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## Blue penguin (*Eudyptula minor*) nest distribution and breeding success on Otago Peninsula, 1992 to 1998

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**Abstract** Annual counts of nests with eggs or chicks (known nests) were made at blue penguin (*Eudyptula minor*) breeding sites on the Otago Peninsula in each November from 1994 to 1997. Although the population has doubled to an estimated 600 known nests over this period, the number of breeding sites on the Otago Peninsula has reduced since the 1970s. Breeding success at three areas at Taiaroa Head were monitored by regular nest checks in the breeding season from 1992 to 1998. At Taiaroa Head reproductive success ranged from 41 to 78% at the three sites during the seven-year study and was generally higher for pairs nesting in nest boxes than for those in burrows. The percentage of breeding pairs that laid a second clutch after fledging at least one chick from their first clutch (double brooded) varied between seasons (0–48%) and was correlated with the date of the onset of breeding. Egg loss, possibly through predation by Norway rats (*Rattus norvegicus*), influenced the significantly lower reproductive success at one area (Area A) at Taiaroa Head during the 1996 season.

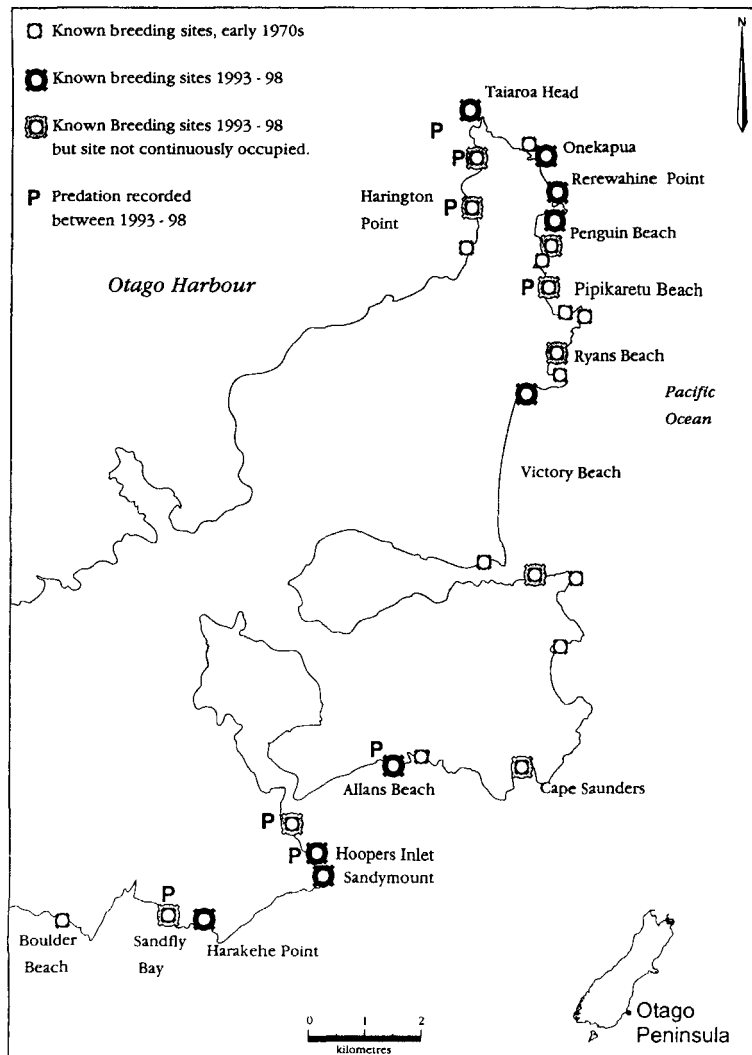
**Keywords** blue penguin; *Eudyptula minor*; Otago Peninsula; Taiaroa Head; breeding; survey; distribution; double brooding; nest box

### INTRODUCTION

Although blue penguins (*Eudyptula minor*) are still relatively common on islands around the coast of New Zealand, many mainland breeding sites support declining populations (Dann 1994; C. Challies pers. comm.). Allan Wright (pers. comm.) conducted a survey of the number of active breeding sites on the Otago Peninsula in the 1970s. Since all life stages of blue penguins are susceptible to predation from introduced mammalian predators (pers. obs.), we predict that the number of unprotected active breeding sites on the Otago Peninsula should have decreased over the last 20 years. We conducted a survey in 1993 similar to Wright's and compared the number of active breeding sites.

