SCIENCE & RESEARCH SERIES NO.86

THE BLUE PENGUIN (*Eudyptula minor*) AT TAIAROA HEAD, OTAGO, 1992-1993

by

Lyndon Perriman and Bruce McKinlay

Published by
Head Office,
Department of Conservation,
P 0 Box 10-420,
Wellington,
New Zealand

ISSN 0113-3713
ISBN 0-478-01694-8

Cataloguing-in-Publication data

Perriman, Lyndon.
The blue penguin (Eudyptula minor) at Taiaroa Head, Otago, 1992/1993 /'by Lyndon Perriman and Bruce McKinlay. Wellington, N.Z. : Dept. of Conservation, 1995.

1 v. ; 30 cm. | Science & Research series, 0113-3713 ; no. 86)
ISBN 0478016948

1. Eudyptula minor. I. McKinlay, Bruce (Bruce J.), 1959- II. Title. III. Series: Science & Research series ; no. 86.
598.441099392 20
zbn95-052703

CONTENTS

THE BLUE PENGUIN (*Eudyptula minor*) AT TAIAROA HEAD, OTAGO, 1992-1993

by
Lyndon Perriman and Bruce McKinlay
Department of Conservation
Box 5244, Moray Place
Dunedin, New Zealand

ABSTRACT

During the 1992-93 breeding season, 152 breeding pairs of blue penguins, *Eudyptula minor*, were found at Taiaroa Head, Otago. Reproductive success ranged from 48-85 percent in three of the six distinct breeding areas on the headland. Egg laying occurred from late July 1992 to early January 1993, with 21 percent of the breeding pairs laying two clutches. Nine percent of the 1992-93 breeding pairs were double-breeders, all of which successfully fledged chicks from two clutches. An average fledging success of ninety seven percent was attained in a season where no predation was recorded.

1. INTRODUCTION

The blue penguin, *Eudyptula minor*, occurs on the New Zealand mainland, several offshore islands and in South Australia and Tasmania. In the Checklist of the Birds of New Zealand (Turbott 1990), all five previously recognized forms are placed in one taxon *E. minor*. Marchant and Higgins (1990) suggest that "further study is needed to test the validity of subspecies".

McKinlay (1993) identified the threats to the continued survival of blue penguins on the mainland of New Zealand. He identified that one of the major issues facing blue penguins is a lack of long-term basic biological information. In 1991-92, a survey of blue penguins on the coast of Otago was completed (Dann, in press). This survey showed that blue penguins at Taiaroa Head on the Otago Peninsula made up 6.3% of the estimated population surveyed on the Otago coast and from small local islands.

A long term study of blue penguins at Taiaroa Head, Otago, was started in 1992 with the following objectives:

- to establish the population size at Taiaroa Head and its immediate environs,
- to monitor breeding success,
- to assess the effects of predation on blue penguin numbers at Taiaroa Head,
- to assess chick and adult mortality, and
- to make comparisons with other blue penguin colonies under study.

These objectives are priorities to meet conservation management needs for this species at this and other mainland locations.

2. STUDY SITE

Taiaroa Head (45° 47'S 170° 44'E) is situated at the NE end of the Otago Peninsula, within the boundaries of Dunedin City, on the SE coast of the South Island, New Zealand (Fig. 1). The headland is a promontory rising to 75 metres above sea level. Pilots Beach is situated at the southern base of this promontory, at the mouth of the Otago Harbour. Between Pilots Beach and Harington Point is an area of steeply sloping ground with rank grass and shrub communities. For a detailed description of the study site see Department of Conservation (1992).

A range of nest sites were used by blue penguins during this season. These included nests in artificial nest boxes, pipes, sea caves, under rocks, vegetation, driftwood, rabbit burrows and in self-excavated burrows.

For ease of study management as well as to recognise significant topographic features, predator presence, and observer access, the study site was divided into six distinct areas. Topographic features of the study areas are summarised in Table l.

Areas A, D and F (Fig. 1) are within the Taiaroa Head Nature Reserve and public access restricted, unlike areas B, C and E, where there is no restriction.

Table 1 Summary of topographic features of the sudy areas. (Numbers 0 to 10 indicate estimated proportion of area for aspect, substrate type or vegetation cover at each of the six areas.)

Area:	A	B	C	D	E	F
Aspect: Flat	7	4	3	3	1	8
Aspect: Sloping	3	6	7	7	9	2
Substrate: Soil	9	1	8	9	6	2
Substrate: Sand	0	8	0	0	3	0
Substrate: Rock	1	1	2	1	1	8
Cover: Grasses	7	8	7	8	6	0
Cover: Shrubs	1	1	1	1	3	0
Cover: None	2	1	2	1	1	10

