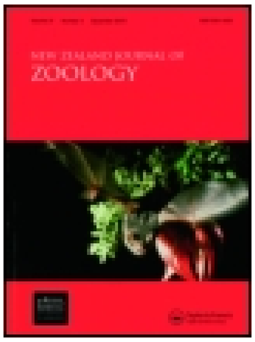

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Fidelity and breeding success of the blue penguin *Eudyptula minor* on Matiu-Somes Island, Wellington, New Zealand

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Abstract A study of the nesting habits and breeding biology of blue penguin *Eudyptula minor* was undertaken over the 1995–96 and 1996–97 breeding seasons on Matiu-Somes Island, Wellington, New Zealand. Male and female blue penguins tended to be faithful to both mates and nest sites, although there was insufficient evidence to detect any association between a bird's breeding success in 1995 and a subsequent change of mate or nest in 1996. Over the 1995 and 1996 seasons the recorded hatching success (0.51 ± 0.11 and 0.63 ± 0.10 respectively), fledging success (0.81 ± 0.12 and 0.85 ± 0.10 respectively) and reproductive success (0.41 ± 0.11 and 0.54 ± 0.11 respectively) were similar each season. There was no significant difference between the proportion of eggs laid, or eggs hatched and chicks fledged, between the two seasons. The mean number of chicks raised over the two seasons was 0.94 ± 0.05 per nest. Replacement clutches were laid by 11 per cent of failed breeders in each season, but only in 1996 were they successful in fledging chicks.

No significant difference was found between the breeding success of the Matiu-Somes Island blue penguin colony recorded during this study and a previous study undertaken on the island 40 years ago.

Keywords blue penguin; *Eudyptula minor*; Matiu-Somes Island; breeding success; mate fidelity; nest fidelity

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INTRODUCTION

The blue penguin is an Australasian coastal species that breeds in loose colonies. Birds begin breeding at the age of three or four years and many established breeders return to the same mate and nest site in successive seasons (Kinsky 1960; Reilly & Balmford 1975; Reilly & Cullen 1981; Waas 1990). The pair bonds of this species are described as sustained or long-term monogamous (Marchant & Higgins 1990). Monogamy in long-lived birds is thought to confer an advantage in that mates show lower levels of aggression and a high degree of within-pair synchronisation (Reilly & Cullen 1981). This allows them to breed more rapidly and efficiently, resulting in an increase in their reproductive success (Clutton-Brock & Harvey 1978). Divorce can lead to lower nesting success or may result from the failure of a clutch (Coulson 1966; Thibault 1994; Badyaev & Faust 1996). Breeding success and fidelity to nest and mate are closely linked topics, and a basic understanding of the population dynamics of a species requires a knowledge of how they affect each other.

Previous studies have shown that mortalities and disturbances caused both by mammalian predators and by humans may be responsible for the decline in numbers of blue penguins (Dann 1992, 1994; Norman, Cullen & Dann 1992; Hodgson unpubl.; Perriman unpubl.). Blue penguins are highly philopatric, so habitat loss and modification may be detrimental to the breeding success of this species. Changes in the density and composition of vegetation have been found to influence the breeding of blue penguins (Fortescue 1995; Bull in press). As the habitat available to nesting blue penguins is changing, often decreasing, it is important that we understand the consequences of habitat change on the productivity of an individual, and hence of the colony, via its effect on changes of nests or mates.

Several environmental changes around the Wellington region threaten blue penguin populations both now and in the future. Coastal roading and increased development around Wellington shores has been causing an increase in deaths and a decline in the breeding population of the blue penguin in the Wellington area. The Little Blue Penguin Foundation was formed in May 1994, initially to protect and to provide a safe habitat for those birds breeding on the mainland, especially in Days Bay, Eastbourne. Other penguins do not breed on the mainland but can be found on all three of the islands in the Wellington Harbour.

