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THE DISTRIBUTION, ABUNDANCE AND STATUS OF ADÉLIE PENGUINS *PYGOSCELIS ADELIAE* AT THE WINDMILL ISLANDS, WILKES LAND, ANTARCTICA

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SUMMARY

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The total breeding population of Adélie Penguins *Pygoscelis adeliae* at the Windmill Islands region in 1989/90 was $93\,092 \pm 9\,300$ pairs at 14 breeding localities. The population has apparently increased by 209% since a survey in the early 1960s, a trend that is shared with many other breeding localities where long-term data are available. Relict colony areas (former breeding sites) were identified at all but two localities currently supporting breeding colonies. The population on Shirley Island, near Casey Station, increased between 1961/62 and 1968/69, but has remained stable since 1968/69, coincident with the opening of Casey Station. The lack of growth in the breeding population is likely to be a result of disturbance by visitors to the island.

INTRODUCTION

The Windmill Islands (66 20S, 110 30E) lie off Wilkes Land in East Antarctica (Fig. 1). Within this region there are three protected areas under the Antarctic Treaty System. These are Ardery and Odbert Islands Specially Protected Area (SPA 3), and two Sites of Special Scientific Interest (SSSI 16 and 17), on Bailey and Clark Peninsulas, respectively. SPAs are recognized as areas of outstanding scientific interest within the Antarctic ecosystem; SSSIs are areas established to undertake or protect scientific investigations.

Human presence in the region began with the establishment of Wilkes Station in 1957/58 on the Clark Peninsula. This was operated by American and Australian personnel until 1968 when Casey Station was opened on Bailey Peninsula.

Early ornithological surveys were undertaken in 1957/58 (Eklund 1961) and 1961/62 (Orton 1963), both of which included descriptions of the breeding distribution and abundance of the Adélie Penguin *Pygoscelis adeliae* population in the region. Several of the breeding localities indicated by Orton (1963) have been resurveyed at irregular intervals (Horne

1983) and one has been the focus of more detailed studies (Penney 1968, Martin *et al.* 1990, E.J.W. & H.R.B. unpubl. data).

However, reviews and compilations have relied on these incomplete surveys collected over several years (Wilson 1983, Murray & Luders 1990, Woehler in press). Here we report the results of a survey of all Adélie Penguin breeding localities undertaken in a single season, and assess the status (distribution and abundance), and long-term population trend for the Windmill Islands region.

METHODS

For this survey, a breeding locality was defined as a geographical feature, either an offshore island or a mainland site, where breeding birds were found in breeding colonies which were identifiable and discrete assemblages of penguins. For example, Shirley Island was a breeding locality with 54 breeding colonies present in 1989/90.

The two mainland breeding localities (Whitney Point and Blakeney Point), were surveyed on 22 and 24 November 1989, respectively. Beall Island was visited on 5 December 1989 before the sea-ice broke out. The 11 other localities were visited using inflatable rubber boats between 7 December 1989 and 9 January 1990. The count of O'Connor Island was made from oblique photographs taken from a peak overlooking the colonies on 1 January 1990.

Counts included all birds present at each colony. During the incubation phase from mid-November to mid-December (Penney 1968), this figure included incubating males and a small percentage of nonbreeding birds that were present in the colonies at the time. However, later in the season, as egg hatching approached, and then when chicks were present in the colonies, the numbers of nonbreeders, prebreeders and failed breeders increased. In addition, both parents were present for varying times at the nest site to feed the chicks and exchange guard duties.

To correct for this difference between nests at the

onset of incubation, (a measure of initial breeding population size), nest loss and total attendance at the colonies (Penney 1968), the 30 colonies present at Whitney Point were monitored throughout the season from late October 1989 to mid January 1990 (E.J.W. & H.R.B. unpubl. data). These colonies provided the necessary calibration data for converting the attendance data on any given census day to initial breeding effort.

The accuracy of the counts is based on codings initiated by Croxall & Kirkwood (1979) that describe the type of count and its accuracy. Counts of nests are designated N, counts of adults A and chicks C. The number following the letter then nominates the accuracy of the count: 1 ($\pm 5\%$), 2 ($\pm 5-10\%$), 3 ($\pm 10-15\%$) and 4 ($\pm 25-50\%$).

The counts presented here are of initial breeding pairs (nests at the onset of incubation), and all were within $\pm 5-10\%$. A majority of the counts was made by one person, thus minimizing the variation attributable to individual counters. We conservatively report our data as $\pm 10\%$ (i.e. N2) for all but one locality (Whitney Point: reported as $\pm 5\%$ or less (N1), E.J.W. & H.R.B. unpubl. data).

The locations of relict colony areas, old sites of previous colonies, (Penney 1968), were also identified and recorded (E.J.W. unpubl. data). Oblique aerial photographs, taken in late January 1972, were made available for this study. In most cases, these photographs were useful only for counting colonies, not individual birds (chicks).

RESULTS

The total breeding population for the Windmill Islands region in 1989/90 was $93\,092 \pm 9\,300$ pairs. This population was distributed over 14 breeding localities in 513 colonies (Table 1 & Fig. 1). The results for each breeding locality are summarized below, including an assessment of the population trend. The increases between 1961/62 and 1989/90 in the breeding populations at each of the 14 breeding localities are presented in Table 2 and Fig. 2.

TABLE 1

PREVIOUS (1955/56 TO 1984/85), AND 1989/90 SEASON CENSUS DATA FROM ADÉLIE PENGUIN BREEDING LOCALITIES IN THE WINDMILL ISLANDS REGION, WILKES LAND, EAST ANTARCTICA, EXPRESSED AS PAIRS. PREVIOUS CENSUS DATA FROM HORNE (1983) OR AS INDICATED. ANARE INDICATES UNPUBLISHED ANARE DATA. NEW ENTRIES AND REVISIONS, INCLUDING THOSE FROM THIS STUDY, ARE LISTED IN BOLD. THE ENTRIES FROM THE 1989/90 SEASON INDICATE THE DATE ON WHICH PARTICULAR LOCALITIES WERE SURVEYED BUT PROVIDE THE ESTIMATE FOR THE TOTAL NUMBER OF NESTS FOR THAT LOCALITY AT THE ONSET OF INCUBATION (SEE METHODS)

