VARIATION IN MAGELLANIC PENGUIN *SPHENISCUS MAGELLANICUS* DIET IN THE FALKLAND ISLANDS

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SUMMARY

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Magellanic Penguins *Spheniscus magellanicus* breed at over 90 locations in the Falkland Islands. The breeding season diet includes small fish (principally nototheniids, immature Southern Blue Whiting *Micromesistius australis* and sprats *Sprattus fuegensis*), the decapod crustacean lobster krill *Munida gregaria*, and small squid (predominantly *Gonatus antarcticus*). However, simultaneous investigation of diets at two colonies 60 km apart indicates considerable variation between sites in the gross composition of the diet. The diet also varies both seasonally and between years at individual sites. The implications of these findings for chick growth, marine ecosystem modelling and conservation are considered.

INTRODUCTION

The past decade has witnessed a proliferation of studies of the diets and foraging ecology of penguins and other seabirds. These studies have enhanced understanding of the functioning of marine ecosystems by enabling estimates to be made for a number of regions of total prey consumption by seabirds (e.g. Croxall & Prince 1987). Such estimates are essential to assessments of the potential influence of commercial fisheries on marine predators. However, seabird dietary studies are often conducted at single sites over relatively short periods and hence may not reflect variation in diets within or between years or between sites. Particularly in the case of opportunistic inshore feeders, a failure to investigate such variations may result in potentially erroneous conclusions at the regional population level.

The Magellanic Penguin *Spheniscus magellanicus* is the most widely distributed of the six species of penguins found breeding in the Falkland Islands (Fig. 1) (R. Woods pers. comm.). Breeding colonies are typically somewhat diffuse with varying densities of nest burrows extending over many kilometres of coastline. Two eggs are laid in late October with chicks hatching *c.* 45 days later in late November and early December. Fledging period is variable, ranging from *c.* 65 to 90 days (N. Harding pers. comm.), with most chicks fledging in early February.

The breeding season diet of the Magellanic Penguin in the Falkland islands has been studied at a number of sites since 1986/87 as part of a research programme investigating the impact of commercial fisheries on Falklands seabirds.