Matiu-Somes Island (24.9 hectares) is home to a diverse range of flora and fauna, and is the site of Wellington's largest blue penguin colony. The Ministry of Agriculture and Fisheries (MAF) operated the island as a quarantine station for over 100 years. In August 1995 the Department of Conservation (DoC) took over its management, and soon classified the island as a Scientific Reserve, with a Historic Reserve on the top of the island to protect the quarantine buildings. The island, which was formerly known as Somes Island, was also renamed Matiu-Somes.

Kinsky (1960) investigated the yearly cycle of the blue penguin on Matiu-Somes Island from observations made during the 1954–55 breeding season and between August 1956 and March 1958. During the 40 years since Kinsky's study, the island's ecosystem has changed in several ways that may have influenced the breeding biology and population status of this colony. The changes include the introduction and later eradication of the ship rat *Rattus rattus*, a programme to revegetate the island, and the institution of open public access to the island soon after DoC took over its control.

There is a legitimate concern that open access poses a threat to the island's current predator-free status, plus other risks to nesting birds. While educating the public about the presence of the wildlife on the island is important, more must be done to ensure that disturbance to birds is minimal. The information obtained from this study may be used to detect any such changes to the blue penguin colony on Matiu-Somes Island in the future, and may also provide information relevant to the conservation of blue penguins elsewhere.

This paper addresses the following aims of the study: (1) to determine if breeding success influences mate or nest fidelity; and (2) to make comparisons with Kinsky's (1960) study and provide baseline data for future monitoring of the colony.

METHODS

Matiu-Somes Island (41°15′S–174°53′E) is the largest of three islands centrally situated in Wellington Harbour. The coastline of the island is made up of pebble beaches and rocky cliff faces, which contain several caves. Over time the vegetation of the island has been modified to accommodate the needs of humans inhabiting it, including grazing by domestic animals. A programme to revegetate the island was commenced in 1981 by the Lower Hutt Branch of the Royal Forest & Bird Protection Society. Today most of the slopes are covered with a mixture of native and introduced plants, although some areas of the island have been retained as grass paddocks. Blue penguins nest all over the island, but the majority of the nests monitored in this study were the easily accessible ones located around the coastline.

The study was carried out over the 1995–96 and 1996–97 breeding seasons. Visits were made at night once every four weeks during the winter months (May–July), then fortnightly during the day from August until the end of each season (January/February).

The initial night visits were used to obtain recovery data from returning penguins and note possible nest sites. Information obtained from the day visits included: location of nests; parents' band numbers; number of eggs laid; number of chicks hatched; the loss of any eggs or chicks from the nest; presence of adled eggs or dead chicks; the band numbers of offspring and siblings; and number of chicks fledged. Data obtained from nests that already contained chicks when found were not used in the calculations of breeding success.

All adults and chicks were flipper banded (New Zealand National Banding Scheme). Chicks were banded when they were acquiring adult plumage on the flippers, as soon as the flipper was large enough to retain the band. They generally reach this stage at six weeks of age (Reilly & Cullen 1979).

A number of birds recaptured during this study had been banded in prior seasons and their sex was already known. Birds newly banded during this study were sexed by bill shape, the male bill being stouter and having a more acutely hooked tip on the upper mandible (Kinsky 1960; Reilly & Cullen 1979; Gales 1988; Renner & Davis 1999).

Fisher's exact tests were used to detect any association between the 1995 breeding success and a subsequent change of nest or mate, and to test for significance between the proportion of replacement clutches counted in the 1950s (Kinsky 1960) and in the present study. The proportion of eggs laid, eggs hatched and chicks fledged were compared between the two seasons monitored using Chi-square analysis. Log-linear modelling was used to determine if there were any significant differences between the average hatching and fledging success recorded on Matiu-Somes Island during the 1950s and the present study. Kruskal-Wallis tests were used to test for significance between losses suffered at various Australasian colonies. The normal approximation was used for calculating all 95% confidence intervals (c.i.) except those for the divorce rate, for which a non-asymptotic calculation was used.