Date	Count	No. of Colonies	Source
Nelly Island 66 12S, 110 11E			
23 Jan 1956	250 (A4)		
1961	100 (N3)	1	Orton (1963)
Jan 1972		2	M.D. Murray (unpubl. photographs)
1 Feb 1974	250 (A3)		
14 Feb 1980	68 (A2)		
24 Dec 1989	554 (N2)	3	This study
Chappel Island 66 11S, 110 26E			
1961	1 200 (N3)		Orton (1963)
1972	8 000 (N3)		
Jan 1972		48	M.D. Murray (unpubl. photographs)
14 Feb 1980	2 618 (A2)		
25 Dec 1989	5 780 (N2)	44	This study
Berkley Island 66 13S, 110 39E			
1961	500 (N3)		Orton (1963)
14 Nov 1974	3 000 (N3)	58	ANARE
14 Feb 1980	2 388 (A3)		
19 Dec 1989	5 141 (N2)	59	This study
Cameron Island 66 13S, 110 37E			
1961	350 (N3)		Orton (1963)
Jan 1972		14	M.D. Murray (unpubl. photographs)
14 Nov 1974	600 (N3)	11	ANARE
14 Dec 1980	540 (A3)		
19 Dec 1989	1 347 (N2)	13	This study
Blakeney Point 66 14S, 110 35E (SSSI 17)			
1961	3 500 (N3)		Orton (1963)
Jan 1972		>20	M.D. Murray (unpubl. photographs)
Dec 1972	2 000 (N4)		D.J. Luders (unpubl. map)
14 Nov 1974	1 000 (N3)		ANARE

3 Dec 1974	1 100 (N3)		ANARE
1980	2 967 (A3)		
3 Dec 1989	5 604 (N2)	29	This study
Whitney Point 66 15S, 110 32E (SSSI 17)			
1959	1 122 (N1)	14	Martin <i>et al.</i> (1990)
1960	1 323 (N1)	14	Martin <i>et al.</i> (1990)
1961	1 155 (N1)	14	Martin <i>et al.</i> (1990)
1961	1 300 (N3)		Orton (1963)
27 Oct 1961	1 000 (A4)		
27 Nov 1963	1 465 (N1)	13	E.J.W. & H.R.B. (unpubl. data)
25 Nov 1964	1 329 (N1)	13	E.J.W. & H.R.B. (unpubl. data)
19 Dec 1971	2 043 (N1)	16	ANARE
29 Oct 1972	1 175 (A3)		ANARE
3 Dec 1974	1 727 (N2)		ANARE
14 Feb 1980	828 (A4)		
15 Dec 1983	4 199 (N2)	28	Martin <i>et al.</i> (1990)
30 Nov 1984	4 181 (N2)	28	E.J.W. & H.R.B. (unpubl. data)
2 Dec 1989	3 803 (N1)	30	This study; E.J.W. & H.R.B. (unpubl. data)
Shirley Island 66 17S, 110 30E			
1961	3 000 (N3)		Orton (1963)
1 Dec 1968	7 344 (N1)	45	ANARE
7 Dec 1971	7 580 (N1)	45	ANARE
26 Jan 1972	9 687 (C1)		
10 Nov 1972	8 534 (N1)	45	ANARE
Dec 1972	8 410 (N3)		D.J. Luders (unpubl. map)
27 Jan 1973	4 366 (C1)		
10 Nov 1973	8 012 (N1)		
18 Nov 1974	7 303 (N1)		
26-28 Nov 1976	7 362 (A1)		
1 Dec 1977	7 049 (N1)	45	ANARE
4 Jan 1985	8 286 (N2)	49	ANARE
7 Dec 1989	7 637 (N2)	52	This study
Beall Island 66 18S, 110 29E			
1961	2 800 (N2)		
1 Dec 1968	4 349 (N1)	24	ANARE
12 Dec 1971	4 713 (N3)	24	ANARE
1972	4 000 (N3)	33	
Dec 1972	5 000 (N4)		D.J. Luders (unpubl. map)
31 Dec 1972	6 510 (N3)		
5 Dec 1989	5 224 (N2)	28	This study
Hollin Island 66 19S, 110 24E			
1961	300 (N3)		Orton (1963)
17 Dec 1972	2 500 (N4)		

23 Jan 1980	1 289 (A2)		
24 Dec 1989	2 801 (N2)	18	This study
Midgley Island 66 20S, 110 24E			
1961	4 200 (N3)		Orton (1963)
2 Dec 1961	4 500 (N4)		
17 Dec 1972	7 500 (N4)		
23 Jan 1980	2 022 (A3)		
26 Dec 1989	7 436 (N2)	37	This study
Odbert Island 66 22S, 110 33E (SPA 3)			
1961	3 500 (N3)		Orton (1963)
1972	1 000+ (N4)		
6 Dec 1972	20 000 (N4)		
Dec 1972	15 000 (N4)		D.J. Luders (unpubl. map)
7+9 Jan 1990	10 689 (N2)	58	This study
Holl Island 66 25S, 110 25E			
1961	3 000 (N3)		Orton (1963)
1972	11 000 (N3)		
1 Jan 1990	11 875 (N2)	56	This study
O'Connor Island 66 25S, 110 28E			
1961	2 000 (N3)		Orton (1963)
1972	5 000 (N3)		
Jan 1972	2 300 (C3)	8	M.D. Murray (unpubl. photographs)
1 Jan 1990	4 748 (N2)	5	This study
Peterson Island 66 28S, 110 32E			
1961	4 500 (N3)		
1972	5 000 (N3)		
6 Dec 1972	10-15 000 (N4)		ANARE
1 Feb 1974	8-10 000 (A3)		
13 Feb 1980 1980	5 946 (A3)		
7+9 Jan 1990	20 453 (N2)	83	This study

