Penguin monitoring and conservation activities in the Gulf St Vincent

July 2017 – June 2018

Report to the Adelaide and Mt Lofty Ranges Natural Resources Management Board
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inspiring achievement

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I. SUMMARY

This project further investigated little penguin (*Eudyptula minor*) population trends in the Gulf St Vincent with a focus on factors that influence breeding success. Granite Island continued to have a high breeding success (1.87 ± 0.27 fledgling per pair; n = 8) while population census and night tour data showed a stabilizing trend (estimated at 28 adult penguins at the time of the census). However, disturbance on Granite Island had increased by 6 fold since 2016 raising some concerns for the long-term survival of the population. Despite low breeding success (0.44 ± 0.22 fledglings per pair; n = 25), population on Troubridge Island also seem to show a stable trend since 2013, with 450 penguins present at the time of the census. The distribution of active nests found within the monitored quadrats between 2016 and 2017 showed consistent densities between the two years, suggesting that the quadrat method was accurate in recording total population size. Althorpe Island however showed a constant declining trend since 2013, with only 18 adults in 2017. Finally, the report shows that breeding success across years and populations is strongly influenced by nest type as well as the local environmental conditions (specifically, sea surface temperatures, air temperatures and wind speeds).

II. INTRODUCTION

This project has been an ongoing project monitoring the decline of little penguins (*Eudyptula minor*) in the Gulf St Vincent (South Australia) and implementing the actions identified by Wiebkin (2011). This project is supported by funding from the Adelaide and Mount Lofty Ranges Natural Resources Management Board, with support for additional investigations provided by Flinders University, the Foundation for National Parks & Wildlife, and the Sir Mark Mitchell Foundation.

This project follows up on previous projects (2013-2017) investigating three main issues: (1) factors that impact reproductive success, (2) factors that impact adult and sub-adult survival, and (3) connectivity between the populations.

The report by Colombelli-Négrel (2017a) showed that Granite Island continued to have the highest breeding success (2.00 ± 0.19 fledgling per pair; n=8) while Emu Bay had the lowest (0.67 ± 0.33 fledgling per pair; n=13). Population censuses and night tours data showed stabilizing trends for Granite Island population since 2012, with 16-18 penguins present in 2016 on Granite Island. Population censuses on Kangaroo Island showed declining trends for Emu Bay and Antechamber Bay but potentially increasing trends at Kingscote. Population censuses showed increasing trends for Troubridge Island, with 466 penguins present at the time of the census. Althorpe Island population showed potentially stable or slightly decreasing trends since the 2013 census. However, the fact that no additional breeding area was located since 2013 suggests that the Althorpe Island population may have decreased significantly since the 132 penguins found in 2004. Finally, little penguins exhibited a stress response when hearing cat calls, even if they had never been exposed to cats previously

The following report outlines the data collected between July 2017 and June 2018. This report (1) continues long-term annual monitoring of targeted populations on Troubridge and Granite Islands and monitoring on Wardang and Althorpe Islands, (2) further investigates factors that influence breeding success, (3) and reports on the progress of the citizen science approach developed on Granite Island to collect regular nightly penguin count data.

III. AIMS

The current funded project had the following objectives: (1) to continue breeding monitoring on Granite and Troubridge islands; (2) to conduct population surveys on Troubridge and Granite islands; (3) to organise community events to educate public about the penguins' situation; and (4) to continue the citizen science approach to collect regular nightly penguin data on Granite Island. This report also provides additional information on factors that impact reproductive success in little penguins and present the results of population surveys on Wardang and Althorpe Islands (Yorke Peninsula) and at Emu Bay (Kangaroo Island).

IV. MATERIALS AND METHODS

Study sites

This project was conducted during the 2017-breeding season between August 2017 and February 2018 on two islands in the Gulf St Vincent: (1) Granite Island (35°37'S, 138°36'E), in the Fleurieu Peninsula, and (2) Troubridge Island (35°06'S, 137°49'E), in the Yorke Peninsula. Additional data are also presented for (1) Wardang Island (34°28'S, 137°18'E, Yorke Peninsula), (2) Althorpe Island (35°22'S, 136°51'E, Yorke Peninsula), and (3) Emu Bay (35º35'S, 137º30'E, Kangaroo Island).

Breeding monitoring

All searches for active nests/burrows started around mid-August. Monitoring was carried out until November on Troubridge Islands and until February on Granite Island. A nest was recorded as active if it contained either eggs, chicks or adults or had clear evidence of penguin presence, such as fresh droppings or a strong penguin smell. Once found active, nests were checked every 10-15 days.

To assess breeding success, the number of eggs, chicks and adults present in each nest was recorded during each visit. A chick was considered as fledged when it disappeared from the nest at about eight weeks of age and was not found predated nor in any of the other nests. If the outcome of a nest was unknown at the end of the monitoring period (e.g., the nest still had eggs and therefore it was unknown whether those eggs would hatch and produce fledglings), it was excluded from the analysis for breeding success. Breeding success was defined as the number of chicks that fledged per breeding pair.

Predation was scored as suspected if eggs or chicks were damaged or removed between visits before the eggs were ready to hatch or before the chicks were ready to fledge, but only if adults were still attending the nest and therefore had not abandoned the nest. Eggs were considered as abandoned if they were found unattended during two consecutive visits and felt cold to the touch. Microchip numbers of birds in nests were also recorded to assess survival.

Granite Island nightly counts

The nightly penguin counts report on the number of penguins counted by the Penguin Tour Guides on the North shore during the Little Penguin Tours. Tours are conducted for visitors to spot little penguins as they return from the ocean at sunset and are ran all year round. Counts are conducted within two hours after dark on a regular basis, and tours last approximately 1 to 1.5 hours. A total of five guides lead the Penguin Tours, with 1-2 guides per night. A total of ten active nests were found in this area during the breeding monitoring, while only four active nests were found on the other parts of the island. Disturbances, such as people walking unauthorised on the island at night with light torches or dogs, were also recorded.

Population Census

Penguin censuses were carried out on Troubridge Island (Yorke Peninsula), Wardang Island (Yorke Peninsula), Althorpe Island (Yorke Peninsula), and Granite Island (Fleurieu Peninsula). Emu Bay (Kangaroo Island) was visited as part of an Ecological Assessment conducted for the Kangaroo Island council.

All censuses were conducted in October 2017. Prior to 2013, censuses were conducted in July-August, four weeks after the first burrow was found with eggs. In 2013, no breeding attempt was observed in August; therefore, the date for the census was shifted to October to follow the "four-week" guideline. Since 2013, the peak of the breeding season has shifted to October (see results), and thus censuses are now conducted in October.