RESULTS

Mate and nest site fidelity

Of the 29 pairs banded in 1995, 12 renewed their partnerships in 1996, 13 pairs were not found breeding in 1996, two birds from different pairs were known to be breeding in 1996 but with unidentified partners, and two pair bonds were broken when birds changed partners. Of the two individuals that changed mates in 1996, the 1995 partner of only one was recovered in 1996. Therefore, from the recovery data obtained during the 1996 breeding season, only one partner of the 29 1995 pairs re-paired with another individual whilst both partners of the pair were still alive. The estimated divorce rate of 3% (c.i. = 0.0009, 0.1768, $n = 29$) is regarded as conservative because 13 of the 29 pairs were not found breeding in 1996, and also because individuals of several 1995 pairs were recorded as breeding with unidentified partners in 1996.

Over the two seasons a total of 74 nest sites were located, of which 59 were used in only one of the two season, and 15 in both. Table 1 shows the different regimes the birds exhibited with respect to the partners and nest sites used during the 1995 and 1996 breeding seasons.

Of the 12 pairs known to have bred together during the 1995 and 1996 seasons, eight used the same nest in both seasons, and the remaining four pairs bred in different nests. Seven of the eight pairs that re-used the same nest sites had bred successfully in the first season. Three of the four pairs that changed nest sites in 1996 bred unsuccessfully in 1995. While the above observation suggests that breeding success may influence nest retention in blue penguin on Matiu-Somes Island, a Fisher's exact test was unable to detect any significant association between 1995 breeding success, or failure, and a subsequent change of nest ($P = 0.07$, $\alpha = 0.05$) or mate ($P = 0.22$, $\alpha = 0.05$).

Breeding success

Table 2 shows the breeding success of the blue penguin pairs monitored on Matiu-Somes Island during the 1995 and 1996 breeding seasons. Only those nests for which the number of eggs laid, eggs hatched and chicks fledged are known are included in this table.

Over the 1995 and 1996 breeding seasons the mean number of chicks fledged per pair was 0.94 (c.i. = 0.05, $n = 82$), the hatching success was 0.57 (c.i. = 0.08, $n = 163$), the fledging success was 0.83 (c.i. = 0.08, $n = 93$), and the reproductive success was 0.47 (c.i. = 0.08, $n = 163$). There was no significant difference between the proportion of eggs laid, hatched and chicks fledged between the two seasons monitored ($\chi^2 = 1.29$, $\alpha = 0.05$, 2df, $P = 0.53$).

Mean hatching, fledging and reproductive success rates in the 1950s calculated from Kinsky's (1960)

Table 1 Retention and breakage of blue penguin pair and nest site bonds between 1995 and 1996 seasons. ‡ 1 = fledged ≥ 1 chick; 0 = no chicks fledged.

Mate	Nest	Success‡ 1995	Success‡ 1996	No. females	No. males
Same	Same	1	1	6	6
Same	Same	1	0	1	1
Same	Same	0	1	1	1
Same	Different	1	1	1	1
Same	Different	0	1	3	3
Different	Same	0	1	1	0
Different	Different	1	1	0	1
Different	Different	1	0	1	0
Different	Different	0	0	0	1

data (0.56 ± 0.07, 0.91 ± 0.05 and 0.51 ± 0.07 respectively) and in the present study (0.57 ± 0.08, 0.83 ± 0.08 and 0.47 ± 0.08 respectively) were very similar. Log-linear modelling confirmed that there was no significant difference in the average hatching ($P = 0.90$, $\alpha = 0.05$) and fledging success ($P = 0.49$, $\alpha = 0.05$) between the two studies.