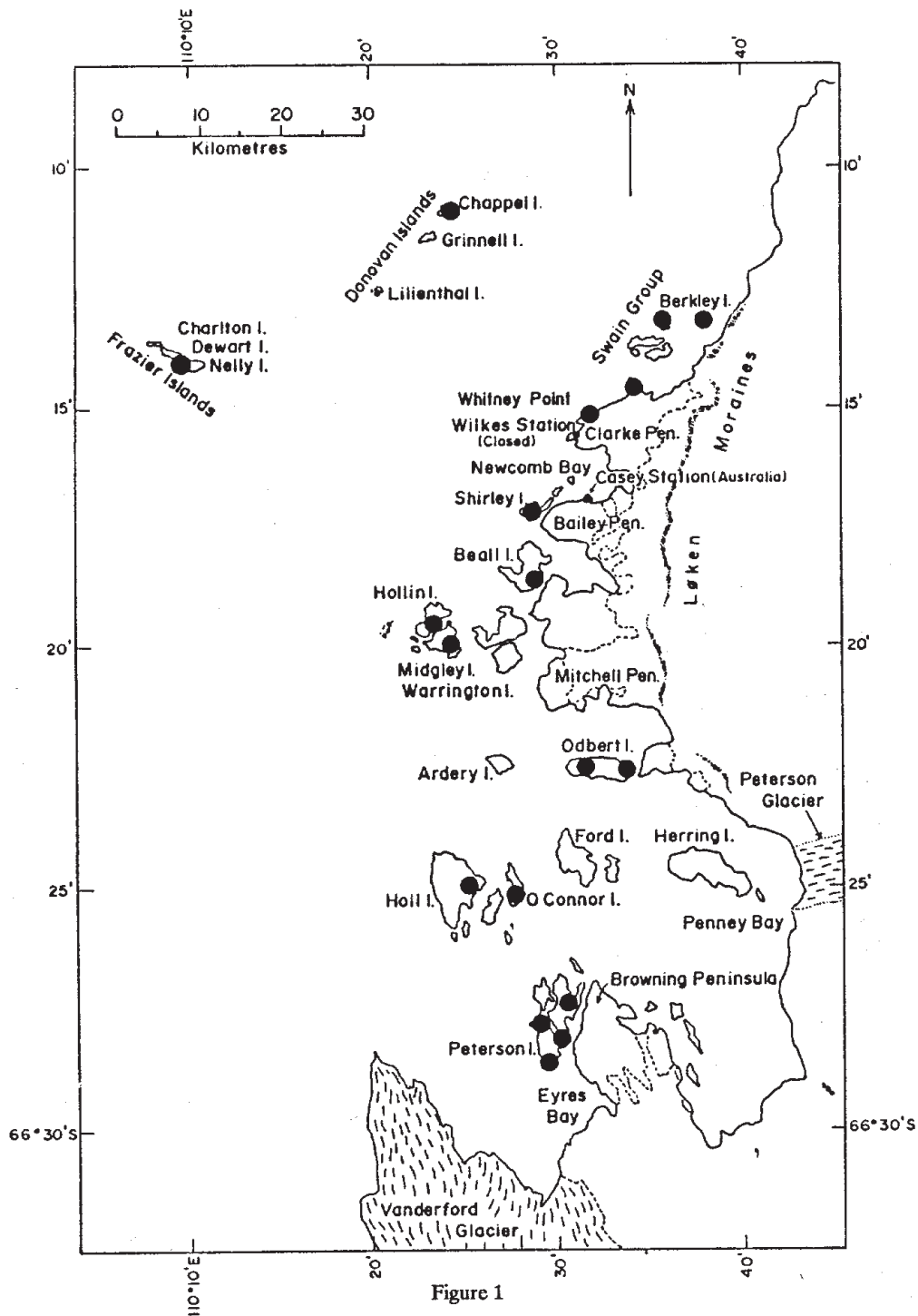


Figure 1

The Windmill Islands region, Wilkes Land, East Antarctica, showing the distribution of Adélie Penguin breeding localities (from Murray & Luders 1990).

TABLE 2

PERCENTAGE INCREASES (BETWEEN 1961 AND 1989) IN THE BREEDING POPULATIONS OF ADÉLIE PENGUINS AT 14 BREEDING LOCALITIES AT THE WINDMILL ISLANDS, WILKES LAND, EAST ANTARCTICA. THE PERCENTAGE INCREASE IS ALSO EXPRESSED AS A MEAN ANNUAL PERCENTAGE INCREASE

Breeding locality	Percentage increase	Mean annual percentage increase
Nelly Island	454	6.1
Chappel Island	382	5.6
Berkley Island	928	8.3
Cameron Island	285	4.8
Blakeney Point	60	1.7
Whitney Point	229	4.3
Shirley Island	155	3.3
Beall Island	87	2.2
Hollin Island	833	8.0
Midgley Island	77	2.0
Odbert Island	205	4.0
Holl Island	296	4.9
O'Connor Island	137	3.1
Peterson Island	355	5.4
Windmill Islands	209	4.0

Nelly Island

Orton (1963) reported 100 nests in one colony on Nelly Island in 1961/62. In 1989/90 there were three colonies high on the northwest ridge of the island, with a combined total of 554 ± 50 nests. Photographs taken in January 1972 show chicks in two colonies. These data indicate an increase in the breeding population between 1959/60 and 1989/90 of approximately 454%. Two relict colony areas were identified during the visit. One was located adjacent to an extant colony and the other was located high on the southwest ridge of the

island.

Chappel Island

Orton (1963) reported $1\ 200 \pm 180$ nests present in 1961/62, and the 1972 photographs show crèches in 48 colonies. In 1989/90, $5\ 780 \pm 580$ nests were recorded in 44 colonies high on the north, east, south and southwest slopes of the island. The total population increased between 1961/62 and 1989/90 by approximately 382%, but a decrease may have occurred between 1972/73 and 1989/90. One relict colony area was located during the 1989/90 visit.