An additional count was conducted on Wardang Island in June 2017. All censuses were conducted by a team of volunteers and the Penguin Ecologist, except on Althorpe Island where the census was conducted by the Friends of Althrope Island Group, and on Wardang Island where the June survey was conducted by the local rangers.

On Troubridge Island, the 2017-census was conducted within six 30x30m quadrats that were selected to reflect varying habitats (open, closed) and penguin densities (low, high). The total population number was estimated based on the survey results obtained from these quadrats. Similar calculations were completed with surveys conducted within the same quadrats in 2016 to ensure that these quadrats best predicted the total population number.

On Wardang Island, the section on the north-east coast near the jetty (see Colombelli-Négrel 2017a) was searched during both visits to estimate difference in population survey results between the two periods (June vs October).

At Emu Bay, a 600m section on both side of the jetty was searched as part of an Ecological Assessment conducted for the Kangaroo Island council (see Colombelli-Négrel 2017b).

Each colony was searched for presence or absence of penguin nests. Once a nest was found, its status was noted as active or inactive. A nest was recorded as active if it contained eggs, chicks or adults, or had clear evidence of penguin presence such as fresh droppings, a strong penguin smell or recent excavation. A nest was recorded as inactive if none of the above criteria was found or if it had cobwebs at the entrance indicating that no large animal was regularly entering/exiting the nest. All active nests were marked with GPS. On Granite Island, nests were also marked with talcum powder to avoid double counting by different team of volunteers.

Additional data

Nest type and nesting behaviours of little penguins

This study examined how nest type and different characteristics of the nesting habitat affect breeding success, predation, and the nesting behaviours of little penguins across three colonies in South Australia (Emu Bay, Troubridge Island and Granite Island). Data on breeding success were collected between 2013 and 2016 as previously described. The following nest characteristics were also noted: (1) nest type (surface, sand, bush, rocks or artificial), (2) shrubs cover (percentage of trees and shrubs cover within a 10m radius of the nest), (3) vegetation cover (percentage of vegetation above the nest estimated visually when standing 1 m away), (3) nest entrance orientation, (4) number of neighbours (number of active nests within a 30m radius), and (5) distance to the beach.

In 2016, a total of 51 adults during incubation and the guarding periods were also video monitored to assess the influence of the characteristics of the nesting habitat on the behaviours of adult penguins. For each video, the time spent in the following behaviours were recorded: (1) sitting, (2) crouching, (3) standing, (4) preening, (5) dozing, (7) resting, (8) vigilance, (9) head shaking, (10) stretching, (11) yawning, and (12) gular fluttering. PASW version 22.0 for Windows (SPSS Inc., Chicago, IL, U.S.A.) was used for all statistical analyses. General linear mixed models were used to examine the relationship

between predation, hatching success, breeding success and the nesting habitat characteristics, and between the nesting habitat characteristics and nesting behaviours.

Local environmental conditions and breeding success

The impact of local environmental conditions on little penguin breeding success was investigated as part of Cameron May's third-year project (2017) entitled 'Determining the Impact of Environmental Conditions of Breeding Success in South Australian Colonies of Little Penguins (*Eudyptula minor*)' under the supervision of Dr Diane Colombelli-Négrel. The project focused on three colonies in South Australia (Kingscote, Troubridge Island and Granite Island) between 2001 and 2016. Breeding data were collected as previously described. Environmental data during the breeding period (mean sea surface temperature, ambient air temperature, wind speed, and rainfall) were collected from the Bureau of Meteorology and Integrated Marine Observing System (IMOS) http://imos.org.au/home.html. Statistical analyses were performed using SPSS 22.0 for Windows (SPSS Inc., Chicago, IL, USA). Generalised linear mixed models were used to test the effect of the environmental parameters on the number of eggs, chicks and fledglings produced per pair.

Timing of nesting and moulting activities

Across their distribution, little penguins breed and moult at different times of the year. As discussed in the previous report, such timing can have significant implications when estimating their population trends (see Colombelli-Négrel 2017a). Little penguins in the eastern side of their range (Tasmania, Victoria, New South Wales and New Zealand) are believed to mostly breed during spring and summer (e.g., Gales 1985; Fortescue 1999; Nisbet and Dann 2009) while those in the western part of their range (South Australia and Western Australia) are believed to mostly breed in autumn and winter (Wiebkin 2011; Cannell et al. 2012). However, the start of breeding can vary markedly from year to year (up to six months; Reilly and Cullen 1981) and between colonies. In Australia, little penguins supposedly moult from February through to April (Reilly and Cullen 1983). This report presents updated information on the timing and breeding of little penguins in the Gulf St Vincent, South Australia.

Automated acoustic recorders

Between September and November 2017, twelve bioacoustics automated recorders developed by the Department of Conservation in New Zealand were deployed on Granite and Troubridge Islands (six per island). On each island, the recorders were positioned every 50m along one transect that crossed penguin breeding territories. The recorders were set to record for three hours just after nightfall and three hours just before dawn and were left to record for two months. Batteries were replaced every two weeks. Playback experiments showed that little penguin calls could be detected by the recorders up to 10m. Therefore, repeated censuses within a 10m radius of each recorder were conducted every two weeks to estimate variation in penguin numbers and the accuracy of the recorders in estimating penguin density.

Ethics

This project was approved by the Flinders University Animal Welfare Ethics Committee (Project numbers No. E388-348-449) and is also supported by a scientific permit to conduct the research (Y26040). Progress report on the numbers of animals that were used will be provided to DEW on 30/6/2018.

V. RESULTS

Breeding monitoring

Between August and December, a total of 45 nests were monitored on Granite and Troubridge islands (Table 1). Out of the 45 monitored nests, 33 showed signs of breeding activity (73%) such as eggs or chicks present in the nest. Two nests showed evidence of abandonment on Granite Island and one nest had evidence of predation on Troubridge Island. The two abandoned nests on Granite Island were located in the high visitation area, near the old penguin centre. The predated nest on Troubridge Island is suspected to have been predated by seagulls. Breeding success on Granite Island was 1.87 (± 0.27) fledglings per pair (n = 8) compared to 0.44 (± 0.22) fledglings per pair (n = 25) on Troubridge Island (Table 2; Figure 1).

Survival: Only two individuals that were previously microchipped were re-sighted in 2017, both on Troubridge Island. No microchipped individual was re-sighted on Granite Island; microchipped individuals on Granite Island were last re-sighted in 2015. The list of re-sighted individuals is presented in Appendix 1.