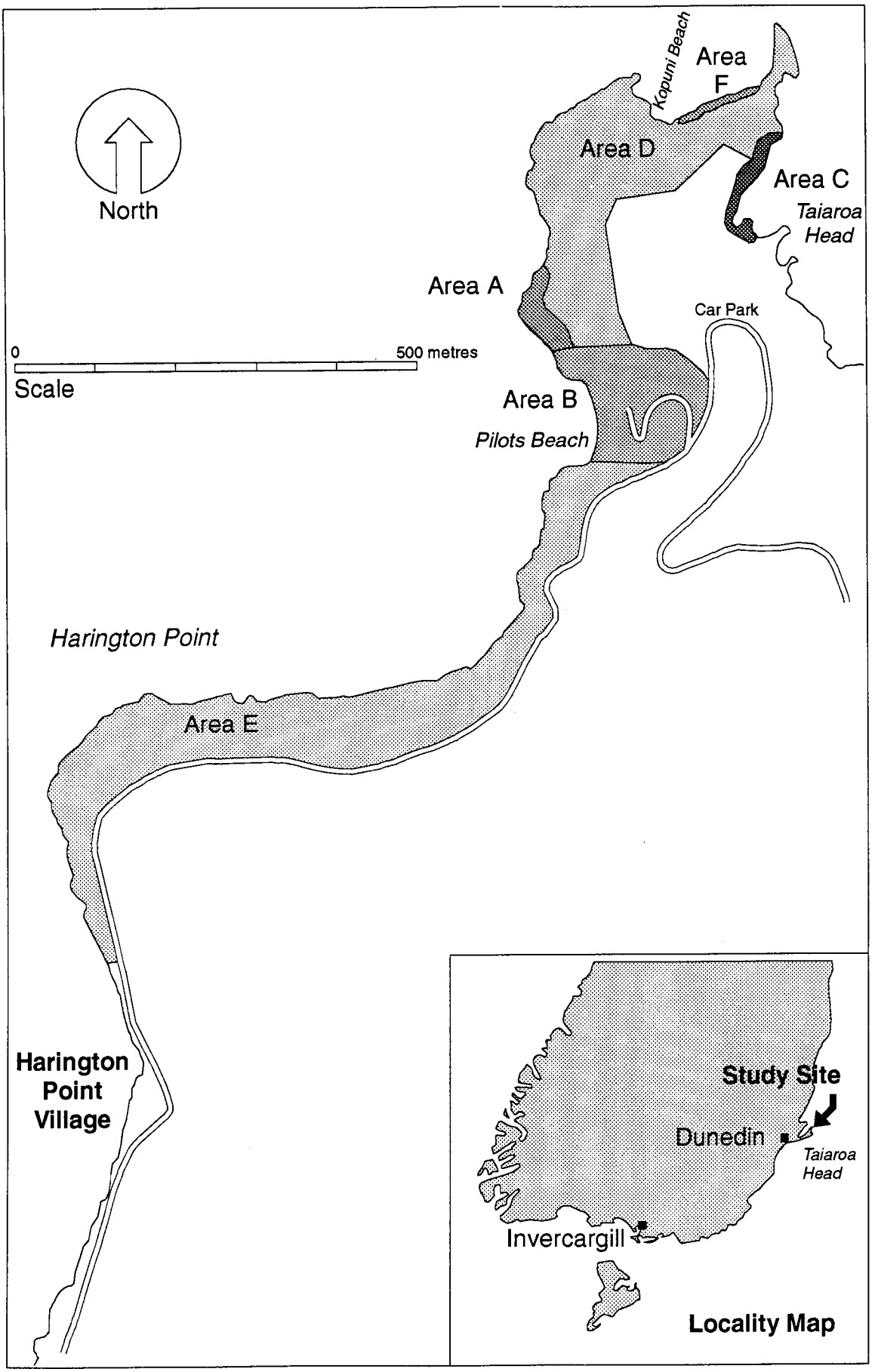

Figure 1 Location of study site and features named in the text.

3 METHODS

3.1 Census

A census of nest sites was carried out in 1992. Photographs were taken of all sides of the headland and surrounding areas to show the general topography of each area. Individual nest sites were recorded on these photographs, showing nest site relationships and height above sea level. Additional close-up nest site photos were taken of accessible and studied sites, so that each nest site was identifiable.

3.2 Banding and Measurements

Birds were banded and measurements were taken throughout the season, either during nest visits, or at night when adult birds returned from the sea to their burrows. For accessible nests, all adults and chicks at each nest site were banded. For all adults, two bill measurements (depth and length) were recorded, along with the weight of the bird. All adult birds were provisionally sexed by the general shape and bulk of their bills (Gales 1988; Kinsky and Falla 1976).

Chicks were banded between four and eight weeks of age, with the majority banded at an age of about six weeks. This range of banding ages of chicks was due to some chicks being difficult to retrieve from burrows.

The age of chicks was estimated by comparison with known aged chicks.

The following criteria can be used to approximately age chicks of unknown age:

1. Four weeks: feathers start to emerge and the down starts to disappear, firstly around the eyes then on the flippers.

2. Five weeks: the chick body is covered by about half feathers and half down.

3. Six weeks: down is only present on the back and neck.

4. Seven weeks: all the down has either gone, or just a little bit on the back of the neck is present.

These criteria are similar to those described by Richdale (1940).

3.3 Monitoring

The monitoring of breeding throughout the season was achieved by regular checks of nest sites, recording the breeding status at each nest, and weighing, banding and measuring birds.

These checks were carried out every week from June 1992 to March 1993 for areas A, B, and C. In areas D, E and F visits were less regular, with the primary purpose of

obtaining adults and chicks for banding, establishing nest numbers and checking for predation.

Monitoring in burrows which had the nest bowl out of reach and sight was achieved by the use of a probe (a flexible piece of a fishing rod). This method enabled distinction by feel between adults, chicks and eggs. Adults and chicks could be distinguished by the force of the bite on the probe and by any noises made. Eggs were identified by the hard roundness felt.

The recording of predation was based on observations of any nest/nest site irregularities such as missing chicks, deserted eggs/young chicks, dead carcasses and/or other predator sign.

Five chicks from three nests in area A were weighed on a daily basis from hatching to fledging, these chicks were weighed to within 10 grams using Pesola scales.