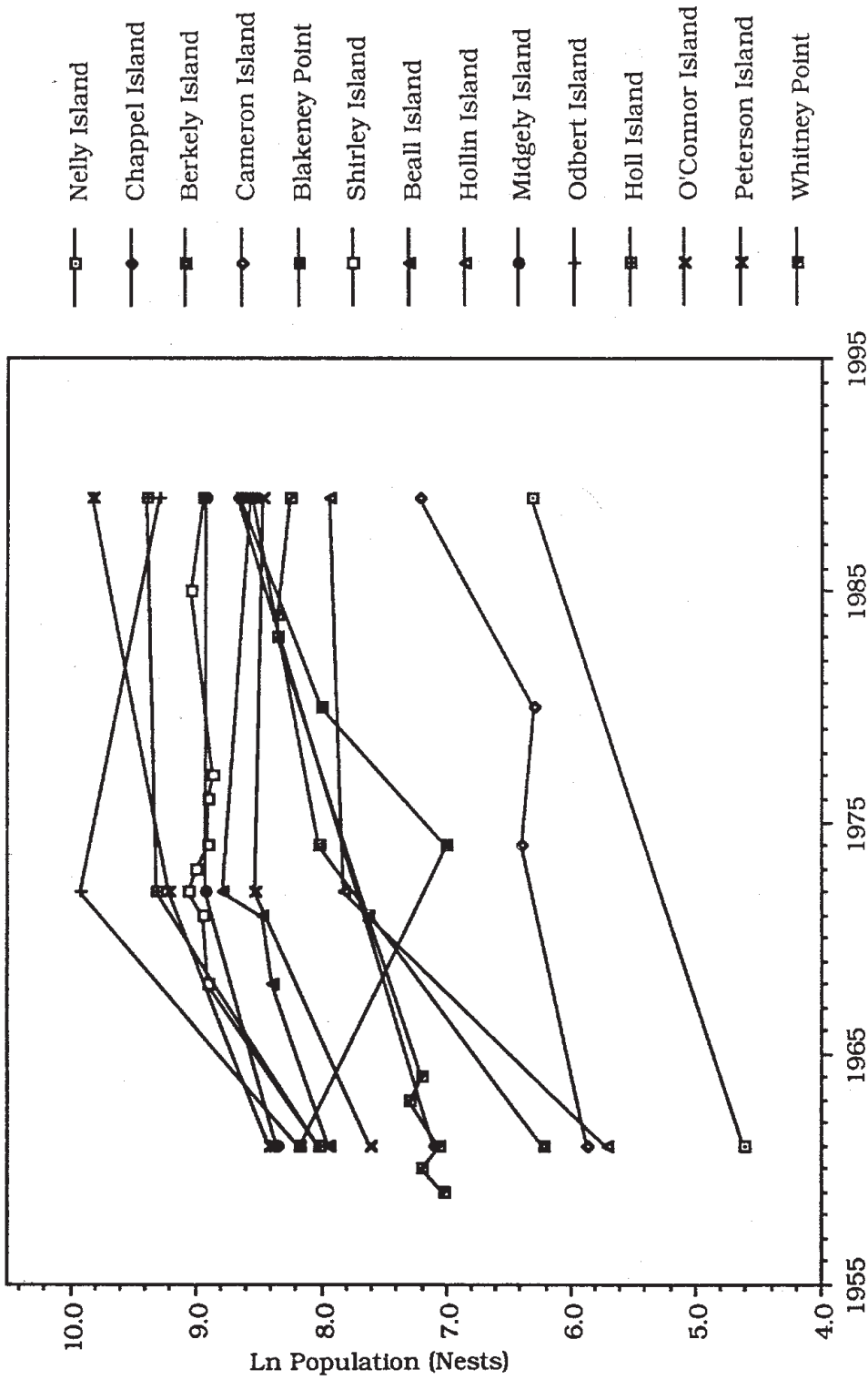


Figure 2

Population changes at the 14 Adélie Penguin breeding localities in the Windmill Islands, 1959/60 to 1989/90.

Berkley Island

Only 500 nests were recorded in 1961/62 (Orton 1963). The 1960 count was made very late in the season and is of little value in assessing population trends. In 1989/90 there were $5\,141 \pm 515$ nests in 59 colonies scattered over most of the island. The most rapid increase in the breeding population occurred between 1961/62 and 1974/75, when the increase was 500% or a mean of 13.8% per annum. Between 1974/75 and 1989/90, the population increased by 71%, and over the period 1961/62 to 1989/90, the increase was 928%, the largest increase in any breeding population in the Windmill Islands region between 1961/62 and 1989/90 (Table 2). No relict colony areas were located during the visit.

Cameron Island

The population on Cameron Island increased from 350 nests in 1961/62 (Orton 1963) to $1\,347 \pm 135$ nests in 13 colonies in 1989/90. There were three colonies present at the western end, and eight along the northern ridge and slopes of the island. The number of breeding colonies in January 1972 was 14; one area identified as relict in 1989/90 was occupied in 1971/72. The most rapid increase in the population occurred between 1980 and 1989/90 (149%). One further area of relict colony surrounding a current colony was located during the visit.

Blakeney Point (SSSI 17)

Orton (1963) reported 3 500 nests at Blakeney Point in 1961/62. Photographs of Blakeney Point taken in January 1972 show 20 colonies, although the coverage was incomplete. The two counts in 1974 are inconsistent with each other, and therefore those data must be considered to be of minimal value. The 1980 count indicated that a decrease in the population may have taken place between 1961/62 and 1980. A total of $5\,604 \pm 550$ nests in 29 colonies was recorded in 1989/90, the lowest rate of increase recorded for the 1961/62 to 1989/90

period for the region (Table 2). These data suggest the population has increased, at least since 1980.

Penney (1968) figured a colony at Blakeney Point in 1959/60. The photo-point for the photograph was relocated during the 1989/90 survey, and a photograph was taken (Figs. 3 & 4). The colony photographed in 1959/60 was no longer present at its former site, and a colony (the same?) was situated immediately adjacent to the site of the colony in 1959/60.

Relict colony areas were present surrounding many of the colonies in 1989/90, in addition to areas totally devoid of breeding birds. Samples of substratum collected for Carbon-14 dating have indicated an age of approximately 5 000Y bp. (I. Goodwin pers. comm.).

Whitney Point (SSSI 17)

Whitney Point has been the site of the population studies undertaken on Adélie Penguins in the Windmill Islands region (E.J.W. & H.R.B. unpubl. data). The breeding populations in 1959/60 to 1960/61 were described in detail by Penney (1968) and additional population counts obtained in 1972/73 and 1983/84 were reported by Martin *et al.* (1990).

An intensive monitoring programme was undertaken during the 1989/90 season and further census data from the 1960s and 1980s were compiled (E.J.W. & H.R.B. unpubl. data). In 1989/90, there were 3 803 nests present in 30 colonies. E.J.W. & H.R.B. (unpubl. data) concluded that the population at Whitney Point increased between 1959/60 and 1989/90, but between 1983/84 and 1989/90 ($4\,000 \pm 200$), exhibited annual fluctuations in the size of the breeding population. The population increased by approximately 229% between 1961/62 and 1989/90.