Penguin colonies	Burrow monitored	Breeding burrows	Eggs	Chicks	Fledglings	Groups with 2nd clutch	Burrows predated
Troubridge	**28**	**25**	**45**	**32**	**11**	**1**	**1**
Granite	**17**	**8**	**18**	**15**	**15**	**2**	**0**
Total	**45**	**33**	**63**	**47**	**26**	**3**	**1**

Table 1*. Number of eggs, chicks and fledglings produced in total per penguin colony. The table also presents the number of burrows with suspected predation.*

Penguin Colonies	2017 Eggs/ Pair (SE)	2017 Chicks/ Pair (SE)	2017 Breeding success (SE)	2016 Eggs/ Pair (SE)	2016 Chicks/ Pair (SE)	2016 Breeding success (SE)
Troubridge	1.80 (0.09)	1.28 (1.18)	0.44 (0.22)	1.90 (0.05)	1.65 (0.13)	1.03 (0.18)
Granite	2.25 (0.13)	1.87 (0.27)	1.87 (0.27)	2.25 (0.25)	2.25 (0.25)	2.00 (0.19)

Table 2*. Breeding success for each penguin colony monitored during the 2017 and 2016-breeding seasons*

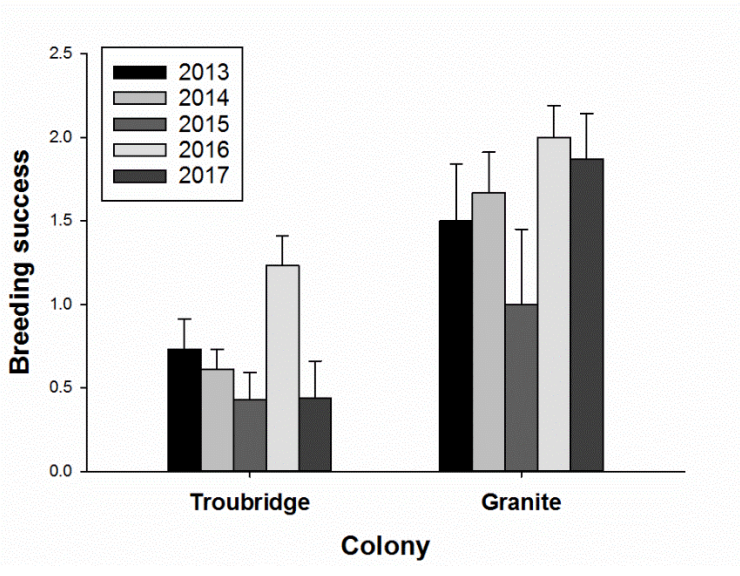

Figure 1. *Breeding success across all the penguin colonies monitored between 2013 and 2017*

Granite Island nightly counts

The daily attendance for the night tour counts occurring on the North Shore is presented in Figure 2. During the night counts, significant disturbances to the penguins were recorded on 13% (38/296) of the monitored nights. The disturbances include: unauthorised vehicles, dogs (on or off leash), bikes, and people wanderings using white torches or flashes. Such disturbances have increased since 2016, when they were recorded in only 2% (6/267) of the nights.

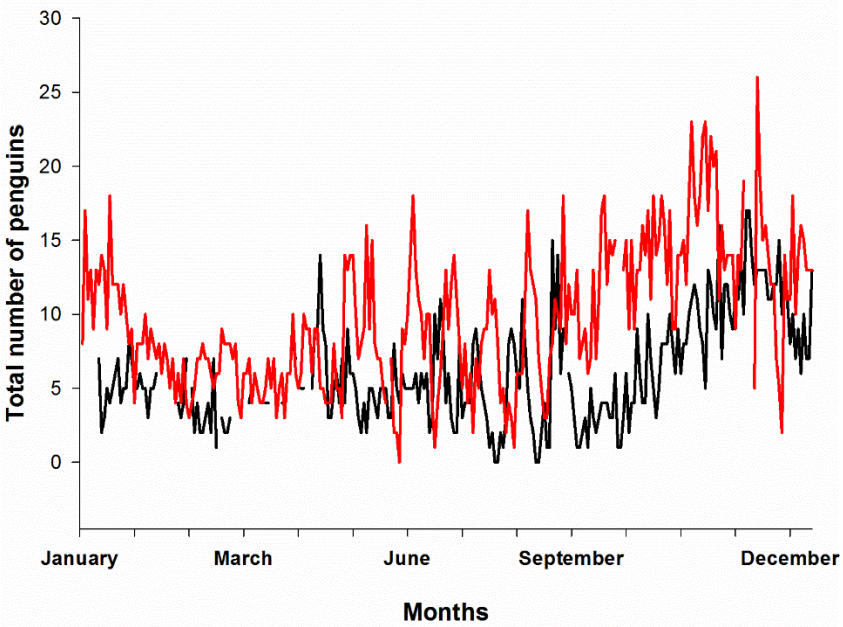

Figure 2. *Daily attendance of little penguins on Granite Island in 2016 (black) and 2017 (red)*

Population Census

Granite Island

Population census on Granite Island was conducted on 13th of October 2017 by 31 volunteers and three penguin researchers. A total of 14 active nests (mostly on the North Shore) were found on the day of the census and the population estimation for Granite Island was 28 adult penguins (Figure 3). Out of the fourteen occupied nests, only two showed signs of breeding activity at the time of the census.