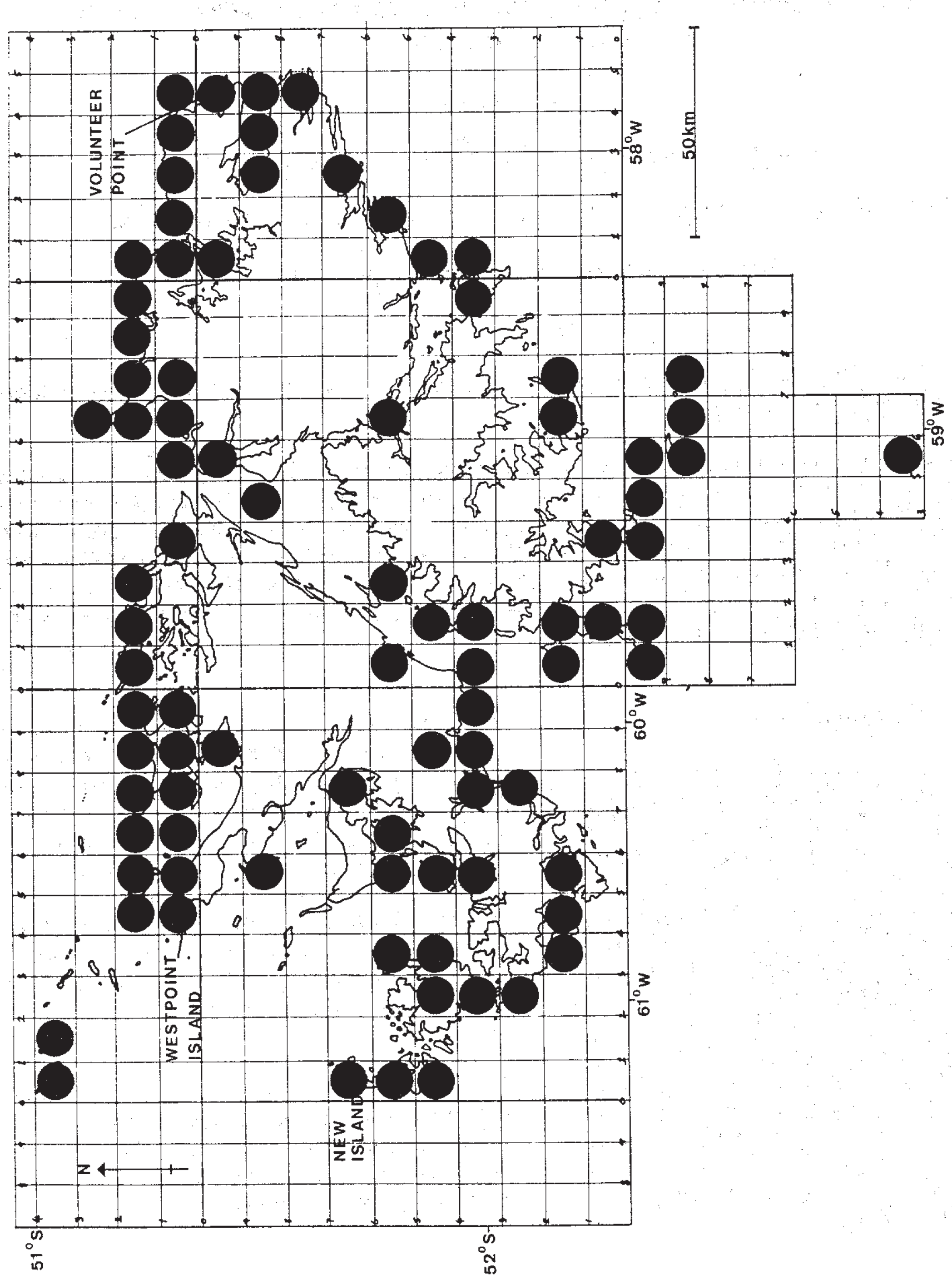

Figure 1

The Falkland Islands, showing study sites and the breeding distribution of the Magellanic Penguin.

METHODS

Diet samples

A total of 108 diet samples was collected at three sites (Fig. 1) between the 1986/87 and 1990/91 breeding seasons (Table 1). The samples from New Island and Westpoint Island in December 1990 were collected specifically to investigate dietary variation between sites. Birds were caught immediately on returning from the sea and a water-flushing technique (Wilson 1984) was used to collect the samples. Birds were flushed several times as necessary until their stomachs were gauged to be empty (Gales 1987). Samples were stored in buffered formalin saline prior to examination.

Samples were drained in a 0.33-mm mesh sieve and blotted to remove excess moisture before being weighed. Samples weighing under 150 g, and larger samples composed entirely of large prey items, were completely sorted with all identifiable prey fragments being extracted. In mixed samples of over 150 g the largest prey items were first extracted and the remainder then randomly subsampled. In calculating the composition of the original sample, it was assumed that the composition of unidentified remainders was the same as in the identified material.

Once separated, the crustacean, fish and cephalopod fractions of the samples were drained, blotted and weighed in the same manner as the original sample in order to assess their relative contributions by wet mass. Numbers of cephalopods were estimated from whole animals, crowns and buccal masses. Loose beaks were assumed to have been present in the stomach prior to ingestion of the most recent meal prior to sampling and were therefore excluded. However, loose beaks were included when investigating the species composition and size classes of squid consumed. Fish numbers were estimated from counts of whole animals, entire skeletons and heads or tails. Numbers of crustaceans were estimated from whole animals plus paired or single eyes, as appropriate.