3.4 Definitions

The following definitions have been used when interpreting the data:

Nest site:	A burrow with evidence of use by birds, having either excreta, fresh footprints or birds present.
Nest:	A nest site with eggs or chicks.
Breeding pair:	A pair who produced eggs in the 1992-93 breeding season.
One-clutch pair:	A pair who attempted to breed only once and laid only one clutch.
Two-clutch pair:	A pair who laid two clutches. This definition includes both replacement-clutch or double-breeding pairs. (See below).
Repacement-clutch pair:	A pair whose first clutch was lost before the normal completion of incubation (approximately 36 days) resulting in re-nesting and laying a second clutch.
Double-breeding pair:	A pair who re-nested after their first clutch of eggs was incubated past the normal incubation period. These pairs may or may not have successfully fledged a chick from their first clutch before re-nesting.
No. of nesting attempts:	The total number of nests, including both attempts from two clutch nests.
Pre-egg:	The pre-egg period is defined as the interval between post-moult of one season to egg-laying of the next season during which time birds are re-establishing bonds, locating a nest site, preparing nests and mating.
Inter-clutch pre-egg:	The term pre-egg is also applied to the period between the first and the second clutch of the same pair during the same season. It is in this instance defined as the interval between the time that the nest is empty, with no adults incubating eggs, or after the chicks have departed from the first clutch and egg-laying of the second clutch.

No. of eggs laid:	The total number of eggs laid.
Eggs lost due to destroyed eggs:	These eggs did not hatch as they were broken accidentally.
Eggs lost due to disappearance:	Eggs that disappeared from nests before the end of the normal completion of the incubation period, where no trace of the eggs could be found.
Eggs that failed due to flooding:	Presumably did not hatch due to flooding of the nest by either heavy rain or encroaching seas.
Deserted eggs:	Eggs abandoned for unknown reasons prior to the completion of the normal incubating period.
Eggs not hatched due to unknown causes:	These eggs were incubated past the normal incubation period, but did not hatch. No distinction has been made here between death of an embryo and infertile eggs.
Pair that fledged 0 chicks:	A pair which attempted to breed once or twice, but fledged no chicks.
Pair that fledged one chick:	A pair which bred once or twice and fledged one chick.
Pair that fledged two chicks:	A pair that bred once or twice and fledged two chicks.
Pair that fledged three chicks:	A pair which bred twice and fledged three chicks.
Pair that fledged four chicks:	A pair which bred twice and fledged four chicks.
Reproductive success:	The number of chicks that fledged, divided by the number of eggs that were produced, expressed as a percentage.
Mean chicks fledged per nest:	The total number of chicks that fledged, divided by the total number of nests.
Mean fledging success:	The number of chicks that fledged from the number of eggs that hatched.
Breeding season:	The length of time after the moult of the previous season to the start of the moult in the following season.

4. RESULTS

4.1 Population Estimate 1992-93

The minimum number of breeding pairs for the 1992-93 season was 152. The distribution of these breeding pairs in each of the six areas is summarised in Table 2. The number of breeding pairs was established by checking all nest sites in each area for eggs or chicks. It is probable that there are other breeding pairs at Taiaroa Head, especially those who nested in long burrows, or in areas where nest checks were not regularly carried out.

Table 2 Distribution of known breeding pairs at Taiaroa Head during 1992-93.

Areas:	A	B	C	D	E	F	Total
No. of breeding pairs	21	29	27	36	5	34	**152**

4.2 Length of Burrows

The length of burrows has had, and will continue to have, a significant impact on data collection. The use of a probe has improved the ability to collect data, but approximately 15% of the nest sites in area B, and 50% of the nest sites in area D, are too long for data collection.

Within Area D, a lot of nest sites are long rabbit burrows, so there is considerable difficulty in obtaining birds from these burrows. Area F has no problems in obtaining birds, but physical access difficulties to the beach cave resulted in only five visits this season.

4.3 Banding

In the 1992-93 season 373 birds were banded, including 106 chicks.

Fifty-eight previously banded birds were recovered, 53 of which were banded in the 1991-92 season by P Dann, and five which were banded in the 1982-84 seasons, by R. Gales. From the adult birds banded this season (1992-93) and the adult birds banded in the 1982-84, 1991-92 seasons, a total of 319 recoveries were made. Some birds were recovered up to nine times during this season.

4.4 Predation

Only one depredated blue penguin was recorded this season in the study site. This was an adult killed by a domestic dog at Pilots beach.

Table 3 Nest summary at Taiaroa Head 1992-93.

	Area A	Area B	Area C	Total
No. of breeding pairs	21	29	27	**77**
No. of nesting attempts	28	31	34	**93**
Ratio of one-clutch to two-clutch pairs	14 : 7	27 : 2	20 : 7	**61 : 16**
No. of successful one-clutch pairs	12 of 14	23 of 27	13 of 20	**48 of 61**
No. of double-breeders, successful twice.	4 of 4	2 of 2	1 of 1	**7 of 7**
No. of successful replacement-clutch pairs	3 of 3	0 of 0	3 of 6	**6 of 9**

4.5 Season Summary

Of the 152 breeding pairs present, 77 (51%) in three areas were followed weekly (Tables 3-6). There were a total of 93 nesting attempts. Only 14 were one egg nests. Sixty one nesting attempts (66%) were one-clutch nests (Table 3).

The greatest cause of egg failure (18 eggs or 34% of failed eggs) was desertion by adults (Table 4). Flooding and unknown causes were responsible for a further 26 failed eggs. Area C had the highest rate of egg failure with half of the eggs laid failing to hatch. Sixty-nine percent of all eggs laid hatched (Table 4).

Table 4 Blue Penguin egg production.