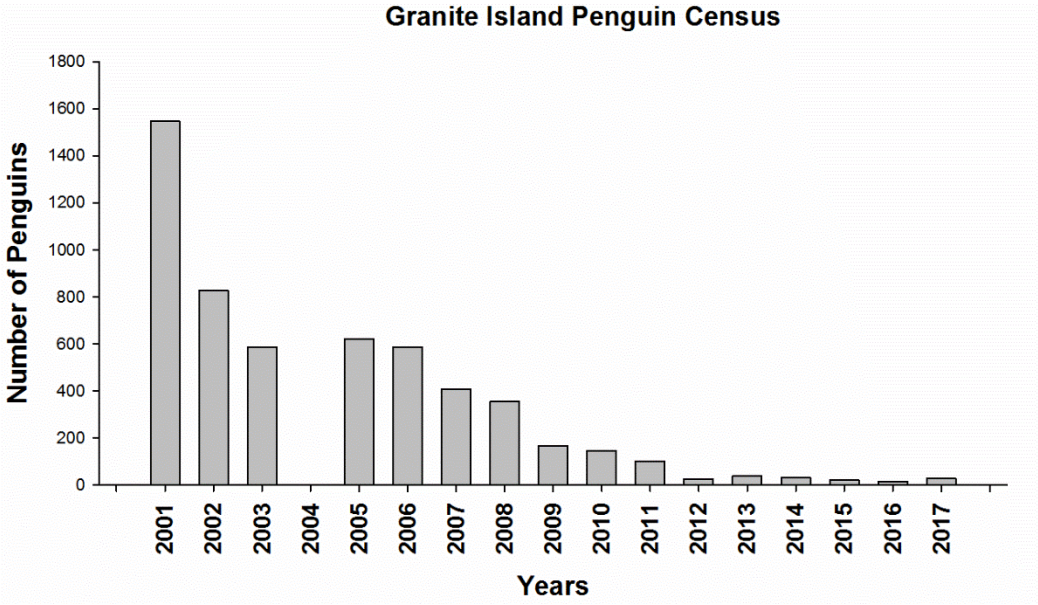

Figure 3. *Estimated population size of little penguins on Granite Island between 2001 and 2017*

Troubridge Island

Population census on Troubridge Island was conducted over three days (4-6th of October 2017) by a team of four people. The census was conducted over six quadrats of varying density and the calculations showed a total of 225 active nests for the whole island, which estimates 450 adults present on Troubridge Island at the time of the census (Figure 4). Figure 5 shows the variation in distribution of the active nests found within each quadrat in 2016 and 2017.

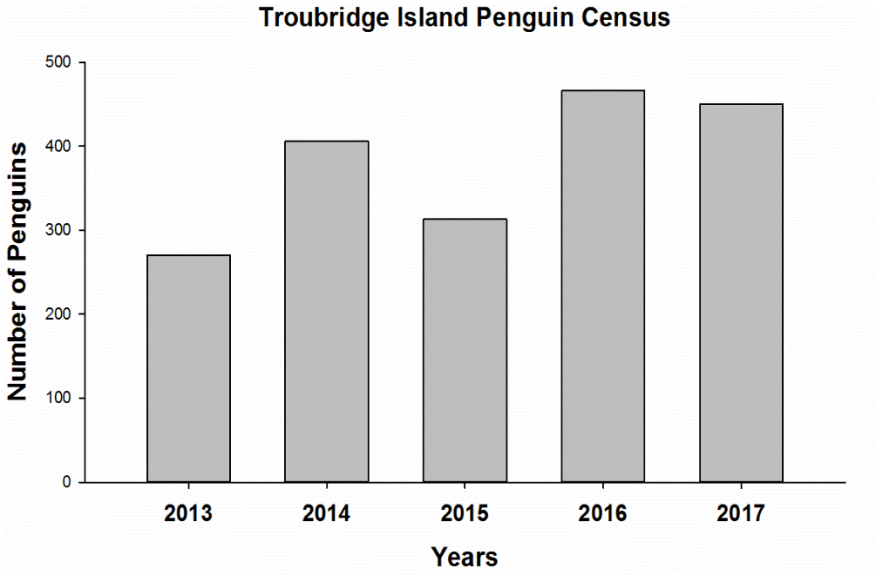

Figure 4. *Estimated population size of little penguins on Troubridge Island between 2013 and 2016*

Figure 5. *Distribution of the active nests found within the six monitored quadrat in 2016 (blue) and 2017 (red).*

Althorpe Island

Althorpe Island was visited in October 2017 by the Friends of Althorpe Island Group and a penguin survey was undertaken in the area previously surveyed in 2013 by the Penguin Ecologist. A total of nine active nests, ten adults, two chicks and six eggs were found were found during this census. This brings the estimated population on Althorpe Island to 18 adult little penguins (Figure 6).

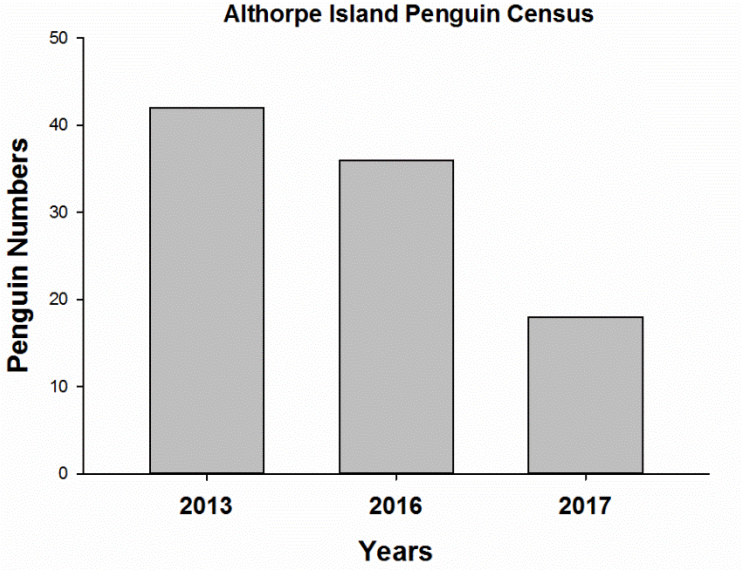

Figure 6. *Estimated population size of little penguins on Althorpe Island in 2013 and 2017*

Wardang Island

The north east coast section (500m long) was visited on the 30th of June 2017 by the local rangers and surveyed for active nests. Seven definitively active nests were found in this section. The area was visited again on the 4th of October 2017 by local rangers and Penguin Ecologist. Seven definitively active nests were also found in this section in October suggesting no difference in population survey results between the two periods. This would bring the penguin counts to 28 adult penguins per km (compared to previous survey conducted at Fossil Beach in 2016 that suggested 64 adults per km).

Figure 7. *Map of Wardang Island showing the different little penguin breeding sites. The site in red (boat rock) was surveyed in 2017.*

Emu Bay

Emu Bay was visited on the 25th October 2017 as part of an Ecological Assessment conducted for the Kangaroo Island council (Colombelli-Négrel 2017b). A total of fifteen active nests were found during the visit within the surveyed section. For comparison, ten active nests were found in the same section in 2016. Based on these numbers, the Emu Bay population in 2017 could be extrapolated to 84 penguins (compared to 56 in 2016). However, caution should be applied when extrapolating from a single quadrat as nesting density within an area can vary between months (Colombelli-Négrel 2017a) and years (Figure 8).