Direct observations of blue penguins are difficult, because they come ashore after dusk and nest in burrows that can be several metres long. They can occupy several nest sites before choosing one in which to breed (Dann 1994; pers. obs.). Onset of breeding is variable between seasons, and within seasons there can be huge variations with the stage of breeding between pairs (Perriman & McKinlay 1995). Yearly variation in breeding success can be caused by colony specific factors like weather and burrow substrate type (Perriman & McKinlay 1995) and non-colony specific factors like food availability (Cullen et al. 1992). By comparing breeding success between colonies that have access to the same feeding grounds, we can separate the importance of food availability from colony specific traits. At one area we provided nest boxes to ease access to nests and allow comparisons of breeding success between nest boxes and natural burrows.

To monitor breeding success we individually marked penguins and we followed the fate of each of the breeding attempts in selected breeding areas during the 1992 to 1998 season. Since blue penguins



**Fig. 1** Distribution of blue penguin breeding sites on Otago Peninsula, early 1970s and 1993 to 1997.

breeding seasons generally span over two calendar years, we have chosen to denote the breeding season as starting in the first calendar year e.g., 1993/94 breeding season becomes "the 1993 season".

## STUDY AREA AND METHODS

### Otago Peninsula active breeding site census

The Otago Peninsula ( $45^{\circ}50'S$ ,  $170^{\circ}40'E$ ) is situated on the south-east coast of the South Island of New Zealand (Fig. 1). Most blue penguin breeding sites are found in bays and on sandy beaches along its eastern coastline.

Distribution surveys of blue penguin breeding sites on the Otago Peninsula were made in each

season from 1993 to 1997. All breeding sites, with evidence of breeding by blue penguins, found by Wright were revisited to determine if these were still active or inactive. New possible breeding sites were obtained by encouraging Department of Conservation field personnel to report new possible active breeding sites. Activity was determined by searching the whole breeding site for burrows. Burrows that had an egg or chick present were recorded as "known nests" (kn) while nest sites where the nest chamber was not visible but had recent sign of use by blue penguins were recorded as "possible nests" (pn). Any sign of predation was also recorded. Access into many sites required abseiling or swimming ashore from a nearby boat.

### Breeding success at Taiaroa Head during the 1992 to 1998 seasons

We defined the breeding season as the period from the end of the moult of one season to the start of the moult of the following season, generally from May to April next year. Reproductive success is defined as number of fledged chicks divided by number of eggs laid. A chick was recorded as fledged when it disappeared from the nest at about eight weeks of age and was not found depredated nor in any of the other nests.

Age at first breeding was determined from chicks banded at the nest that later returned to breed at the same area. Only individuals that were regularly found in a nest incubating eggs (or later with chicks) were included in the analysis of age at first breeding.

Three breeding areas at Taiaroa Head were monitored during the 1992 to 1998 seasons.

**Area A** A 0.2 ha, narrow, flat area that is bounded by steep cliffs and the Otago Harbour. For ease of handling blue penguins, nest boxes ( $n = 24$ ) were placed along the length of Area A during the 1992 to 1995 seasons. Blue penguins breed in artificial nest boxes or burrows in soil. In each season all burrows and nest boxes with recent evidence of use by blue penguins were monitored every second week from the beginning of May until the appearance of the first egg, and weekly thereafter.

**Area C** Area C is a steep 0.3 ha site exposed to the Pacific Ocean. Nests are confined to burrows in grass covered slopes or under rocks on the

beachfront. Some penguin nests are flooded by sea swells during storms. The monitoring protocol was the same as at Area A, except for the 1995 to 1997 seasons when monitoring remained at fortnightly intervals throughout. There was no survey in this area during the 1998 breeding season.

**Area F** A 0.2 ha area situated west of the northern tip of the headland, backed by steep cliffs. Blue penguin nests are located in rock crevices and under driftwood. Sites for burrows in soil are limited. Annual nest census was carried out at Area F in each breeding season (with the exception of the 1998 season), with increased visits (weekly) during the 1994 and 1995 breeding seasons.

In the analysis of timing of egg-laying we used linear regression. Logistic regression was used when comparing area-dependent nest success and nest success from nest boxes and natural burrows.