		Area A	Area B	Area C	Total
No. of breeding pairs		21	29	27	**77**
No. of eggs produced		53	59	60	**172**
No. eggs not hatched due to:	Destroyed eggs	2	0	2	**4**
No. eggs not hatched due to:	Disappeared	3	1	0	**4**
No. eggs not hatched due to:	Flooding	2	0	14	**16**
No. eggs not hatched due to:	Desertion	5	4	9	**18**
No. eggs not hatched due to:	Unknown causes	2	3	6	**11**
Total No. eggs not hatched		14	8	31	**53**
No. eggs hatched (%)		39 (74)	51 (86)	29 (48)	**119 (69)**

In the 1992-93 season 97% of chicks fledged (Table 5). Four chicks in three nests died before fledging. All four chicks were less that one week old and they probably died as a result of either exposure to cold or from drowning. All chicks, when found dead, had their nest bowl flooded.

Table 5 Blue Penguin chick production. Taiaroa Head 1992-93.

	Area A	Area B	Area C	Total
No. of pairs	21	29	27	**77**
No. eggs laid	53	59	60	**172**
No. chicks hatched	39	51	29	**119**
No. chicks died before fledging.	2	0	2	**4**
No. chicks fledged	37	51	27	**115**
Fledging Success	95%	100%	93%	**97%**
Reproductive success	70%	86%	45%	**67%**
Average No. chicks fledged per nest	1.76	1.76	1.0	**1.49**

As shown in Table 3, most of the pairs were one-clutch pairs (n=61 pairs) and therefore the most common number of chicks fledged was 1 or 2 chicks (Table 6). Only six pairs (8%) fledged three or four chicks. In area C, 37% (10 pairs) of the breeding population contributed nothing to this season's chick production. Two-clutch pairs were more successful in fledging chicks than one-clutch pairs (Table 7). However, two-clutch pairs have a lower rate of reproductive success, due to the inclusion of replacement-clutch pairs, who by definition had a failed first clutch.

Table 6 Pair productivity.

	Area A	Area B	Area C	Total
No. pairs fledging : 0 chicks	2	4	10	**16(21%)**
No. pairs fledging : 1 chick	7	2	9	**18 (23%)**
No. pairs fledging : 2 chicks	9	21	7	**37 (48%)**
No. pairs fledging : 3 chicks	0	1	0	**1 (1 %)**
No. pairs fledging : 4 chicks	3	1	1	**5 (7%)**
Total	**21**	**29**	**27**	**77**

Applying a statistical test (Mann-Whitney U test) to the mean egg production per pair and the mean number of chicks fledged by one-clutch and by two-clutch pairs shows that there is a significant difference ($Z = 6.12$, $P = 0.001$) for egg production. There was no significant difference detected for fledglings ($Z = 1.02$, $P = 0.5$) between the one-clutch and two-clutch pairs.

Twenty one percent (16 pairs) of the breeding pairs in areas A, B and C at Taiaroa Head laid two clutches during the 1992-93 season. The seven double-breeding pairs were responsible for producing 25 chicks of the 115 chicks that fledged from areas A, B and C this season. The nine replacement-clutch pairs raised eight chicks and all but

Table 7 Comparison of egg production between one-clutch and two-clutch pairs.

	No. of Pairs	No. eggs laid	Mean No. eggs per pair (±SD)	No. chicks fledged	Mean No. chicks per pair (± SD)	Reproductive success
One-clutch pairs	61	112	1.84 ± 0.37	83	1.36 ± 0.82	74%
Two-clutch pairs	16	60	3.75 ± 0.45	32	2.0 ± 0.88	53%

one of these fledged. Twenty-eight percent of the chicks fledged were produced from two-clutch pairs.

Tables 8 and 9 compare double-breeding pairs and replacement-clutch pairs with the two clutch pairs so that comparisons of the mean number of eggs produced per pair and the mean number of chicks fledged per pair can be made.

Table 8 Egg production between one-clutch, replacement-clutch and double-breeding pairs.

	No. pairs	No. eggs laid	Mean No. eggs laid per pair (± SD)
One-clutch pairs	61	112	1.84 ± 0.37
Replacement-clutch pairs	9	32	3.56 ± 0.53
Double-breeding pairs	7	28	4.00 ± 0.00

There was no significant difference in the mean number of eggs laid between double-breeding pairs and replacement-clutch pairs (U = 1.43, P = 0.15), whereas there were significant differences between numbers of eggs produced by one-clutch pairs compared with double-breeding (U = 4.30, P = 0.0001) and replacement-clutch (U = 4.81, P = 0.0001) pairs.

Table 9 Comparisons of number of chicks fledged between one-clutch pairs, replacement-clutch pairs and double-breeding pairs.

	No. pairs	No. chicks fledged	Mean No. of chicks fledged per pair (± SD)	Reproductive success
One-clutch pairs	61	83	1.36 ± 0.82	74%
Replacement-clutch pairs	9	7	0.78 ± 0.66	22%
Double-breeding pairs	7	25	3.57 ± 0.78	89%

Significant differences in mean numbers of chicks fledged per pair occurred between one-clutch pairs and double-breeding pairs (U = 3.95, P = 0.0001). There was also a significance difference between numbers of fledglings of double-breeding pairs and replacement-clutch pairs (U = 3.23, P = 0.001) and between numbers of fledglings from replacement-clutch pairs compared with one-clutch pairs (U = 1.99, P = 0.005).

Table 10 Comparison of reproductive success and fledgling productivity between one-clutch pairs, second clutch replacement pairs and the first and second clutch of the double-breeding pairs.

	Reproductive Success	Mean No. chicks fledged per pair (± SD)
One-clutch pairs	74%	1.36 ± 0.82
Replacement-clutch pairs : second clutch	44%	0.78 ± 0.66
Double-breeding pairs : first clutch	93%	1.86 ± 0.38
Double-breeding pairs : second clutch	86%	1.71 ± 0.49

Table 10 compares one-clutch pairs, replacement-clutch pairs and double-breeding pairs to see which pairs were more successful. This table shows that with the distinction made between the first and second clutch for replacement-clutch pairs, the reproductive success is still markedly lower than for either clutch of the double-breeding pairs or the one-clutch pairs. As by definition the first clutch of a replacement-clutch pair fails, these are not included in Table 10.