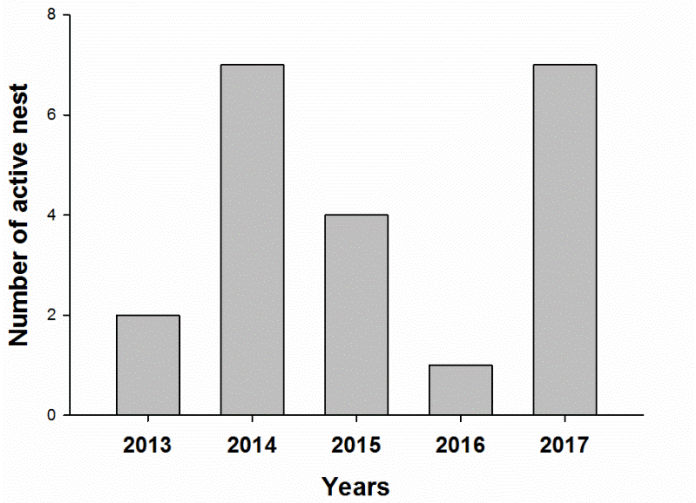

Figure 8. *Variation nesting density within a 50m quadrat surveyed between 2013 and 2017*

Additional data

Nest type and nesting behaviours of little penguins

Neither predation nor vigilance were influenced by the characteristics of the nest (all $P > 0.19$). However, nest type was an important factor for both hatching success and thermoregulation: birds nesting in rock nests had the highest hatching success ($F_{4, 135} = 2.56$; $P = 0.04$), while individuals nesting in bush nests engaged more in gular fluttering ($F_{2,8} = 4.67$; $P = 0.04$). Bush nests also had the highest percentage of vegetation cover, and birds nesting in nests with high vegetation cover had longer dozing bouts ($F_{8,8} = 22.94$; $P < 0.0001$), suggesting a potential trade-off between thermoregulation demands and disturbance by other nesting little penguins.

Local environmental conditions and breeding success

Overall, the results of the Generalized Linear Mixed Model (GLMM) analyses showed that there was a negative correlation between the number of eggs produced per pair and sea surface temperatures ($F_{1,340} = 13.84$, $P < 0.0001$), and a positive correlation between the number of eggs produced and air temperatures ($F_{1,340} = 4.25$, $P = 0.04$). Wind speed or rainfall did not impact the number of eggs produced per pair (all $P > 0.35$). The number of chicks produced per pair was positively impacted by sea surface temperatures ($F_{1,340}= 11.34$, $P = 0.001$) and negatively impacted by wind speed ($F_{1,340}= 13.72$, $P < 0.0001$), but was not impacted by air temperatures or rainfall (all $P > 0.06$). Finally, the number of fledglings produced per pair was positively impacted by sea surface temperatures ($F_{1,340}= 9.22$, $P = 0.003$), but negatively impacted by air temperatures ($F_{1,340}= 5.49$, $P= 0.020$) and wind speed ($F_{1,340}= 6.47$, $P = 0.01$). Rainfall had no impact on number of fledglings ($P > 0.22$).

Timing of nesting and moulting activities

Figure 9 presents the updated timing of breeding and moulting activities of little penguins in the Gulf St Vincent for Granite, Kangaroo and Troubridge Islands. The data were collected between 1998 and 2017 on Granite Island, between 2008 and 2016 for Kangaroo Island (for the Kingscote, Emu Bay and Antechamber Bay colonies), and between 2004 and 2017 for Troubridge Island. Data omitted on the figure (for example information on moulting on Troubridge Island) were not collected.

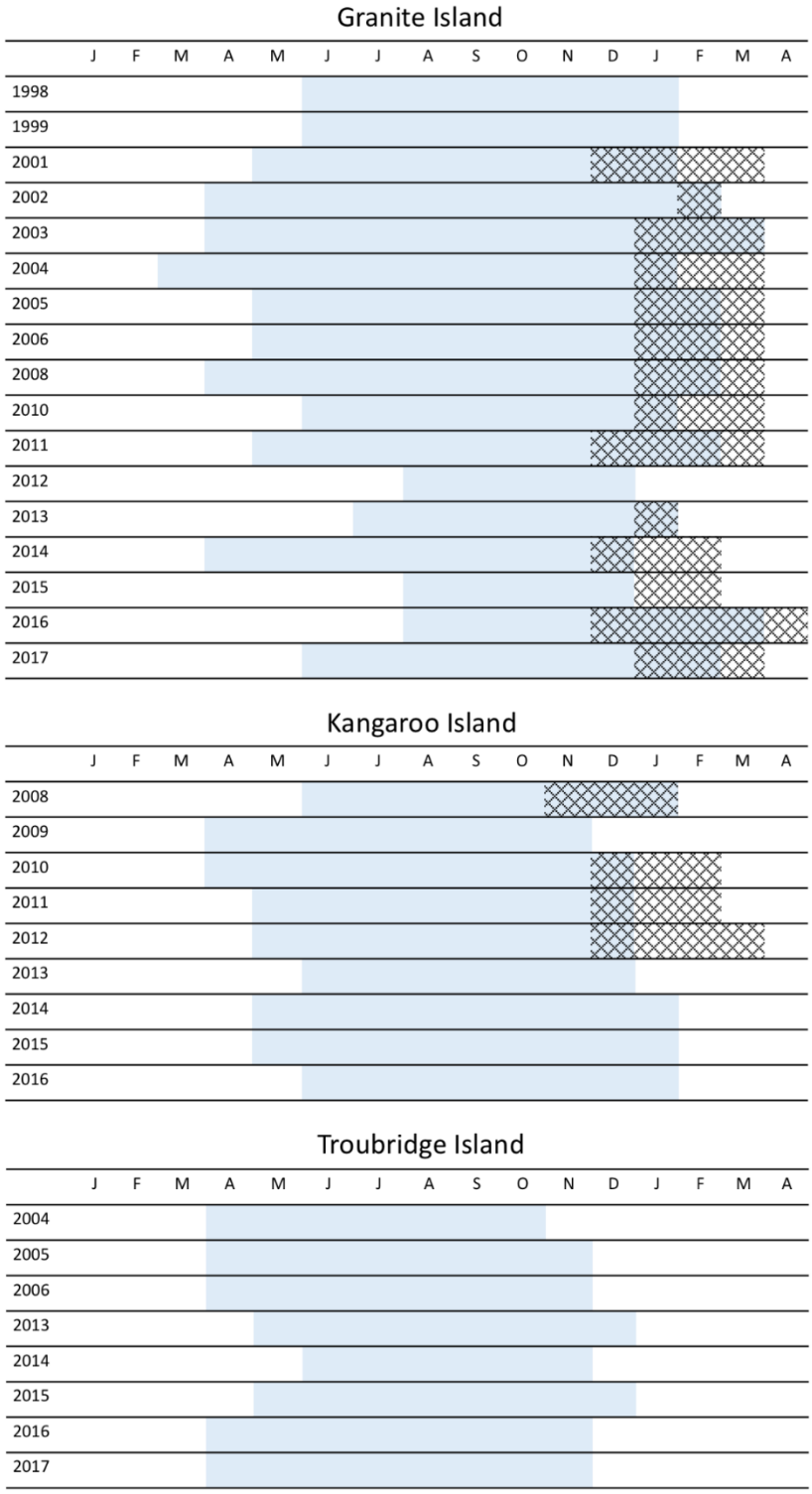

Figure 9. *Timing of breeding (blue) and moulting (cross-hatched) activities of little penguins in the Gulf St Vincent. The data are presented for Granite Island (1998-2017), Kangaroo Island (2008-2016) and Troubridge Island (2004-2017). Moulting data were not collected on Troubridge Island.*