A total of 20 relict colony areas was shown to be present at Whitney Point by Penney (1968), and one additional area was identified during this

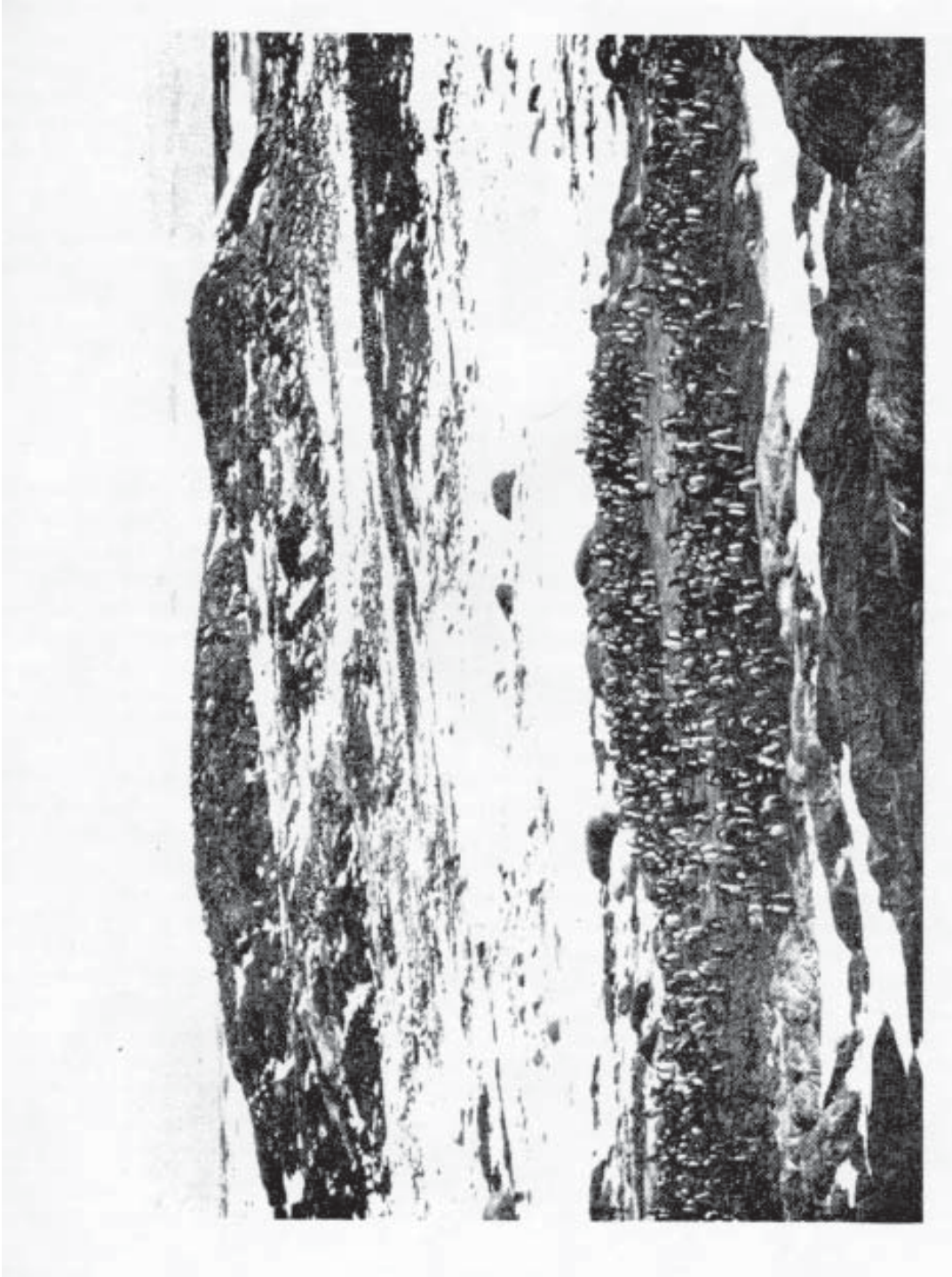


Figure 3

Photograph of a colony at Blakeney Point in 1969/60, taken from Penney (1968).