Table 11 Double-breeding pairs breeding success.

Nest No.	Week 1st clutch Laid	No. eggs	Week Fledged	No. Fledged	Week 2nd clutch Laid	No. eggs	Week Fledged	No. Fledged
A8	31.7.92	2	13.11.92	2	20.11.92	2	22.2.93	2
A9	29.8.92	2	5.12.92	2	12.12.92	2	15.3.93	2
B6	29.8.92	2	20.11.92	2	20.12.92	2	15.3.93	2
A l	4.9.92	2	5.12.92	2	12.12.92	2	15.3.93	2
A5	4.9.92	2	28.11.92	1	12.12.92	2	8.3.93	1
B 14	4.9.92	2	5.12.92	2	27.12.92	2	8.3.93	1
CIO	4.9.92	2	28.11.92	2	?	2	1.3.93	2

The mean number of chicks fledged per pair for one-clutch pairs was not significantly different from the first clutch (U = 1.34, P = 0.18,) or the second clutch (U = 0.86, P = 0.39) for double-breeding pairs. In contrast, there was a significant difference between the mean number of chicks fledged from one-clutch pairs and the second clutch from the replacement-clutch pairs (U = 1.99, P = 0.046). Similarly, significant differences in the mean number of chicks to fledge occurred between both clutches of the double-breeding pairs compared with the second clutch of the replacement-clutch pairs (first clutch, U = 2.59, P = 0.001), (second clutch, U = 2.28, P = 0.02).

Table 11 clearly shows the time span ranges for birds to successfully re-nest. Eggs of the second clutch are laid as soon as one week (in the A8 and A9 pairs), or in the case of the B6 pair, one month after the chicks from the first clutch have departed. Table 12 summarises the breeding timing and success of the nine replacement-clutch pairs.

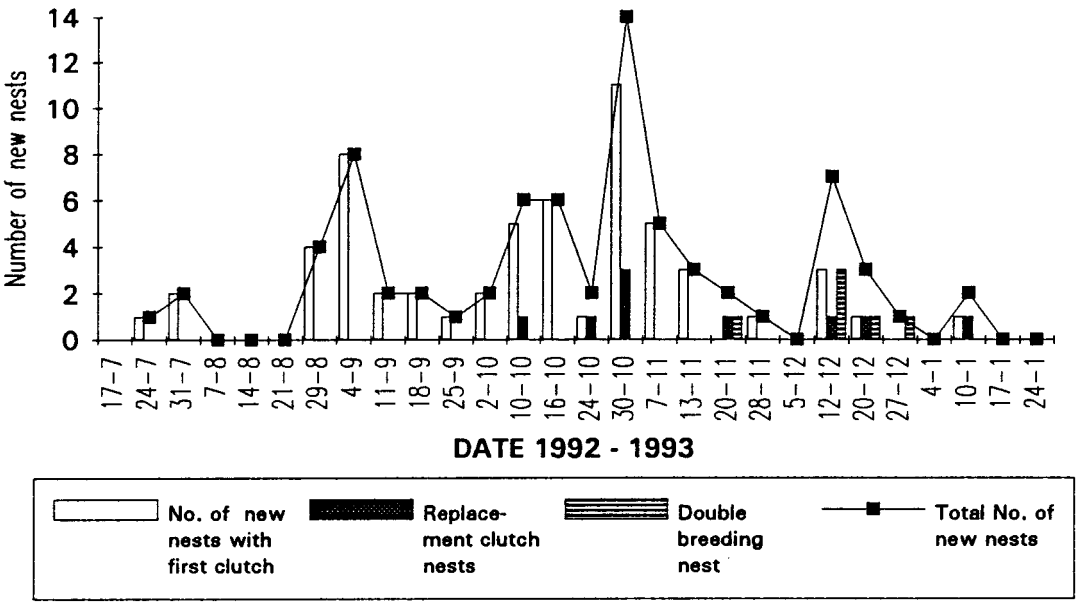

Figure 2 Summary of times when new nests for one-clutch, replacement-clutch and double-breeding pairs were found at Taiaroa Head during the 1992-93 season.

Table 12 Replacement-clutch pairs breeding success.

Nest No.	Week 1st clutch laid	No. eggs	Week deserted	Eggs failed due to:	Week 2nd clutch laid	No. eggs	Eggs failed due to:	Week chick/s fledged	No. chicks fledged
A15	24.7.92	2	7.8.92	F	10.10.92	2		17.1.93	2
C5	31.7.92	2	28.8.92	F	30.10.92	2		24.1.93	1
C4	4.9.92	2	11.9.92	A	30.10.92	1		24.1.93	1
C8	4.9.92	2	11.9.92	F	30.10.92	1	C		
C18	18.9.92	2	16.10.92	U	7.11.92	2	U	8.2.93	1
C26	10.10.92	1	16.10.92	De	30.10.92	2	U		
A36	16.10.92	2	30.10.92	A	20.11.92	2	Di	22.2.93	1
C2	30.10.92	2	28.11.92	F	10.1.93	2	DeM		
A23	30.10.92	1	7.11.92	De	12.12.93	2	Di	15.3.93	1

Key for reasons why eggs not hatched:

F = water/flooding
De = deserted
U = unknown reason
A = accidentally broken
C = burrow collapsed
Di = eggs disappeared
DeM = eggs deserted as adults started to moult.

Figure Two summarises the breeding season. It shows that there were three peaks in the arrival of new nests - late August, October and mid December. The latter peak is due to two-clutch pairs attempting to breed again for the second time.