However, while some breeding is still observed on Granite and Kangaroo Islands in winter, the peak of the breeding activities has shifted to spring and summer on these islands, particularly on Granite Island. Figure 10 therefore presents an updated schedule from Wiebkin (2011) for the colonies on the eastern side of the Gulf St Vincent. The moulting period remains the same as previously described by Wiebkin (2011).

	Months											
Breeding activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Laying Eggs												
Raising Chicks												
Moulting												

Figure 10. *Breeding activities of little penguins during each month of the year for the colonies located on the eastern side of the Gulf St Vincent. Dark shading represents a peak in breeding activity.*

Automated acoustic recorders

A total of 3132 hours of recordings were collected during the 2017 breeding season on Granite and Troubridge Islands for the 12 recorders (six per island) over the two month period. Acoustic analyses to estimate call rate in relation to nesting density are still underway. However, the regular surveys (conducted every two weeks within a 10m radius of each recorder) show high variation in nesting density between visits on both islands (Figure 11).

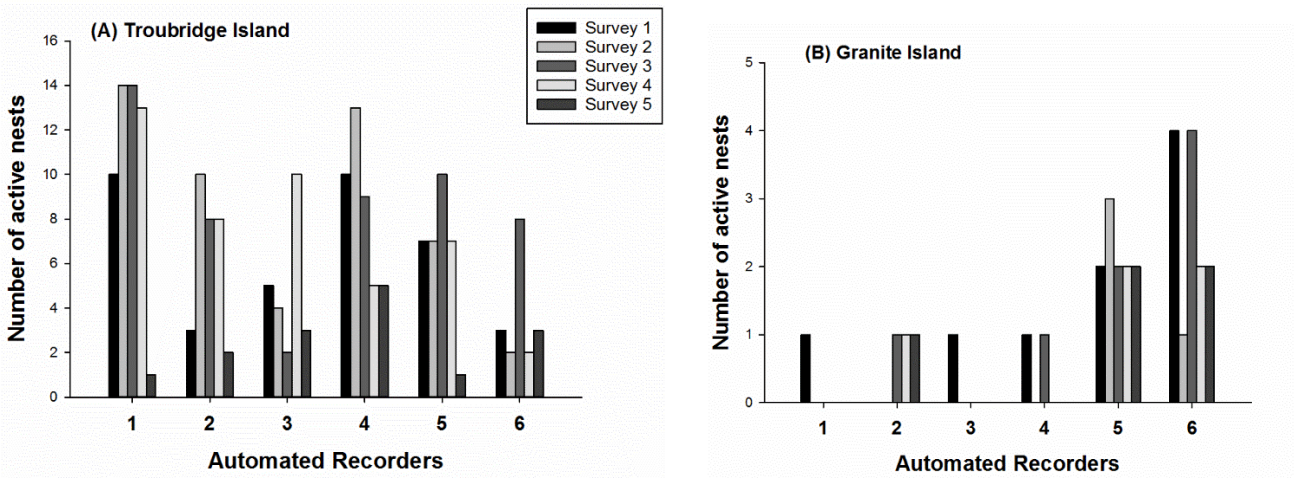

Figure 11. *Number of active nests found during each survey within a 10m radius of the six acoustic recorders on (A) Troubridge Island and (B) Granite Island.*

VI. DISCUSSION

The main findings of this study are: (1) Granite Island population continued to have a high breeding success; (2) Granite and Troubridge Island populations showed stable trends, but (3) Althorpe Island population showed a decreasing trend since the last census; (4) breeding success was influenced by nest type and the local environmental parameters; and (5) disturbance on Granite Island had increased by 6 fold since 2016.

In the Yorke Peninsula, population on Althorpe Island seems to show a constant declining trend. In 2013, 42 adults were recorded in the breeding area surveyed compared to only 18 adults in 2017. This is quite alarming considering that the population has already decreased significantly since 2004 when the population was estimated at 132 adults (see Wiebkin et al. 2012). On Wardang Island, only seven active nests were found in 2017 at Boat Rock, which brings the population count for this 500m long section to 14 adult penguins (or 28 adults per km). Previous visit in 2016 estimated the total numbers of little penguins for Wardang Island to approx. 256 birds based on 64 adults per km and only four active breeding areas (Colombelli-Négrel 2017a). Considering the high differences observed between the two counts, additional surveys across the whole island are clearly needed to confirm little penguin total population number for Wardang Island.

Population on Troubridge Island however seem to show a stable trend (accounting for annual variation) since 2013 (Figure 4). The distribution of active nests found within the six monitored quadrats between 2016 and 2017 showed consistent densities between the two years, suggesting that this method was accurate in recording total population size. Considering that population census over the whole island can be quite invasive and disruptive (see also Ellenberg et al. 2007), it is suggested in the future to alternate between a full population census and a quadrat census to minimise disturbance. Breeding success on Troubridge Island however was very poor, and one of the lowest on record. Yet, it should be noted that five nests had young chicks of 4-5 weeks during the last visit. As their likelihood of survival to fledgling stage was too uncertain to estimate, they were not counted into the total fledgling count. But if these chicks have survived, the total fledgling number would be 20 chicks and breeding success would be 0.80 (± 0.20) fledglings per pair, which is within the normal range for Troubridge Island.