Of 35 clutches that were lost over the two seasons, four were replaced. These replacement clutches were laid by two pairs in each breeding season, but only in 1996 were they successful, when both hatched two chicks. A Fisher's exact test confirmed that there was no significant difference ($P = 1.00$, $\alpha = 0.05$) between the proportion of failed breeding pairs producing replacement clutches on Matiu-Somes Island during Kinsky's (1960) study and this study.

Losses

Table 3 shows the total losses of offspring during both breeding seasons. The proportions of eggs and chicks lost were similar in the 1995 and 1996 seasons: 0.83 (c.i. = 0.11, n = 48) and 0.79 (c.i. =

Table 2 Summary of breeding success of the blue penguin colony on Matiu-Somes Island over the 1995 and 1996 breeding seasons. † Includes replacement clutches; ‡ Results reported are mean ± 95% confidence intervals, with number in parentheses.

	1995–96	1996–97
Number of nests	42	40
Number of eggs laid †	81	82
Mean number of eggs laid per nest	1.9	2.1
Number of chicks hatched	41	52
Number of chicks fledged	33	44
Hatching success ‡	0.51 ± 0.11 (81)	0.63 ± 0.10 (82)
Fledging success ‡	0.81 ± 0.12 (41)	0.85 ± 0.10 (52)
Reproductive success ‡	0.41 ± 0.11 (81)	0.54 ± 0.11 (82)
No. chicks fledged per nest ‡	0.79 ± 0.12 (42)	1.1 ± 0.10 (40)

Table 3 Comparative offspring losses in Australian and New Zealand blue penguin colonies. Results reported are mean ± 95% confidence intervals, with number in parentheses.

	Percent losses			
Location	Total	Egg stage	Chick stage	Reference
Matiu-Somes Is.				
1995	0.59 ± 0.11 (81)	0.83 ± 0.11 (48)	0.17 ± 0.10 (48)	This study
1996	0.46 ± 0.11 (82)	0.79 ± 0.13 (38)	0.21 ± 0.13 (38)	This study
New Zealand				
Matiu-Somes Is.	0.49 ± 0. 07 (209)	0.89 ± 0.06 (103)	0.11 ± 0.06 (103)	Kinsky (1960)
Matiu-Somes Is.	0.53 ± 0.08 (163)	0.81 ± 0.08 (86)	0.19 ± 0.08 (86)	This study
Taiaroa Head	0.51 ± 0.04 (577)	0.85 ± 0.04 (292)	0.15 ± 0.04 (292)	Perriman (unpubl.) and Perriman & McKinlay (1995)
Australia				
Phillip Is.	0.65 ± 0.05 (356)	0.53 ± 0.06 (230)	0.47 ± 0.06 (230)	Reilly & Balmford (1975)
Bruny Is.	0.83 ± 0.03 (635)	0.37 ± 0.04 (527)	0.63 ± 0.04 (527)	Hodgson (unpubl.)

0.13, n = 38) losses respectively during the egg stage and 0.17 (c.i. = 0.10, n = 48) and 0.21 (c.i. = 0.13, n = 38) respectively during the chick stage.

Kruskal-Wallis tests were performed to test for any significance between the losses recorded at Matiu-Somes Island, Taiaroa Head, Phillip Island and Bruny Island (Table 3). There was a significant difference between the four colonies in total losses (χ^2 = 11.37, α = 0.05, 3df, P = 0.0099) and chick losses (χ^2 = 12.13, α = 0.05, 3df, P = 0.007) but not in the losses of eggs (χ^2 = 4.99, α = 0.05, 3df, P = 0.1724).

DISCUSSION

Mate and nest site fidelity

Although blue penguins are generally described as being faithful to their mate and nest (Kinsky 1960; Reilly & Balmford 1975; Reilly & Cullen 1981; Waas 1990) little statistical work has been done to investigate this aspect of the species ecology or its influence on the productivity of a colony.