4.6 Nest Site Habitat

The average number of chicks fledged per pair compared with nest site habitat in three nest types is summarised in Table 13 and includes all breeding pairs. Burrows include both self excavated burrows and burrows made by rabbits. Other nest types include nesting under rocks, in pipes and above ground, but under vegetation.

Significant variations between the mean fledging rate of areas and nest site habitat were evident. Significant differences in the mean number of chicks fledged per pair were indicated between areas A and C ($Z = 2.28$, $P = 0.02$) and between areas B and C ($Z = 2.98$, $P = 0.003$). There was no significant difference in the mean number of chicks fledged from pairs in areas A and B ($Z = 0.61$, $P = 0.54$).

Pairs nesting in nest boxes had a greater mean number of chicks fledged per pair than either those nesting in burrows ($U = 2.12$, $P = 0.03$) or in other nest types ($Z = 2.27$, $P = 0.02$). No significant difference was obvious between the mean number of chicks to fledge from burrows compared with other nest types ($Z = 0.96$, $P =. 0.34$).

Individual nest site habitat and site topography, and soil type, may affect blue penguin breeding. The generally poorer success rate for Area C, which is below average for each of the two nest types associated with it, is probably a result of Area C's aspect and elevation combined with soil type, rather than to individual nest site selection. Twenty two percent of this season's nests in Area C were found in areas that are exposed to heavy seas. Most of these nests were flooded at some time as a direct result of this exposure.

4.7 Chick Growth

Figure Three records the average daily weight gain and weight range for five chicks measured from hatching to the fledging date of the first of the five chicks. Weight gain is generally constant and it is only into the latter stages that the weight range expands greatly. The first of the chicks fledged on day 55 and the last chick fledged 60 days after hatching.

Table 13 Chicks fledged per pair compared to nest site habitat in three nest types.

	Burrow	Nest box	Other nest type	Mean (±SD)
Area A	1.38 ± 0.74 (n=8)	2.71 ± 1.25 (n=7)	1.17 ± 0.75 (n=6)	1.76 ± 1.14 (n=-21)
Area B	1.8 ± 0.81 (n=21)	1.67 ± 1.53 (n=3)	1.6 ± 0.89 (n=5)	1.76 ± 0.87 (n=-29)
Area C	1.09 ± 1.04 (n=-23)	N/A	0.5 ± 0.58 (n=4)	1.00 ± 1.00 (n=-27)
Mean	1.42 ± 0.96 (n=-52)	2.4 ± 1.35 (n=10)	1.13 ± 0.83 (n=-15)	1.49 ± 1.05 (n=-77)

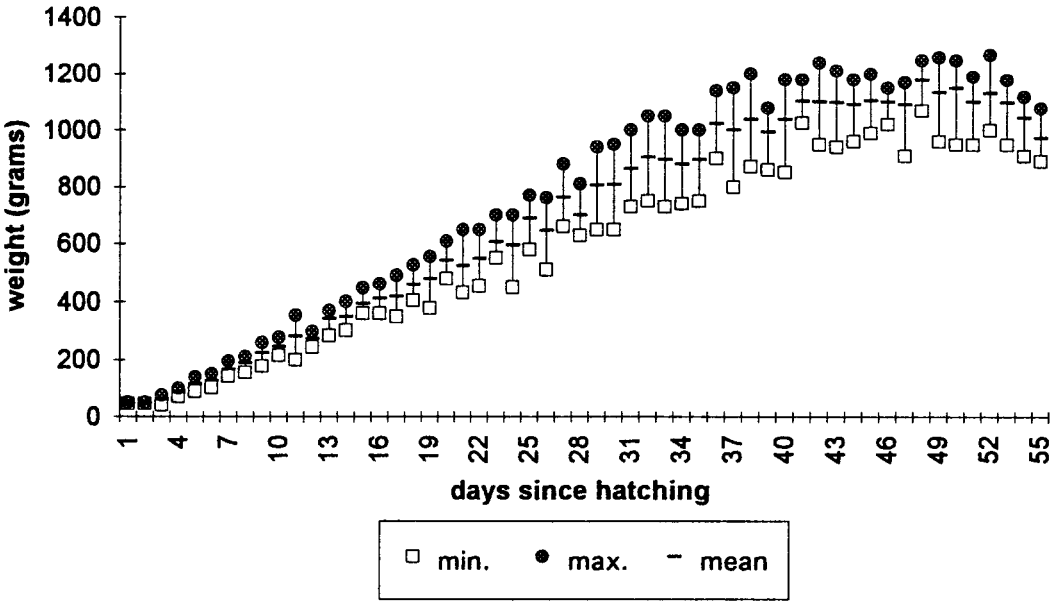

Figure 3 Average daily weight gain and weight range of five chicks at Taiaroa Head, 1992-93.

5. DISCUSSION

5.1 Definitions

The definitions given in the methods have been developed to reduce confusion. The consistent use of these definitions at all study sites will lead to improved coordination of data collection and interpretation.

Several seabird species breed at Taiaroa Head, with blue penguins being one of the more abundant species found. Some penguin burrows were shared with either rabbits, *Oryctolagus cuniculus* or sooty shearwaters, *Puffinus griseus*. In these situations a common burrow entrance is used, but the burrow forks into separate chambers, separating rabbits, sooty shearwaters and blue penguins from each other.

5.2 Population Estimates

Dann and Cullen (1990), using data from Victoria, Australia, have estimated that the breeding population makes up 43% of the total population. Using this figure and assuming that the ratio is the same for New Zealand and Australian populations, it can be calculated that the total number of blue penguins at Taiaroa Head is possibly not less than 843 individuals.