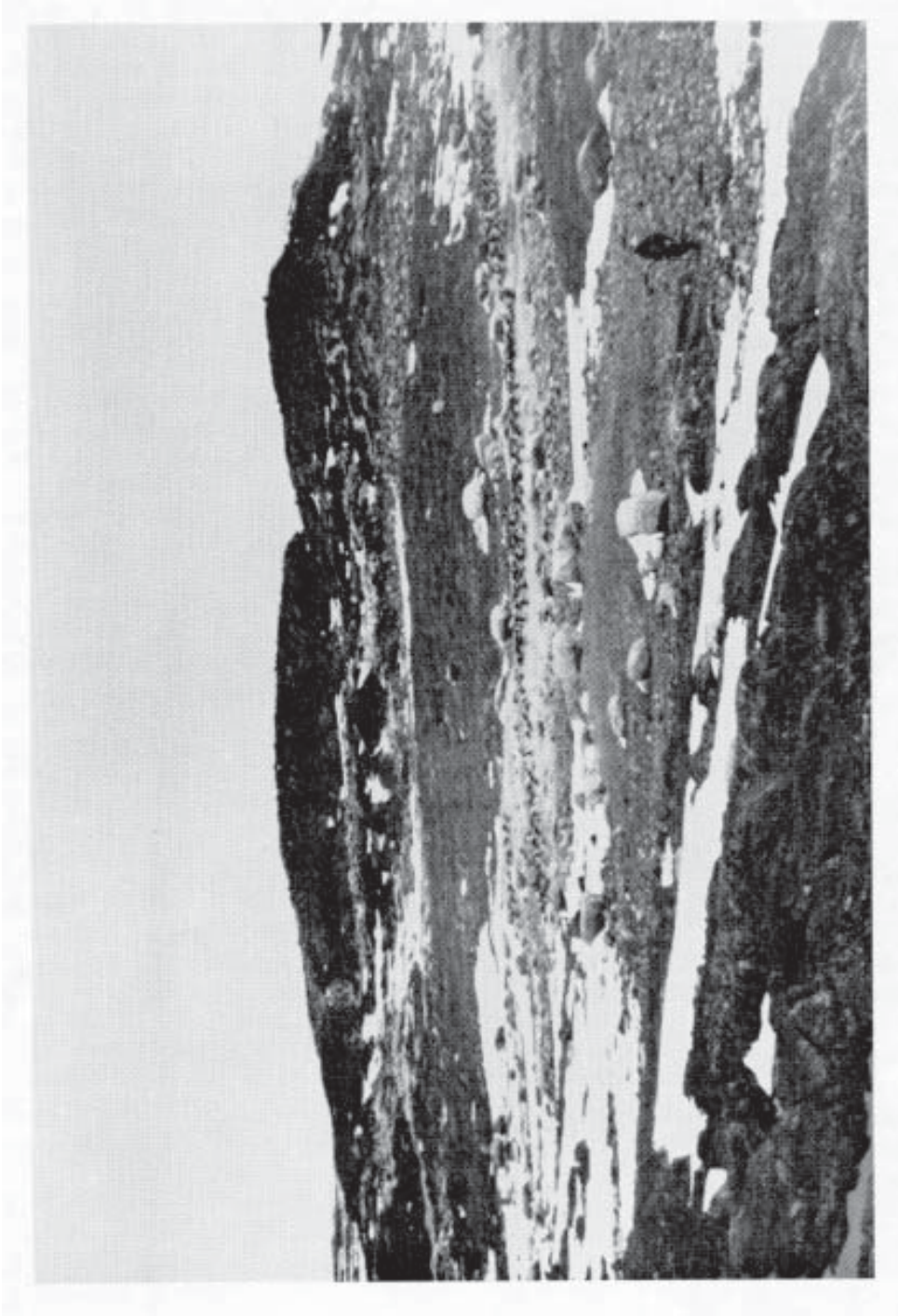


Figure 4

Photograph of a colony at Blakeney Point in 1989/90.

survey.

Shirley Island

A series of annual counts during the 1970s followed the initial estimate of 3 000 nests in 1961/62 (Orton 1963), and a detailed census in December 1968 identified 7 344 nests in 45 colonies. The colonies present on Shirley Island had been marked by painting a colony number on a nearby rock surface (unpubl. ANARE data). By 1974/75 Colonies 42 and 43 were no longer recognizable as individual colonies, and a new colony, 31A, had formed. A count in 1984/85 recognized a total of 49 colonies on Shirley Island, which increased to a total of 52 colonies with 7 637 nests in 1989/90. The population on Shirley Island increased between 1961/62 and 1968/69, but has remained stable since then ($7\,800 \pm 750$, or $\pm 9.6\%$ for census data 1968/69 to 1989/90), and the census data are of sufficient frequency to detect annual fluctuations in the size of the breeding population. The census data for the 45 colonies originally marked on Shirley Island in 1968, between 1968/69 and 1989/90 are shown in Fig. 5. Relict colony areas were identified at the western end of Shirley Island in 1989/90, and Colony 14 was no longer extant.

Beall Island

As with Chappel Island, the population on Beall Island may have decreased following an increase between 1961/62 and 1972/73. A survey in December 1971 reported $4\,713 \pm 470$ nests in 24 colonies, and in 1989/90, the survey located $5\,224 \pm 520$ nests in 28 colonies on the southeast slopes of the island. Over the period 1961/62 to 1989/90, the population increased by 87%, one of the lowest rates of increase for the region (Table 2). Several areas of relict colony were located during this survey. One was down-slope of an extant colony, and the others were approximately 0.5 km from the nearest colony.

Hollin Island

The population on Hollin Island increased by 733% from 300 nests in 1961/62 (Orton 1963) to $2\,500 \pm 940$ nests in 1972/73, and may only have increased slightly, if at all, between 1972/73 and 1989/90, because the difference between the 1972/73 and 1989/90 data is 12%, barely greater than the error inherent to ground counts. A total of 18 colonies with $2\,801 \pm 250$ nests was counted in the central region of the island during the 1989/90 survey and there were two large areas of relict colony present on the northwest ridges.

Midgley Island

The population on Midgley Island was between 4 200 and 4 500 nests in 1961/62 (Orton 1963, Horne 1983). A survey in 1972/73 reported $7\,500 \pm 2\,800$ nests and in 1989/90 there were $7\,436 \pm 750$ nests in 37 colonies. The colonies were located high on the central summit area and the southeastern ridges. At least five relict colony areas were located during the 1989/90 visit. The population increased between 1961/62 and 1972/73 by 79%, and differed by less than 1% between the 1972/73 and 1989/90 counts, indicating an unchanged population.

Odbert Island (SPA 3)

There are only two previous counts of the population on Odbert Island. Orton (1963) reported 3 500 nests in 1961/62. An unpublished map (compiled by D.J. Luders) recorded 15 000 nests in December 1972 that was reported as $20\,000 \pm 7\,500$ by Horne (1983).

Orton (1963) reported the number of nests from only one of the two areas presently used on the island. His description read "3 500 nests at the western end, with a smaller rookery to the east". Thus the maximum possible number of nests on Odbert Island in 1961/62 would have been less than 7 000. However, in 1989/90, the western end of the island contained $4\,700 \pm 450$ nests, which was