Across years and populations, breeding success (number of fledglings produced per breeding pair) was influenced by nest type as well as the local environmental conditions (specifically, sea surface temperatures, air temperatures and wind speeds). Nest type is important for breeding success in many species of penguins (e.g., Seddon and Van Heezik 1991; Frere et al. 1992; Paredes and Zavalaga 2001; Sherley et al. 2012), including little penguins (e.g., Bull 2000; Renner and Davis 2001; this study). Other studies have suggested that the influence of nest type on breeding success may be highly correlated with differences in the thermodynamic characteristics of the nest (Frost et al. 1976; Seddon and Davis 1989; Mauricio et al. 1999; Lei et al. 2014). In support for this hypothesis, the number of chicks produced in Cameron May's study was not significantly impacted by air temperatures, suggesting that nests or incubating parents offered some protection against extreme temperatures to their eggs and young chicks. The number of fledglings produced per pair however was negatively impacted by air temperatures. Increased air temperatures have been shown to increase stress in adult little penguins both during breeding and moulting (Dann and Chambers 2013; Ganendran et al. 2016). It can therefore be assumed that fledglings would face similar stress than adults from increased air temperatures, which remains to be tested. Variation in microclimate and climate protection between nest type in relation to different breeding activities should be further explored for little penguins, especially considering the common use of artificial nest boxes (see Ropert-Coudert et al. 2004; Lei et al. 2014).

The number of chicks and fledglings produced were negatively associated with wind speeds. Ropert-Coudert et al. (2009) examined the impacts of small scale environmental changes on marine food resources and found that increased wind speeds resulted in mixed ocean layers and more dispersed preys, resulting in lower foraging success for little penguins. This may explain the findings from Cameron May's study, as increased wind speeds would result in less successful or longer foraging trips (or more energy demanding trips) thereby decreasing breeding success. Similarly, as found by Cullen et al. (2009), the number of chicks and fledglings produced per breeding pair was positively impacted by sea surface temperatures, which is known to be linked to primary productivity and prey availability and distribution. But variation in sea surface temperatures has been found to impact little penguin breeding success, both negatively and positively (Mickelson et al. 1992; Perriman et al. 2000; Cullen et al. 2009; Cannell et al. 2012), suggesting that more complex ecological processes may be involved (Cullen et al. 2009). Further investigations into how local environmental conditions impact little penguin breeding success is therefore needed, both temporally and spatially.

This report also highlights high variation in the timing of the different breeding activities of the South Australian little penguins. Timing of breeding and moulting not only vary spatially but also temporally as emphasised by Figure 9. During the last breeding season, birds on Troubridge Island started breeding later than usual as evidenced by the 4-5 weeks old chicks found on the last visit, while birds on Granite Island started their breeding earlier than usual as 4-5 weeks old chicks were found in August. The timing for moulting however seems less variable (Figure 9). Such variation confirms the idea that breeding activities are governed by an array of local environmental factors (see also Cullen et al. 2009).

Finally, this report showed that population on Granite Island shows stable trends since 2012, with a potential increase in 2017 as suggested by the nightly counts (Figure 2). There is therefore hope for the future of Granite Island population, particularly as their breeding success continue to remain high (Figure 1). However, as stated in the previous report (Colombelli-Négrel 2017a), urgent measures need to be taken to decrease disturbance from human activities on this island. The fact that disturbances at night have increased by 6 fold in just one year is alarming. While there is a higher number of visitors during the day than during the night, little penguins are particularly vulnerable to disturbance at night time when returning to their nests after their foraging trip. Regular surveys and data from the night tours show that most of the penguins are nesting near the old penguin centre (see also Figure 11), which is also an area of high human activities. When animals are continuously exposed to stressful factors, they enter a chronic state of stress (Cyr and Romero 2007), which can lead to stress-related diseases (Mortimer and Lill 2007), suppress their immune system (Cyr and Romero 2007), disrupt their foraging abilities (Angelier et al. 2008), lead to nest or colony desertion (Burger and Gochfeld 1993), reduce their reproductive success (McClung et al. 2004) or lower juveniles' development (Lupien et al. 2009). Such regular disturbances can therefore have serious consequences for the long-term survival of the little penguin population on Granite Island.

VIII. DIRECTIONS FOR FUTURE RESEARCH

1) Continue long-term annual monitoring of populations trends, survival, threats and breeding success across targeted populations in the Gulf St Vincent to build reliable databases.

2) Further investigate the impact of local environmental parameters on breeding success and population trends.

3) Conduct population surveys and identify threats at strategic sites to get a better understanding of the little penguin status in South Australia as outlined in Dann (2016).

4) Assess spatial variation of predation by long-nosed fur seals across more colonies within South Australia to measure the long-term impacts for little penguin population trends as outlined in Dann (2016).

5) Identify parasite infections, viruses and vectors across colonies with different population trends to better assess their impact on population trends.

6) Investigate variation in food availability, foraging effort and resource use between colonies and their impact on population trends.

7) Determine to which extent little penguins can respond to environmental change (i.e., introduced predators, disturbance from human activities and climate change).

8) Develop population viability analysis models to explore how variation in each of the parameters listed above affect population trends and population vulnerability.

IX. MANAGEMENT RECOMMENDATIONS

1) Continue rat control on Granite Island to maintain high breeding performance. Increase in rat density was reported in March 2018.

2) Improve security on Granite Island to prevent the increase in human disturbance at night.

3) Implement additional measures to limit Troubridge Island reduction in size (see Colombelli-Négrel 2017a).

X. COMMUNITY ENGAGEMENT

Thirty-one volunteers participated in the Granite Island penguin census in October 2017. An additional fourteen volunteers participated in field trips to collect the data and helped with penguin census on the other islands. Five guides collected the night tour little penguin counts and raised public awareness about little penguin conservation issues during the tours to thousands of tourists over the year. One third-year student worked on a little penguin related project (specifically investigating the impact of environmental factors on breeding success). I gave a presentation to the public on Granite Island on 13th of October for the census, to ASMS International Science Fair activity on the 5th of September 2017 and to U3A Flinders on 14th of September 2017. I gave several interviews for journals and radios such as to ABC Sydney and ABC National on 3rd of November 2017 and ABC Adelaide on 16th of November 2017. I was interviewed by five year-12 students for their research assignment. Research assistants Vanessa Owens and Stephen Hedges raised public awareness about little penguin conservation issues and presence of little penguins on Granite Island to 72 people.

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XII. REFERENCES

Angelier F, Giraudeau M, Bost CA, Chastel O (2008). Corticosterone and foraging behaviour in a diving seabird: The Adélie penguin, *Pygoscelis adeliae*. *General and Comparative Endocrinology* **156**: 135-144.

Bull LS (2000). Factors influencing little penguin *Eudyptula minor* egg success on Matiu-Somes Island, New Zealand. *Emu* **100**: 199-204.