## RESULTS

### Changes in number of breeding sites at Otago Peninsula

Early in the 1970s, 29 active breeding sites were found on the Otago Peninsula (Allan Wright pers. comm.). During the present survey, 11 of the 29 breeding sites found in the 1970s had no sign of breeding by blue penguins (Fig. 1). Of the 18 sites remaining, only nine had continuous evidence of use by blue penguins during these five seasons (Fig. 1).

**Table 1** Blue penguin nests with eggs or chicks (known nest, kn) and nests where the nest bowl was not visible but with signs of breeding nearby (possible nests, pn) on the Otago Peninsula, 1994 to 1997.

Site	Predator accessibility Easy/difficult	Time of predator trapping	1994		1995		1996		1997	
			kn	pn	kn	pn	kn	pn	kn	pn
1 Taiaroa Head	E	All year	134	nc	181	nc	215	nc	279	nc
2 Onkapua cliff site	D	Above site in summer	nc	nc	nc	nc	29	9	26	5
3 Rerewahine Point	D	Above site in summer	61	18	63	20	59	11	nc	nc
4 Penguin Beach	E	In summer	75	28	112	38	122	37	152	34
5 Pipikaretu Beach	E	In summer	2 <sup>*1</sup>	nc	2 <sup>*1</sup>	nc	3 <sup>*1</sup>	nc	5	0
6 Ryans Beach	E	No trapping	0	0	1 <sup>*1</sup>	0	3 <sup>*1</sup>	nc	5	0
7 Victory Beach	E	1 week in summer	2	2	4	2	15	2	23	4
8 Allans Beach	E	No trapping	5	2	13	4	20	nc	8	4
9 Hoopers Inlet (South-east side)	E	No trapping	1	0	2	2	4	2	5	2
10 Sandymount (sea cave)	D	No trapping	nc	nc	13	6	14	4	22	12
11 Bay north-west of Harakehe Point	D	No trapping	nc	nc	32	5	29	nc	24	4
12 Sandfly Bay	E	2 weeks in summer	4	1	7	3	17	4	6	4
		Total	284	51	430	80	530	69	555	69

nc = no count, <sup>\*1</sup> H. McGrouther (pers. comm.).

Six of those nine sites are located in areas where there is either predator control operating (Table 1; sites 1,2,3 and 4) or where predator access is restricted by physical barriers e.g., steep cliffs (Table 1; sites 10 and 11). Predation was recorded at eight sites during the 1993 to 1997 surveys (Fig. 1).

Despite the reduction in the distribution of blue penguin nests on the Otago Peninsula, their population increased from 1994 to 1997 (Table 1). The number of known nests in breeding areas where predators were controlled increased on average 3.4 times over the period, while the number of nests in breeding areas where predators were not controlled increased 2.8 times over the same period.

There have been notable increases in number of known nests at some of the smaller colonies away from the end of the Otago Peninsula. The number of known nests found at Victory Beach increased 10 times (Table 1). The number of pairs breeding at Sandymount and Allans Beach areas has also increased with the provision of nest boxes (Fig. 2). A predation event in the 1997 season at both sites coincided with a reduction of known nests (Fig. 2).

#### Timing of egg laying and breeding success at Taiaroa Head during the 1992 to 1998 seasons

Timing of egg production varied over the seven breeding seasons, and there was a positive correlation between early nesting attempts within a season and the probability of double brooding (Fig. 3,  $P < 0.01$ ). Almost half (48%) of the pairs that produced eggs (defined as breeding pairs) in Area A during the 1993 season laid a second clutch of eggs after the successful fledging of at least 1 chick from their first clutch (defined as double brooding pairs). Breeding started much later in the 1998 season than in the 1993 season, so there was no double brooding that season (Fig. 3).

The reproductive success (number of chicks fledged divided by the number of eggs laid) at Areas A and C ranged between 41 and 78% (Table 2), was significantly higher ( $P < 0.01$ ) at Area A. Birds nesting in nest boxes achieved higher breeding success ( $P < 0.06$ ) than those in burrows (Fig. 4).

There have been marked increases of the number of known nests at Taiaroa Head. In the 1992 season there were 21 known nests at Area A and 27 at Area C (Table 2). In the 1997 season the number of known nests increased to 51 at Area A and to 41 at Area C.