5.3 Breeding Cycle

As shown in Figure Two, there is a gap during early August when no pairs laid. This may possibly be attributed to the heavy seas and rain experienced then. It is possible that pairs did not attempt to breed until the weather and their dampened nest site became favourable to begin breeding. Figure Four summarises the overall breeding season.

The pre-egg stage for the first clutch of eggs for blue penguins at Taiaroa Head spread over a six month period from at least June 1992 to early January 1993. As nest monitoring was only initiated in June 1992, the pre-egg stage may have started earlier. The period of inter-clutch pre-egg stage can also vary in length, with some replacement-clutch pairs not commencing egg laying for their second clutch until from two weeks to two months after they deserted their first clutch. The time between the departure of chicks from the first clutch of double-breeding pairs till the time of laying their second clutch ranged from one month to less than one week.

At the peak of the season, when the greatest number of birds were breeding, there were birds and nests at almost every stage of the breeding cycle from pre-egg of the first clutch, right through to the pre-moult stage for pairs who had fledged chicks from either one or two clutches.

Laying dates for the first clutch spanned a period from 24 July 1992 until 10 January 1993. Only those pairs making early nesting attempts, such as those who had laid their first clutch of eggs before early November, attempted to breed a second time this

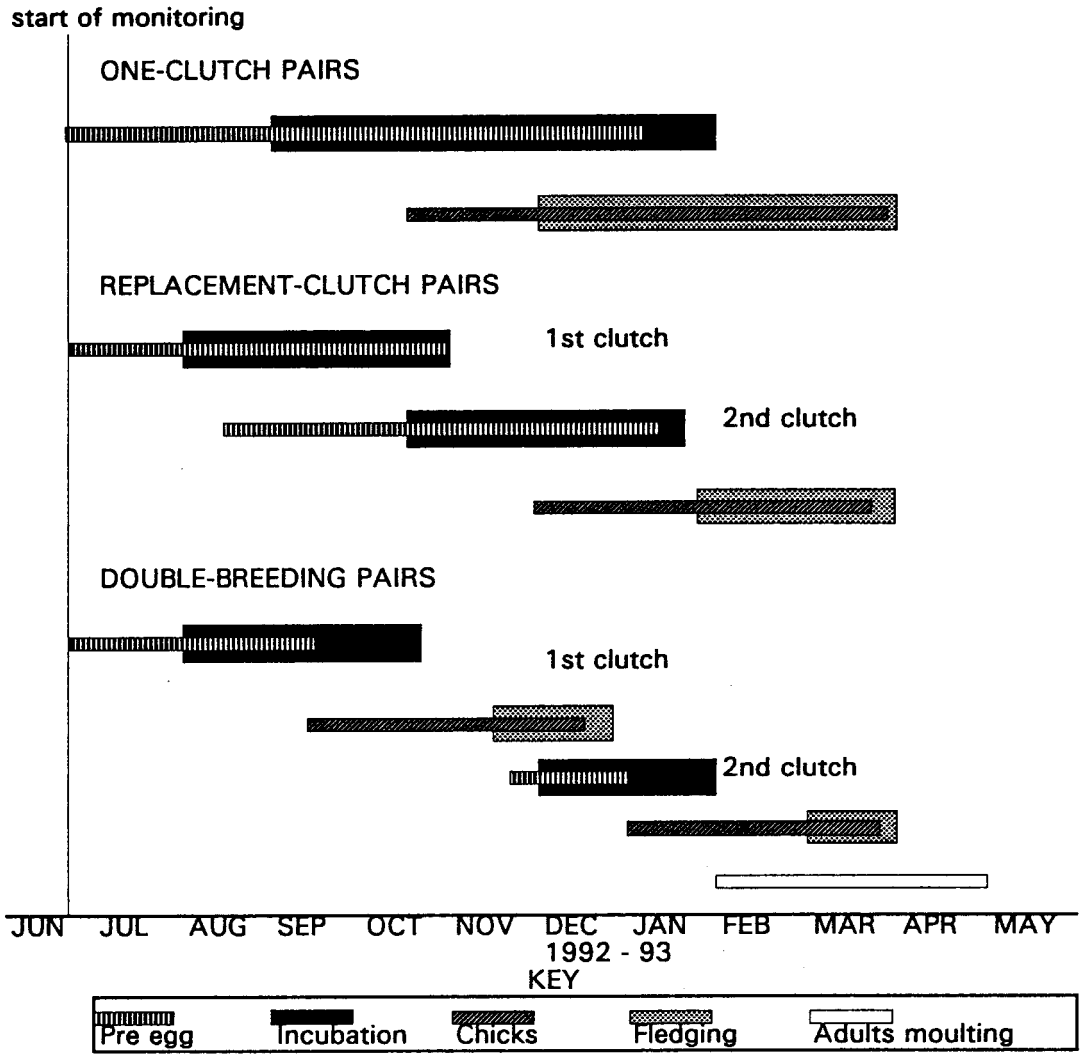

Figure 4 Summary of the breeding cycle for blue penguins at Taiaroa Head during 1992-93.

season. The time of egg laying for the second clutch varied from mid-October until late December for replacement-clutch pairs. One exception was a pair who laid their second clutch between 4 and 10 January 1993. Three weeks later this pair deserted their fertile eggs to begin moulting. All seven double-breeding pairs that were successful in fledging chicks from their first clutch, laid their first clutch before early September. As their chicks did not fledge until November, these pairs did not produce a second clutch of eggs until the period late November to late December. This resulted in their second clutch chicks fledging from late February till late March. At this time many one-clutch pairs had finished breeding and a high proportion were starting or had completed moulting. The total breeding season for the double-breeders lasted just over six months, excluding the pre-egg stage of the first clutch.