Pledger & Bullen (1998) calculated the probabilities of mate and nest site fidelity and provided statistically valid evidence that blue penguins on Matiu-Somes Island show a strong tendency to return to their previous nest and mate. Jones (unpubl.) observed low mate fidelity in blue penguin on Tiritiri Matangi Island, New Zealand, and thought that this may have been a result of the high mortality in this population, however site tenacity was very strong.

Reilly & Cullen (1981) found that nesting success was unaltered following a change of mate compared with re-mating, and they concluded that there seemed no advantage in re-mating with a former partner. My data infer that it is the bond to the nest that has a greater influence on breeding success rather than the bond to a mate. Bull (in press) found that nest type influences egg success, it therefore follows that it would be beneficial to return to those nests that were of higher quality and/or produced more offspring. This was the case, with 10 of the 15 nests re-occupied in 1996 being of the type that Bull (in press) found to be of higher quality. Fishers' exact tests were unable to find any association between the 1995 breeding outcome and change of nest (P = 0.07) or mate (P = 0.22). However, a larger data set might provide a better test of the hypothesis that breeding failure influences a subsequent change of nest. The lack of 1995 pairs recovered in 1996 meant that conclusions are tentative with respect to effects of breeding success on mate retention.

If the bond to the nest is in fact more influential on breeding success than the pair bond, then habitat modification and destruction may be more detrimental to the productivity of a colony than natural mortality of partners.

Other variables, irrespective of breeding failure, may be responsible for birds changing nest sites. Some birds may be forced to change nests due to nest damage (Reilly & Cullen 1981) or to removal of nest cover (Kinsky 1960; pers. obs.). Australian blue penguins frequently nest in sand burrows, a habitat not available on Matiu-Somes Island. More burrow damage is expected in sand due to the weaker substrate coherence. On Matiu-Somes Island some self-excavated soil burrows had collapsed by the end of the breeding season, other nests failed when rocks around them were disturbed, and were not re-used the following season. Nests located along the main walking track failed in 1995 and were not reoccupied in 1996. Several studies have found that the proportion of birds relocating nests is higher in areas where predators are present (Thibault 1994; Badyaev & Faust 1996).

It is important to understand the consequences for productivity of pairs changing nests. If for some reason a pair has to locate a new nest site in a subsequent season, this may reduce the productivity of a colony. Time taken to choose and prepare the site may delay the onset of breeding and consequently reduce the likelihood of the pair laying a second clutch.

The very low recovery rate of the 1995 breeding pairs could be responsible for the apparently low divorce rate calculated for the birds on Matiu-Somes Island. Potential nesting sites are abundant all over the island, and a high proportion of the 1995 nests were not reoccupied in 1996. However many potential nesting sites are located on steep cliffs covered with dense vegetation, making access by humans to some of these sites very difficult. I believe that some of the 1995 breeding birds that were not recovered in 1996 had relocated further up the slopes.

On Matiu-Somes Island Kinsky (1960) found that all pair bonds were renewed between 1956–58, but noted some divorces in later seasons. A divorce rate of 18% per year was observed in blue penguins on Phillip Island and was thought not to be affected by the breeding success, or failure, of the previous year (Reilly & Cullen 1981). This figure is considerably higher than 3% per year calculated over the 1995 and 1996 breeding seasons on Matiu-Somes Island.

Breeding success

Nests were visited fortnightly to minimise disturbance, so the exact dates of laying, hatching and fledging could not be established. Reilly & Cullen (1981) encountered a similar problem. While more accurate records could have been obtained by more frequent visits, the results documented by Kinsky's (1960) weekly visits were not significantly different from those obtained in this study. Giese (1996) found that while regular nest checking of Adélie penguins produced the most accurate record of breeding success, it also significantly interfered with reproduction, and she argued that less frequent visits may produce more meaningful results. This dilemma of balancing the amount of researcher disturbance with the need to obtain accurate records can be achieved by such means as implanted transponders or control nests. Implanted transponders can reduce the number of times a bird needs to be handled during a study, however these devices are expensive. Control nests are checked only at the beginning and end of the study, but while they may reduce observer effects some populations are too small to allow the separation of the control and experimental groups large enough to provide any statistically valid results.