The lowest reproductive success at Area A was recorded in the 1996 season (Table 2). During this season more eggs disappeared than usual from, or were found broken near, known nests. Behind many

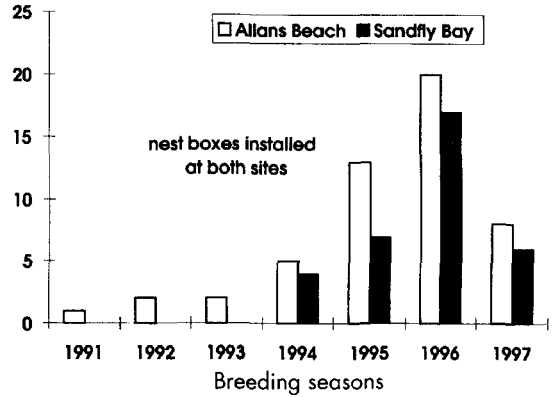


Fig. 2 Number of known nests found at two sites on the Otago Peninsula, before and after installation of nest boxes. 1991 to 1997. Damaged nests and dead birds were found in both areas in 1997, which could explain the drop in number of known nests in that year.

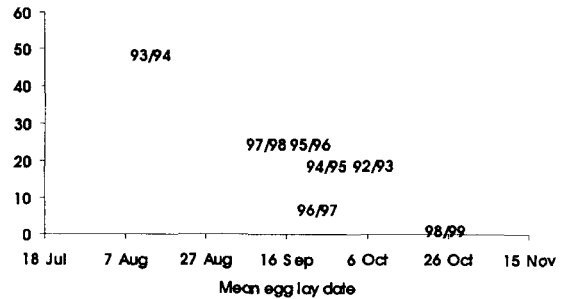


Fig. 3 The percentage of breeding pairs double brooding at Area A, Taiaroa Head, plotted against the mean egg laying date, 1992 to 1998 seasons.

nest boxes there were small holes going down under the box and into the nest chamber. Near one hole, a newly broken egg with a fresh rat dropping on it was found. Rat traps baited with peanut butter were set throughout that area during the first 10 days of December 1996. During this period, six Norway rats (*Rattus norvegicus*) were caught within the area where most of the egg losses had been recorded.

#### Age of first breeding attempt

Of 301 chicks banded at Taiaroa Head in the 1992 to 1995 seasons (authors' unpubl. data), 42 were found breeding in subsequent seasons. Four birds bred at less than 16 months old, in the following season after fledging, and 25 as two year olds (Table 3). We used  $< 16$  months as the minimum age for

**Table 2** Summary of breeding success of blue penguins at Taiaroa Head during the 1992 to 1998 seasons.

AREA A				
Season	Known nests	Eggs hatch %	Chicks fledged %	Reproductive success %
1992	21	74	95	70
1993	23	69	92	63
1994	33	78	92	72
1995	38	69	90	62
1996	45	45	89	41
1997	51	60	94	56
1998	42	81	96	78
AREA C				
Season	Known nests	Eggs hatch %	Chicks fledged %	Reproductive success %
1992	27	48	93	45
1993	19	52	81	42
1994	24	64	81	52
1995	28	60	87	43
1996	38	58	89	45
1997	41	53	76	41
AREA F				
Season	Known nests	Eggs hatch %	Chicks fledged %	Reproductive success %
1994	45	40	58	23
1995	53	58	75	43

**Table 3** First recorded breeding attempt of known-age blue penguins that were banded as chicks during the 1992 to 1995 seasons. Individuals breeding at 16 months or younger attempted to breed in the season following the one in which they were hatched. All of the birds first breeding at 21–25 months, and one one first breeding at 26–30 months, bred in the second season after they were hatched.

Age at first breeding record (months)	Number
less than 16	4
16–20	1
21–25	23
26–30	2
31–35	6
36–40	3
45 or older	3

analysis, since it separates those that were fledged late and bred early in their second summer season from those that were fledged early one year and first bred late in the next year.

## DISCUSSION

### Population distribution

The number of active blue penguin breeding sites on the Otago Peninsula has almost halved during the past 30 years. However, the total population size on the Otago Peninsula has increased since 1994, especially in areas where predators are controlled. Daily inspections of predator traps at Taiaroa Head started in 1968 (C. Robertson pers. comm.), primarily for the protection of royal albatross (*Diomedea epomophora sanfordi*). It is likely that blue penguins will continue to survive within such areas, as they do in other areas provided with artificial nest sites (nest boxes) and protection from introduced mammals. At Katiki Point (50 km north of Otago Peninsula) the provision of nest boxes and predator trapping has increased the resident blue penguin population (J. Jones pers. comm.). A combination of public awareness and the provision of nest boxes stopped predation by dogs (*Canis familiaris*) on blue penguins in Oamaru, North Otago, and the growth of that colony has been similar to that at Taiaroa Head (D. Houston pers. comm.).