For the 1992-93 season, blue penguins at Taiaroa Head in areas A, B, and C produced a total of 172 eggs with a hatching success of 69 percent. It appears that eggs failed to hatch due mainly to external physical events such as nest flooding rather than

infertility. Eighteen eggs were recorded as deserted, but a proportion of these could have been flooded, but due to infrequency of visits this is not certain.

Ninety-seven percent of all chicks that hatched in areas A, B, and C at Taiaroa Head fledged. No predation of chicks was recorded, and this may be a significant factor in such a high fledging success. All of the chick loss was recorded in four nests, each containing young chicks, and was due to chick exposure (either cold or drowning). Two chicks who both lost a sibling from two of these nests survived. Many other nests had a similar problem, but in most cases larger chicks were present and were probably old enough to move away from the flooded area and survive to fledging.

Adult moulting started soon after the chicks departed. As little as 2-3 weeks was needed for the adults to increase their own body weights from around 1 kg for females, or from just over 1 kg for males, to around 1.5-1.9 kg for either sex (with males usually slightly heavier) before moulting commenced. In one case, the adult started moulting in a burrow with its single chick, while its mate continued foraging for food to feed the chick, until that chick departed, and the second adult began moulting.

It has been shown in Table 10 that even with a second clutch, the replacement-clutch pairs have a significantly lower mean rate of chicks fledged per pair than either one-clutch pairs or either clutch of the double-breeding pairs. This is probably due to a combination of the individual nest site and general aspect of that particular area where the replacement-clutch pair nested. Many first clutch eggs of the nine replacement-clutch pairs presumedly failed due to exposure to excess water (Table 12) in the nest, but these pairs came back to the same nest site and relaid. Therefore, these second-clutch eggs could potentially fail (chilling of embryos or drowning) if the same external conditions occur while incubating these second clutches.

The benefits to the population of double-breeding are yet to be determined. There are significant differences in the mean number of chicks to fledge from double-breeding pairs compared with one-clutch pairs. However, the mean fledging rate per pair between one-clutch pairs compared with either of the two clutches of the double-breeding pairs is not significantly different. Therefore, it may be assumed that one-clutch pairs are just as successful at fledging chicks as double-breeding pairs, but are limited to only one-clutch. The small number of double-breeding pairs (9%) that successfully bred means that the total impact of double-breeding is likely to be limited unless there is a skewed survival rate amongst juveniles from the second clutches.

The additional effort required to raise a second clutch can have an adverse impact on adults, through additional energy costs, and can reduce the amount of time available to prepare for the moult.

5.4 Nest Site Habitat

The average number of chicks fledged per pair was considerably lower in Area C than in areas A or B. This may be largely due to Areas C's aspect and elevation combined with general topography, soil type and contact with water from either heavy rain or sea,

than to individual nest site selection. While area A has the highest mean number of chicks fledged per pair in nest boxes, this was probably due to there being four double-breeding pairs included in those who bred in nest boxes in area A. Area B also had high mean numbers of chicks fledged per pair. This area only had two double-breeding pairs and therefore their influence on the mean number of chicks to fledge from any nest site habitat is limited. It is probable that the high mean rate of chicks fledged per pair in area B is due to the substrate in Area B being sand, which has better drainage, than nests with soil as the substrate as in areas A and C. Area B is generally not exposed to sea extremes, which affects a proportion of nests in Area C.

6. CONCLUSION

From the percentages of eggs hatched and chicks fledged, blue penguins at Taiaroa Head appeared to have a good breeding season. No predation occurred, which may have influenced the high fledging success. This first season's study has given an understanding of the breeding structure of blue penguins at Taiaroa Head and has provided insight towards more adequate monitoring in subsequent seasons.

7. ACKNOWLEDGEMENTS

Dean Nelson and Chris Lalas gave of their time in the field and along with Brian Patrick and Steve Broni reviewed early drafts of this report. Thanks is also extended to Greg Hawker for graphic design and to Joy Taite for final formatting. Christopher Robertson gave guidance, helpful support and critically reviewed the final manuscript.

8. REFERENCES

Dann, P. (in press). The breeding, distribution and abundance of Blue penguins in Otago. *Notornis.*

Dann, P. and Cullen, J.M. 1990. Survival patterns of reproduction and life time reproductive output of little penguins *Eudyptula minor* on Philip Island, Victoria, Australia. Pp. 63-84 In Davis L.S. and Darby J.T. (Eds), *Biology of Penguins.* Academic Press, San Diego.

Department of Conservation, 1992. Taiaroa Head Reserves Resource Inventory. *Otago Conservancy Miscellaneous Report series Number 1.* Dunedin.

Gales, R. 1988. Sexing Adult Blue Penguins by External Measurements. *Notornis* 35: 71-75.

Kinsky, F.C. and Falla, R.A. 1976. A subspecific Revision of the Australasian blue penguin *Eudyptula minor* in the New Zealand Area. *Records of National Museum of New Zealand 1:* 105-126.

Marchant, S.T. and Higgins P.J. (Coordinators), 1990. Handbook of Australian, New Zealand and Antarctic Birds, Volume 1. Oxford University Press, Melbourne.

McKinlay, B. 1993. Blue Penguin work: Otago. Unpublished Report to the Regional Conservator, Department of Conservation, Dunedin File BIR 19, 5p.

Turbott, E.G. (Convenor), 1990. Checklist of the Birds of New Zealand and the Ross Dependency, Antarctica. Third Edition. Random Century. Auckland.

Richdale, L.E. 1940. Random notes on the genus *Eudyptula* on the Otago Peninsula, New Zealand. *Emu* 40: 180-217.