There was no significant difference ($P = 1.00$, $\alpha = 0.05$) between the proportions of failed breeding pairs producing replacement clutches on Matiu-Somes Island during this study and in the 1950s (Kinsky 1960), and both studies confirmed that a second clutch was never laid following the successful raising of a first. Production of multiple clutches, in the form of replacement clutches only, has been observed in Tasmania (Hodgson unpubl.) and Auckland (Jones unpubl.). In comparison, double brooding has regularly been recorded in Otago (Gales 1985; Perriman & McKinlay 1995), Oamaru (Houston unpubl.), Phillip Island (Reilly & Balmford 1975; Reilly & Cullen 1981), Lion Island (Rogers, Eldershaw & Walraven 1995) and Bowen Island (Fortescue 1995). At Otago, Lion Island and Bowen Island the number of pairs producing a second clutch was found to be positively correlated with the timing of egg production of a pair's first clutch (Gales 1985; Fortescue 1995; Rogers et al. 1995; Perriman unpubl.). Rogers et al. (1995) attribute to high food availability, the early onset of breeding that subsequently allows for a second clutch within one season. Therefore variation in the dates of laying and incidence of double-broods, may both reflect differences in the availability of food at each of the colonies.

Since Kinsky's (1960) study on Matiu-Somes Island there have been three major changes to the islands ecosystem that could have influenced the breeding status of the blue penguin population breeding there. First, ship rats were introduced to the island in the late 1960s (Department of Conservation 1998). They were subsequently eradicated in the late 1980s, but because the blue penguin population was not intensively monitored while they were present, the effect of rat predation on the population is unknown.

Second, the revegetation of the island. Kinsky (1960) described the island slopes as being covered with grass, scrub, flax and rushes. Today, through annual plantings, the island's vegetation is a mixture of native and introduced plants. Bull (in press) found that on Matiu-Somes Island the nest type used influences the success of a blue penguin egg. Consequently habitat modification and ecological restoration in areas that blue penguins inhabit may alter the nest types available to the birds and thereby affect productivity.

Third, the policy of open public access implemented by DoC soon after it took over the management of the island in 1995. This study was undertaken at the beginning of the open access regime and therefore provides baseline information against which future studies can be assessed.

Despite these changes the data provided no evidence of any significant differences in the rate of breeding success compared with the 1950s. If breeding success was affected by the presence of rats on the island, the rates of success have since recovered. Annual plantings are continuing on the island, so monitoring of the blue penguin population should also continue in order to detect any changes in productivity brought about by changes to the composition of nest types on the island. Also efforts must be made to ensure that people remain on the walking tracks away from the main concentration of nesting penguins.

Losses

Not only are the total offspring losses documented for the two Matiu-Somes Island studies similar, but so too are the distributions of losses during the egg and chick stages (Table 3), more frequently during the egg stage (confirmed by Kruskal-Wallis tests). Comparisons with other sites indicate that this is not the case for all Australasian blue penguin colonies (Table 3).

When investigating the breeding biology of the blue penguin in herbland and woodland habitats on

Bowen Island, Fortescue (unpubl.) found differences in a number of breeding parameters, including the stage of losses. In the herbland, higher mortalities occurred during the egg stage. This stage depends less on food availability than does the chick stage, and Fortescue concluded that failure during the egg stage was due to environmental stresses in the burrow. Other authors attribute differences in egg and chick losses to the age and breeding experience of the adult birds (Reilly & Cullen 1981; Ainley et al. 1983; Dann & Cullen 1990; Weimerskirch 1990). Fortescue (unpubl.) hypothesized that "failure at the early stages of breeding leads to desertion of burrow sites and a shift, over some years, to more favourable (woodland) sites".