### Taiaroa Head monitoring

The number of known nests at Taiaroa Head's Area A doubled during the 1992 to 1998 period, probably influenced by the provision of nest boxes in the 1992 to 1995 seasons. At Area C there has been no provision of additional nest sites, and the number of known nests increased only 1.52 times over the same period (Table 2). Many nests at Area C were prone to flooding throughout the study, which reduced the breeding success in this area (Perriman & McKinlay 1995; Perriman 1997). We deliberately did not place any nest boxes in Area C, so that the reproductive success recorded in that area could reflect the potential of other sites if given protection from land-based predators. This potential could be increased further with the provision of nest boxes (Fig. 4).

### Egg loss at Area A in the 1996 season

Norway rats are known predators of blue penguin eggs (Stahel & Gales 1987). There was no conclusive evidence to prove that Norway rats did break eggs or remove them from nests at Area A. However, the burrowed holes, a rat dropping on a freshly broken egg, and the distribution of the rats that were trapped, all suggest that Norway rats were probably responsible.

### Reproductive success

Blue penguins are capable of double brooding in Australia (Stahel & Gales 1987), but it has not been recorded for any other New Zealand blue penguin colony outside of the Otago region (Gales 1985; L. Bull pers. comm.; C. Challies pers. comm.). In a four year study at Lion Island, New South Wales, Rogers et al. (1995) recorded reproductive successes of between 50–73%, similar to those from our Area A, but with lower percentages of double brooding pairs (5–23%). We found that there was annual variation in the timing of egg laying and in the number of double-brooding pairs. Cullen et al. (1992) showed that the onset of breeding depends on food availability. This suggests that blue penguins will attempt to breed when conditions are most favourable, and that the annual variation in breeding success and double brooding at Taiaroa Head is probably at least in part attributed to food supplies.

### Age of first breeding

At Taiaroa Head, four birds started breeding as one year olds and over half of the 42 known aged birds were less than two years of age at their first known breeding attempt (Table 3). By contrast, Dann & Cullen (1990) reported that two years was the

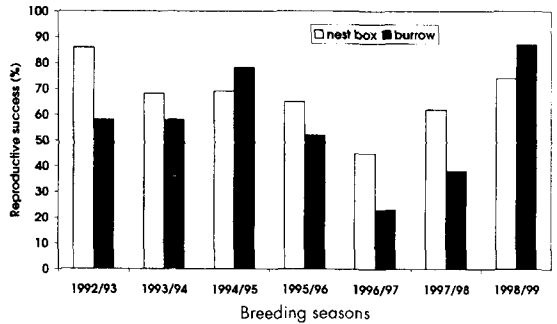


Fig. 4 Reproductive success of blue penguins in nest boxes versus those in burrows. Area A, Taiaroa Head 1992 to 1998 seasons.

youngest age for the commencement of breeding for blue penguins at Phillip Island, Australia. No other penguin species has been recorded breeding at one year of age (Marchant & Higgins 1990).

### Survival of blue penguins on the Otago Peninsula

Over 80% of the present number of known nests are located within two kilometres of the predator-controlled area of Taiaroa Head. It is likely that many of the other small colonies will die out unless they are protected from mammalian predators. Predation was recorded at eight sites during this study, and many of the known predator-killed birds were found dead in their nests, indicating predators smaller than dogs. It was thought that mustelids (stoats *Mustela erminea* or ferrets *Mustela furo*) were the most likely predators at many sites (Perriman 1997; pers. obs.). Present predator control methods for mustelids are expensive to maintain over a long period and a wide area, and as adult blue penguins use their nest sites throughout the year, predation by introduced mammals is possible at any time. Attempts to reduce predation are assisted to some extent by the location of most of the blue penguin population at the end of the Otago Peninsula where there is predator control. However, a population with a restricted distribution can more easily be devastated by other events, e.g., the grounding of a ship with a petroleum spill in the vicinity of the Otago Harbour. Programmes to maintain blue penguins on the Otago Peninsula should consider these unlikely, but possible, risks.

## ACKNOWLEDGMENTS

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