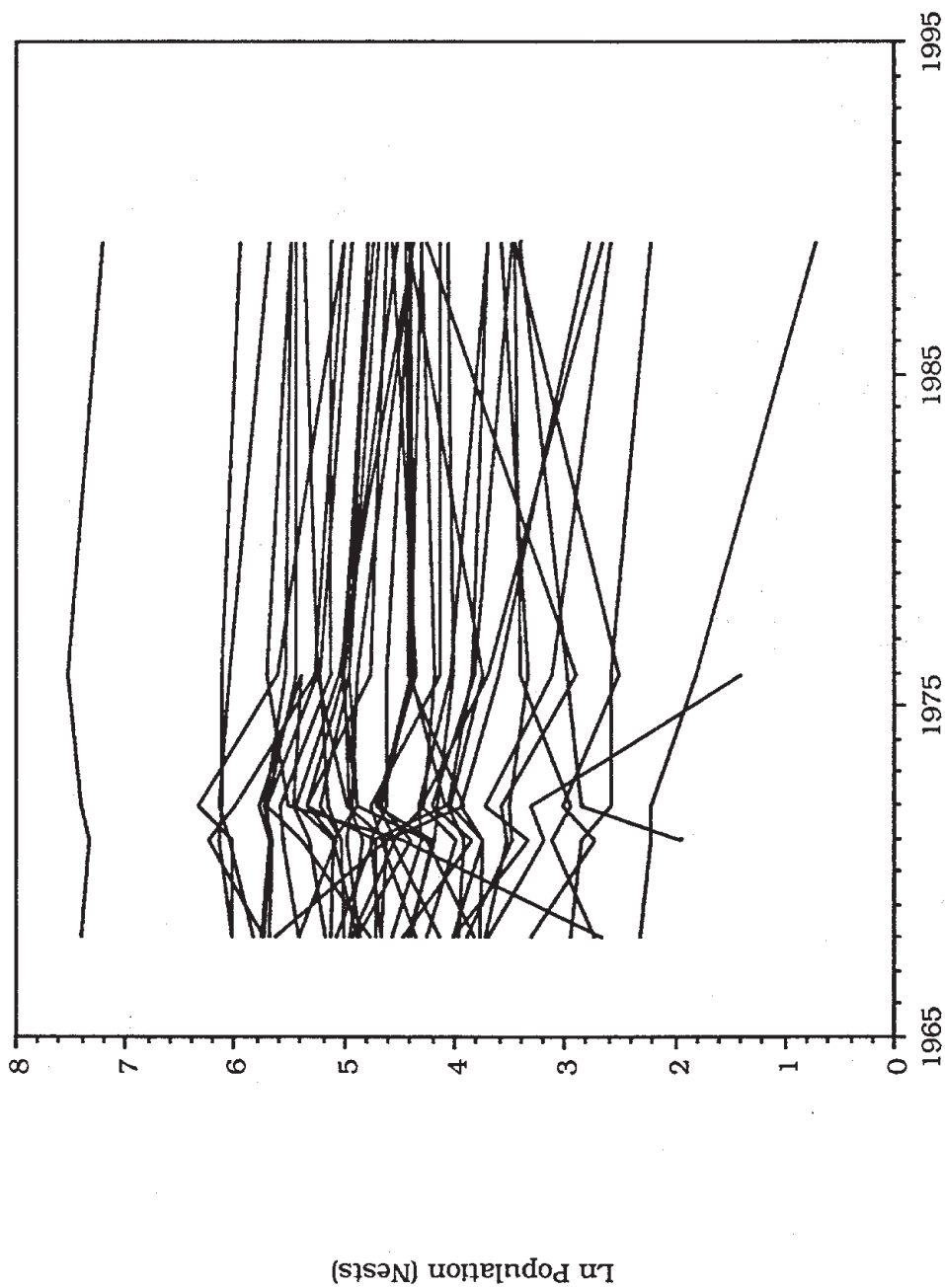


Figure 5

Population changes in the original 45 colonies on Shirley Island, 1968/69 to 1989/90. New colonies identified in 1989/90 are not included.

approximately 80% of the number present at the eastern end, $6\,000 \pm 600$. If these proportions were also present at Odbert Island in 1961/62, then the eastern end could have held up to 4 400 nests at the time. In the absence of quantitative data from the eastern end in 1961/62, the original figure of 3 500 has been used in examining population trends. Based on these data, the population has increased by 205% between 1961/62 and 1989, or at a mean rate of 4% per annum.

The unpublished map by D.J. Luders from December 1972 shows $10\,000 \pm 2\,000$ nests at the western end and $5\,000 \pm 1\,000$ nests at the eastern end of the island. This is the opposite to the situation in 1989/90, and may be attributable to either the proportion of nests at each end of the island varying from year to year, or more likely to counter error.

The 1989/90 survey located $10\,689 \pm 1\,000$ nests in 58 colonies on Odbert Island. A total of 31 colonies was present at the southeast of the island and an additional 27 colonies were located on the central north to northwest slopes and higher ridges. Extensive relict colony areas were present at both ends of the island.

Holl Island

There are only two previous counts of the Adélie Penguin population on Holl Island. Orton (1963) reported 3 000 nests in 1961/62 and an unpublished map (compiled by D.J. Luders) from 1972 indicated $11\,000 \pm 1\,650$ nests in three areas on the island. Penney (1968) did not include Holl Island in his figure of the breeding distribution for the region. The 1989/90 survey counted $11\,875 \pm 1\,000$ nests in 58 colonies at the extreme northwest, central northeast and east of the island. Four relict colony areas were found.

The population increased by 267% between 1961/62 and 1972/73, but the difference between the 1972/73 and 1989/90 counts was only 8%, within the error limits of the count method. The

population has apparently not increased between 1972/73 and 1989/90.

O'Connor Island

Orton (1963) reported 2 000 nests in 1961/62, and oblique aerial photographs taken in January 1972 show approximately 2 300 chicks. The 1989/90 survey located $4\,748 \pm 470$ nests in five colonies. Many of the smaller colonies present in 1972/73 had coalesced into the largest colony (approximately 4 370 nests in 1989/90). Three small colonies present in 1972/73 had all enlarged, and the large colony present in 1972/73 had expanded to the south side of the central area. Based on the 1989/90 count, the population had increased by 137%, or approximately 3.1% per annum.

Peterson Island

The population on Peterson Island is as poorly documented as that of Odbert Island. Only two previous counts, those in 1961 and 1972/73, are of any use for examining population trends. In 1961/62 there were 4 500 nests (Orton 1963), and in 1972/73 the population had increased to a minimum of $10\,000 \pm 2\,000$ nests (unpubl. map, compiled by D.J. Luders). In 1989/90 the population was $20\,453 \pm 2\,050$ nests in 83 colonies in the northeast, central and southwest of the island. The population increased by 133% between 1961/62 and 1972/73, and by 105% between 1972/73 and 1989/90. Only small areas of relict colony were located in 1989/90, adjacent to extant colonies (D.J.S. & E.J.W. pers. obs.).

DISCUSSION

Population trends

The breeding population of Adélie Penguins in the Windmill Islands increased substantially between the 1961/62 and 1989/90 surveys. The documented increase of 209%, with individual breeding localities increasing between 60% and 928%, represents a

significant increase in the biomass of Adélie Penguins in the region. Given an average mass of 4.4 kg (Croxxall 1984), the population of $93\,092 \pm 9\,300$ breeding pairs is equivalent to almost 820 tonnes in biomass, and represents approximately 3.6% of the total world breeding population and biomass of Adélie Penguins (2.61 million pairs and 23 000 tonnes respectively, Woehler in press).

