it is not known how long they remain at the colony. It is not possible to get the counts of these two groups by counting nests with breeding activity. It would be possible to get counts of penguins coming ashore in the evening in different areas on multiple occasions and use this in conjunction with the burrow counts to get an estimate of the wider population. Counts of penguins coming ashore would be best achieved with a series of cameras.

5.1 Conclusion

The four-year baseline adult breeding population estimates demonstrate large fluctuations due to a range of natural factors including a significant predation event. It will be necessary to monitor a range of environmental factors and breeding participation over a longer time period to determine if the population size variations are due to natural factors or impacts arising from the Action. These factors include SST, turbidity, salinity and dissolved oxygen (from hourly data collected by Department of Water and Environmental Regulation in Cockburn Sound) and monthly rainfall. However, the Construction Environmental Management Plan will include a monitoring and adaptive management approach that aims to prevent significant levels of anthropogenic disturbance from being received at the nesting colonies, thereby reducing the potential for significant impact on little penguin breeding participation and breeding success.

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