Burger J, Gochfeld M (1993). Tourism and short-term behavioural responses of nesting Masked, Red-footed, and Blue-footed, Boobies in the Galapagos. *Environmental Conservation* **20**: 255-259.

Cannell BL, Chambers LE, Wooller RD, Bradley JS (2012). Poorer breeding by little penguins near Perth, Western Australia is correlated with above average sea surface temperatures and a stronger Leeuwin Current. *Marine and Freshwater Research* **63**: 914-925.

Colombelli-Négrel D (2017a). Penguin monitoring and conservation activities in the Gulf St Vincent, July 2016 – June 2017. Report to Adelaide and Mount Lofty Ranges NRM Board.

Colombelli-Négrel D (2017b). Ecological assessment of the impacts of the development of the boat ramp on little penguins and their habitat at Emu Bay. Report to the Kangaroo Island Council.

Cullen J, Chambers LE, Coutin P, Dann P (2009). Predicting onset and success of breeding in little penguins *Eudyptula minor* from ocean temperatures. *Marine Ecology Progress Series* **378**: 269-278.

Cyr NE, Romero LM (2007). Chronic stress in free-living European starlings reduces corticosterone concentrations and reproductive success. *General and Comparative Endocrinology* **151**: 82-89.

Dann P (2016). Independent report on the risk assessment for little penguins in South Australia including management recommendations and priorities. Report to DEWNR

Dann P, Chambers LE (2013). Ecological effects of climate change on Little Penguins *Eudyptula minor* and the potential economic impact on tourism. *Climate Research* **58**:67-79.

Frost P, Siegfried W, Burger A (1976). Behavioural adaptations of the Jackass Penguin, *Spheniscus demersus* to a hot, arid environment. *Journal of Zoology* **179**: 165-187.

Ellenberg U, Setiawan AN, Cree A, Houston DM, Seddon PJ (2007). Elevated hormonal stress response and reduced reproductive output in Yellow-eyed penguins exposed to unregulated tourism. *General and Comparative Endocrinology* **152**: 54-63.

Fortescue M (1999). Temporal and spatial variation in breeding success of the Little Penguin *Eudyptula minor* on the east coast of Australia. *Marine Ornithology* **27**: 21-28.

Frere E, Gandini P, Boersma D (1992). Effects of nest type and location on reproductive success of the Magellanic Penguin *Spheniscus magellanicus*. *Marine Ornithology* **20**: 1-6.

Gales R (1985). Breeding seasons and double brooding of the little penguin *Eudyptula minor* in New Zealand. *Emu* **85**: 127-130.

Ganendran LMB, Sidhu LA, Catchpole EA, Dann P, Chambers LE (2016). Effects of ambient air temperature, humidity and rainfall on annual survival of adult little penguins *Eudyptula minor* in southeastern Australia. *International Journal of Biometeorology* **60**: 1237-1245.

Lei BR, Green JA, Pichegru L (2014). Extreme microclimate conditions in artificial nests for Endangered African Penguins. *Bird Conservation International* **24**: 201-213.

Lupien SJ, McEwen BS, Gunnar MR, Heim C (2009). Effects of stress throughout the lifespan in the brain, behaviour and cognition. *Nature Reviews: Neurosciences* **10**: 434-445.

Mauricio S, Mario R, Fracisco B (1999). Thermal ecology of the Humboldt penguin (*Spheniscus humboldti*): effects of the nest-site selection on adult and chick survival. *Natural History of Chile* **72**: 447-455.

McClung MR, Seddon PJ, Massaro M, Setiawan AN (2004). Nature-based tourism impacts on yellow-eyed penguins *Megadyptes antipodes*: does unregulated visitor access affect fledging weight and juvenile survival? *Biological Conservation* **119**: 279-285.

Mickelson MJ, Dann P, Cullen JM (1992). Sea temperature in Bass Strait and breeding success of the little penguin *Eudyptula minor* at Phillip Island, south-eastern Australia. *Emu* **91**: 355-368.

Mortimer A, Lill A (2007). Activity-related variation in blood parameters associated with oxygen transport and chronic stress in little penguins. *Australian Journal of Zoology* **55**: 249-256.

Nisbet ICT, Dann P (2009). Reproductive performance of little penguins *Eudyptula minor* in relation to year, age, pair-bond duration, breeding date and individual quality. *Journal of Avian Biology* **40**: 296-308.

Paredes R, Zavalaga CB (2001). Nesting sites and nest types as important factors for the conservation of Humboldt Penguins (*Sphensicus humboldti*). *Biological Conservation* **100**: 199-205.

Perriman L, Houston D, Steen H, Johannesen E (2000). Climate fluctuation effects on breeding of blue penguins (*Eudyptula minor*). *New Zealand Journal of Zoology* **27**: 261-267.

Reilly P, Cullen J (1981). The little penguin *Eudyptula minor* in Victoria, II: Breeding. *Emu* **81**: 1-19.

Reilly P, Cullen J (1983). The little penguin *Eudyptula minor* in Victoria, IV: Moult. *Emu* **83**:94-98.

Renner M, Davis LS (2001). Survival analysis of Little Penguin *Eudyptula minor* chicks on Motuara Island, New Zealand. *Ibis* **143**: 369-379.

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

Ropert-Coudert Y, Kato A, Chiaradia A (2009). Impact of small-scale environmental perturbations on local marine food resources: a case study of a predator, the little penguin. *Proceedings of the Royal Society of London B* **276**: 4105-4109.

Seddon PJ, Van Heezik Y (1991). Effects of hatching order, sibling asymmetries, and nest site on survival analysis of Jackass Penguin chicks. *The Auk* **108**: 548-555.

Seddon PJ, Davis LS (1989). Nest-site selection by Yellow-eyed Penguins. *The Condor* **91**: 653-659.

Sherley RB, Barham BJ, Barham PJ, Leshoro TM, Underhill LG (2012). Artificial nests enhance the breeding productivity of African Penguins (*Spheniscus demersus*) on Robben Island, South Africa. *Emu* **112**: 97-106.

Wiebkin AS (2011). Conservation management priorities for little penguin populations in Gulf St Vincent. Report to Adelaide and Mount Lofty Ranges Natural Resources Management Board. SARDI Research Report Series No.588. Adelaide.

Wiebkin AS, Bool NM, Tomo I, Gilbert N (2012). Little Penguin Conservation Project. July 2011 - July 2012. Report to Department for Environment and Heritage, Adelaide.

XIII. APPENDIX 1 - List of microchipped individuals that were re-sighted in 2017

Island	Reference Number	Year Microchipped
Troubridge Island	982000063644673	2014
Troubridge Island	157468403	unknown