Counts made in early to mid November, at a time preceding or coinciding with the peak in the number of adults ashore (Penney 1968), could be expected to be unreliable indicators of the size of the breeding population because colonies are known to reach their peak numbers at different times and rates, and the relationship between peak numbers and nesting pairs is variable and colony specific (E.J.W. & H.R.B. unpubl. data). The counts of adults in January or February in previous years cannot be used for estimates of the population since there is a large and rapid departure of postbreeding adults from the colonies at that time and an influx of birds returning to moult (Penney 1968).

The patterns of increase at the various breeding localities varied. The rate of increase in the breeding population at Whitney Point, the best documented of the 14 breeding localities in the region, was considered linear between 1959/60 and 1983/84 (Martin *et al.* 1990). At the other breeding localities, the rates of increases between 1961/62 and 1972/73 were generally greater than those between 1972/73 and 1989/90, although some exceptions were noted. For example, the breeding population at Blakeney Point decreased between 1961/62 and 1974/75, and then increased between 1974/75 and 1989/90. The population on Chappel Island may also have decreased between 1972/73 and 1989/90, but the data are insufficient to make a more detailed assessment. The data for the other breeding localities are also insufficient (with the exception of Shirley Island, see below), to describe short-term trends in detail. Why one locality has increased more rapidly than others (Table 2) is not

clear, but has been shown for other breeding localities (Dumont d'Urville, Thomas 1986; Mawson, Woehler *et al.* 1989). Clearly, nesting habitat is not a limiting factor, because relict colony areas were identified at all but two of the current breeding localities, and relict areas are present at other islands not visited during this survey (E.J.W. pers. obs.). In such a small geographic area, the supply of food is unlikely to affect differentially the various breeding localities.

Examining breeding population data collected over 11 years, Trivelpiece *et al.* (1990) caution the use of short-term data as a basis for extrapolating long-term trends. Citing three baseline-spot census data pairs, the same breeding population of Adélie Penguins was stable, increased by 2.4% and decreased by 3.1% per annum over an 11-year period. Changes of such magnitude are significant for long-lived species, and Trivelpiece *et al.* (1990) highlight the value of regular monitoring over longer time periods in order to assess true population status and trends. Annual fluctuations in the sizes of breeding populations, varying between 1% (Whitehead *et al.* 1990) and 21% (Trivelpiece *et al.* 1990) for consecutive seasons have been attributed to environmental variables.

The data reported here overcome these limitations, despite the limited number of intervening counts, by the 30-year time scale involved in the data collection. Accurate counts of Adélie Penguin breeding localities dating back to the 1950s or 1960s covering such an extent of coastline and islands are few, and particularly valuable in that they provide an earlier baseline to measure population change(s) and trends than monitoring programmes more recently initiated (Woehler in press).

Human impact on Adélie Penguins breeding on Shirley Island

The Adélie Penguin breeding population on Shirley Island was counted regularly between 1968/69 and 1977/78 (Table 1; Horne 1983, unpubl. ANARE biology logs). These counts coincided with the

onset of incubation, and began with the opening of nearby Casey Station.

These Shirley Island counts have provided evidence that station visitors and counts affect populations of Adélie Penguins. Whereas the breeding population at every other breeding locality in the Windmill Islands region increased between 1961/62 and 1989/90, the population on Shirley Island increased between 1961/62 and 1968/69, and has remained stable since then. All counts between 1968/69 and the present survey have reported the total number of nests to be $7\,800 \pm 750$, ($\pm 9.6\%$), within the error margin for ground counts ($\pm 10\%$).

Impacts of scientific programmes inducing a decrease in breeding populations of Adélie Penguins, including banding and counting, have previously been documented for colonies in the Ross Sea area (Thompson 1977, Ainley *et al.* 1983, Wilson *et al.* 1990). The close approach of people (30 m) was sufficient to induce an increased heart beat in incubating Adélie Penguins (Culik *et al.* 1990). It appears that the frequency of visitation to Shirley Island was insufficient to induce a decrease in the breeding population, perhaps due to the fact that the island is not visited after early January each year following the break out of sea-ice, but was, (and probably still is), of sufficient intensity to suppress the increase demonstrated elsewhere in the region.

Shirley Island is the nearest destination for viewing breeding Adélie Penguins by station personnel and visitors to Casey. The walk to Shirley Island takes approximately 15 minutes from the old station, and only five minutes from the new station. Visitors use the island for obtaining photographs of the penguins, views of the grounded icebergs in Vincennes Bay, and as a change from station routine and duties.

An estimate can be made of the level of station visitors to Shirley Island, by recording the number of visitors in each group, and assuming a minimum visit of one hour per group, (this is a conservative

estimate, because many visits were known to last several hours). During the 1989/90 season, when 70 summer personnel were present at Casey, visits to Shirley Island were of 70, 112, 87 and 6 person-hours for the respective months of October, November, December, and until 2 January, when the sea-ice broke out, a minimum total of 275 person-hours, but the actual figure was probably close to between 500 and 600. These visits occurred during the occupation, incubation and chick phases of the Adélie Penguin breeding cycle.

Further evidence for the impact of visitors to the island comes from the census data of the original 45 colonies identified in 1968/69 (R.A. Mackenzie, unpubl. station logs). Of the 25 eastern colonies on Shirley Island, nine have decreased by more than 50% between 1968/69 and 1989/90, including one that is no longer extant, compared with a decrease in only three western colonies in the same time period. Six new colonies have formed at the western end of the island, comprising over 1 400 nests in 1989/90, whereas only one new eastern colony has formed (three nests in 1989/90), after the 1968/69 survey.

Both the old and new stations are close to the eastern end of Shirley Island, where visitors first arrive. Also, the sea-ice at the eastern end of the island is the last to break out, further concentrating the entry of visitors. The three colonies at the western end that showed a decrease were close to the route used by visitors to gain access to the highest point on the island. In effect, the size of the breeding population of Adélie Penguins on Shirley Island has not changed, but the breeding effort has 'shifted' to the western end, away from the station and station visitors, while the breeding population has increased at every other breeding locality in the region.

We argue that this level of visitation (both the survey visits from 1968/69 to 1977/78), and the recreational visits since then, is responsible for the Shirley Island population remaining stable, rather than increasing as did other breeding localities in

the region. Cowan (1979) described decreases in some colonies and the occupation of new colonies on Shirley Island between 1961/62 and 1977/78. An alternative argument, that Shirley Island has reached its maximum carrying capacity for nesting Adélie Penguins, seems unlikely because there are extensive areas of relict colony present on the island.

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