TABLE 1

DETAILS OF DIET SAMPLES COLLECTED FROM MAGELLANIC PENGUINS AT THE FALKLAND ISLANDS

Site	Date(s)	Breeding status	Number
New Island	16-27 Nov 1986	Incubation	12
New Island	7 Dec 1986 -13 Feb 1987	Chick-rearing	39
Volunteer Pt.	19-26 Dec 1989	Chick-rearing	15
Volunteer Pt.	6-8 Jan 1991	Chick-rearing	12
New Island	13-15 Dec 1990	Chick-rearing	15
Westpoint Is.	13-15 Dec 1990	Chick-rearing	15

Cephalopods were identified by examination of lower beaks (Clarke 1986). Dorsal mantle lengths (DML) and masses were estimated from lower rostral lengths with reference to Clarke 1986 and E. Hatfield (unpubl. data). Beaks of under 1.5 mm were measured to the nearest 0.1 mm using an ocular scale in a binocular microscope, larger beaks were measured with Vernier calipers. Whole fish and skeletons were identified by reference to various keys and guides (Norman 1937, Stehmann 1979, Efremenko 1983, Andersen 1984, Fisher & Hureau 1985) and to a reference collection of species caught commercially. Otoliths, where present, were identified by comparison with the author's reference collection and with reference to Hecht (1987). Standard lengths were assessed either directly from whole animals and skeletons or, for Southern Blue Whiting *Micromesistius australis*, from otoliths. Only apparently unworn otoliths were used (Gales 1988) and a regression of whiting length on otolith length was prepared by the author (ln fish length = -0.259 + 1.47 ln otolith length, n=122, r^2=94.8%). The decapod crustacean, lobster krill *Munida gregaria* is readily recognized (Matthews 1932).

Chick growth

Chicks were weighed using Salter spring balances. Bill lengths, equivalent to the length of the exposed culmen, were measured to the nearest 0.1 mm using Vernier calipers.

RESULTS

All the results given refer to the observed wet mass composition of the pooled samples from each location within the time period specified. No attempt has been made to reconstruct the initial intake of food.

New Island 1986/87

Figure 2 illustrates the composition of samples collected during the incubation and chick-rearing periods on New Island in the 1986/87 breeding season (Table 2). During incubation, the squid *Gonatus antarcticus* made up almost two-thirds of the samples. Fish, predominantly nototheniids and immature Southern Blue Whiting, made up a further 31%. The mean estimated DML and mass of the *Gonatus* were 28.9±4.56 mm (n=2208, range 18.5-47.1 mm) and 0.84±0.50 g (n=2208, range 0.08-3.81 g). The average length of intact nototheniid skeletons was 16.5±3.31 mm (n=59, range 11.0-23.0 mm). Too few intact Blue Whiting otoliths were present to obtain size estimates for this species.

During the chick-rearing period there was a marked change in the composition of the samples with fish, predominately nototheniids, Southern Blue Whiting and sprats *Sprattus fuegensis*, accounting for 55% of wet mass. Cephalopods, again predominately *Gonatus*, made up a further 30% with the remaining 15% being lobster krill. The mean estimated DML and mass of the *Gonatus* was greater than during incubation at 35.9±7.88 mm (n=3378, range 16.6-62.3 mm) and 1.87±1.34 g (n=3378, range 0.08-8.34 g), possibly reflecting the birds' use of a single growing stock. Only six intact nototheniid skeletons were recovered, ranging in length from 14.0 to 22.5 mm. The estimated standard length, from otoliths, of the Southern Blue Whiting was 59.1±13.01 mm (n=197, range 28.0-90.0 mm). Sprat skeletons averaged 33.7±2.53 mm (n=117, range 29.0-41.0 mm) in length.

Volunteer Point 1989/90 and 1990/91

Figure 3 illustrates sample composition at Volunteer Point in the 1989/90 and 1990/91 chick-rearing periods (Table 2). In both seasons cephalopods, predominantly *G. antarcticus* but with significant quantities of *Loligo gahi*, made up the bulk of the samples. However, whereas in 1989/90 lobster krill made up one-third of the samples and fish less than 5%, in the following season lobster krill were absent and fish made up almost 10%. Although direct comparisons cannot be made because the samples