If differences in losses at the egg and chick stages are due to the age and breeding experience of a bird, then the age structure of a population may in part explain why different stages suffer the greater losses at each of the colonies. Unfortunately the majority of studies are short-term, and many include birds of unknown age, so no firm conclusions can be made regarding the influence of age and breeding experience on the stage of losses.

The timing of availability and abundance of food supply may also, in part, explain the proportion of losses suffered at the different stages. First, when food is scarce birds have to forage further and are subsequently away from the nest for longer periods. This delay in returning to the nest increases the chances of desertion of the eggs or chicks by the incubating bird (Weavers 1992; Renner unpubl.). Alternatively, if less food is available then adults may be unable to find sufficient food for both themselves and their chicks. Consequently chicks may weigh less and the colony may suffer from high chick mortality due to increased levels of starvation (van Heezik 1990; van Heezik & Davis 1990; Cullen, Montague & Hull 1992; Fortescue 1995). Therefore the timing of food availability will determine which growth phase bears the highest proportion of losses recorded at each of the colonies.

CONCLUSIONS

This study was undertaken at the beginning of the open public access regime. The only other comprehensive study on blue penguins on the island was carried out over 40 years ago. The timing of this study has therefore provided the opportunity to obtain both updated as well as baseline information on the productivity levels of this colony, from which future breeding studies can be assessed.

The results from this study show that the breeding success of this colony is equivalent to what it was 40 years ago. Matiu-Somes Island evidently provides a suitable site for blue penguin to breed. Presently it is free of mammalian predators, and human access is restricted to areas of the island away from the main concentrations of nests.

Many authors describe blue penguins as returning to the same mate and nest site in successive seasons (Kinsky 1960; Reilly & Cullen 1981; Hodgson unpubl.). Equally well documented is the increasing frequency of disturbance and destruction to blue penguin habitat caused by humans and introduced predators (Dann 1992, 1994; Norman et al. 1992; Hodgson unpubl.; Perriman unpubl.). Such destruction and modification must impact on these nest site and pair bonds, thus it is essential that we understand the consequences for breeding success of a change of mate or nest. The data obtained during this study could not fully test a potential association between the breeding success of blue penguins on Matiu-Somes Island and a change of mate or nest site, but the question is important and should be further examined using a larger data set.

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REFERENCES

Ainley, D. G.; LeResche, R. E.; Sladen, W. J. L. 1983: Breeding biology of the adélie penguin. Berkley, University of California Press.

Badyaev, A. V.; Faust, J. D. 1996: Nest site fidelity in female wild turkey: potential causes and reproductive consequences. *Condor 98*: 589–594.

Bull, L. in press: Factors influencing little penguin *Eudyptula minor* egg success on Matiu-Somes Island, New Zealand. *Emu 100*.

Clutton-Brock, T. H.; Harvey, P. H. 1978: Readings in Sociobiology. San Franciso, W. H. Freeman & Company Ltd.

Coulson, J. C. 1966: The influence of the pair-bond and age on the breeding biology of the kittiwake gull *Rissa tridactyla. Journal of Animal Ecology 35*: 269–279.

Cullen, J. M.; Montague, T. L.; Hull, C. 1992: Food of little penguins *Eudyptula minor* in Victoria: comparison of three localities between 1985 and 1988. *Emu 91*: 318–341.

Dann, P. 1992: Distribution, population trends and factors influencing the population size of little penguins *Eudyptula minor* on Phillip Island, Victoria. *Emu 91*: 263–272.

Dann, P. 1994: The abundance, breeding distribution and nest sites of blue penguins in Otago, New Zealand. *Notornis 41*: 157–166.

Dann, P; Cullen, J. M. 1990: Survival, patterns of reproduction, and lifetime reproductive output in little blue penguins (*Eudyptula minor*) on Phillip Island, Victoria, Australia. *In*: Davis, L. S.; Darby, J. T. *ed*. Penguin biology. San Diego, Academic Press Ltd. Pp. 63–84.

Department of Conservation 1998: Matiu scientific reserve working plan – community focus on an island environment. Wellington, Department of Conservation. Pp. 26.

Fortescue, M. E. 1995: Biology of the little penguin *Eudyptula minor* on Bowen Island and other Australian colonies. *In*: Dann, P.; Norman, I; Reilly, P. *ed*. The penguins: ecology and management. Sydney, Surrey Beatty. Pp. 364–392.

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

Gales, R. P. 1988: Sexing adult blue penguins by external measurements. *Notornis 35*: 71–75.

Giese, M. 1996: Effects of human activity on adélie penguin *Pygoscelis adeliae* breeding success. *Biological Conservation 75*: 157–164.

van Heezik, Y. 1990: Seasonal, geographical and age-related variations in the diet of the yellow-eyed penguins (*Megadyptes antipodes*). *New Zealand Journal of Zoology 17*: 201–212.

van Heezik, Y.; Davis, L. 1990: Effects of food variability on growth rates, fledging sizes and reproductive success in the yellow-eyed penguin *Megadyptes antipodes. Ibis 132*: 354–365.

Kinsky, F. C. 1960: The yearly cycle of the northern blue penguin (*Eudyptula minor novaehollandiae*) in the Wellington Harbour Area. *Records of the Dominion Museum Wellington 3*: 145–218.

Marchant, S.; Higgins, P. J. 1990: Handbook of Australian, New Zealand and Antarctic birds, Volume 1 Ratites to ducks, Part A Ratites to petrels. Melbourne, Oxford University Press.

Norman, F. I.; Cullen, J. M.; Dann, P. 1992. Little Penguins *Eudyptula minor* in Victoria: Past, present and future. *Emu 91*: 402–408.

Perriman, L.; McKinlay, B. 1995: The blue penguin (*Eudyptula minor*) at Taiaroa Head, Otago 1992–93. *Science and Research Series No. 86*. Wellington, Department of Conservation.

Pledger, S.; Bullen, L. 1998: Tests for mate and nest fidelity in birds with application to little blue penguins (*Eudyptula minor*). *Biometrics 54*: 61–66.

Reilly, P. N.; Balmford, P. 1975: A breeding study of the little penguin *Eudyptula minor* in Australia. *In*: Stonehouse, B. *ed*. The biology of penguins. London, Macmillan Press. Pp. 161–187.

Reilly, P. N.; Cullen, J. M. 1979: The little penguin *Eudyptula minor* in Victoria, I: Mortality of adults. *Emu 79*: 97–102.

Reilly, P. N.; Cullen, J. M. 1981: The little penguin *Eudyptula minor* in Victoria, II: Breeding. *Emu 81*: 1–19.

Renner, M.; Davis, L. S. 1999: Sexing little penguins *Eudyptula minor* from Cook Strait, New Zealand using discriminant function analysis. *Emu 99*: 74–79.

Rogers, T.; Eldershaw, D.; Walraven, E. 1995: Reproductive success of the little penguin *Eudyptula minor* on Lion Island, New South Wales. *Wildlife Research 22*: 709–715.

Thibault, J. C. 1994: Nest-site tenacity and mate fidelity in relation to breeding success in cory's shearwater *Calonectris diomedea. Bird Study 41*: 25–28.

Waas, J. 1990: An analysis of communication during the aggressive interactions of little blue penguins (*Eudyptula minor*). *In*: Davis, L. S.; Darby, J. T. *ed*. Penguin biology. San Diego, Academic Press Ltd. Pp. 345–375.

Weavers, B. W. 1992: Seasonal foraging ranges and travels at sea of little penguins *Eudyptula minor*, determined by radiotracking. *Emu 91*: 302–317.

Weimerskirch, H. 1990: The influence of age and experience on breeding performance of the antarctic fulmar, *Fulmarus glacialoides. Journal of Animal Ecology 59*: 867–875.