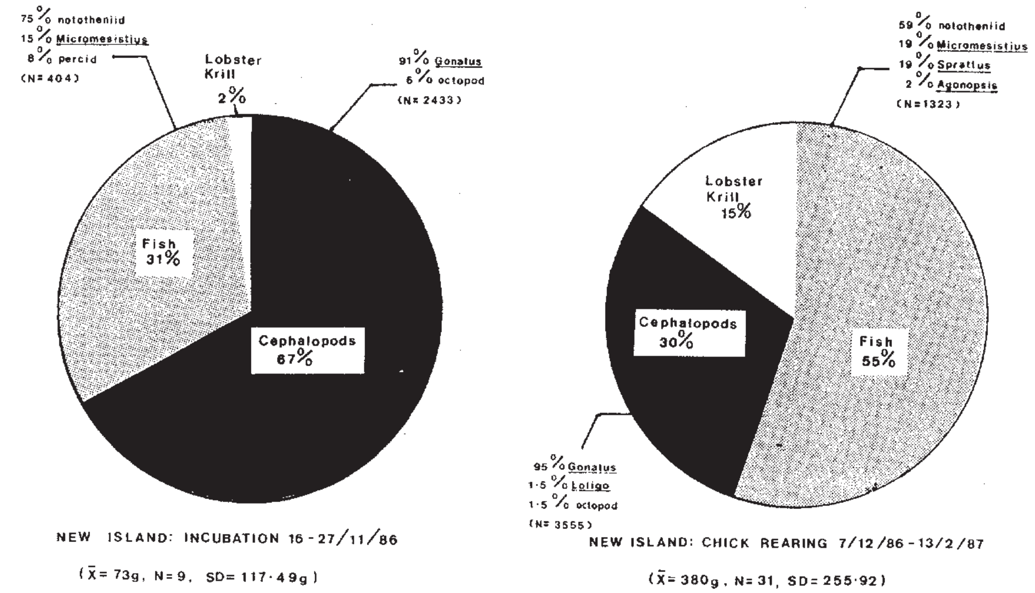

Figure 2

Composition of diet samples from Magellanic Penguins collected during the incubation and chick-rearing periods at New Island in 1986/87. Pie charts show the relative contributions by wet mass of fish, cephalopods and lobster krill to the pooled samples. Species breakdown, by number, of the fish and cephalopod fractions are also given.

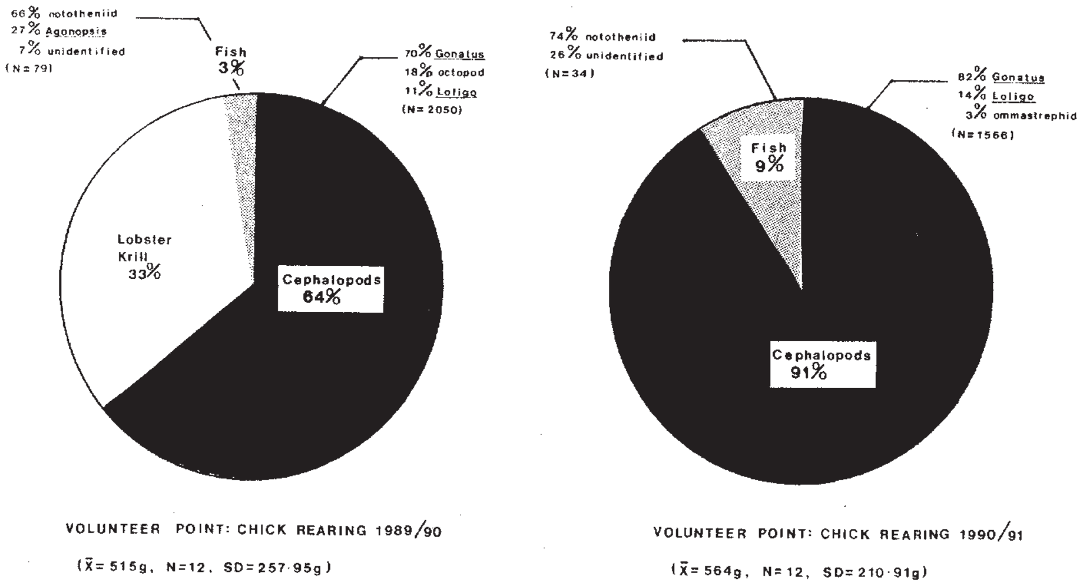

Figure 3

Composition of diet samples from Magellanic Penguins collected at Volunteer Point during the 1989/90 and 1990/91 chick-rearing periods. Pie charts show the relative contributions by wet mass of fish, cephalopods and lobster krill to the pooled samples. Species breakdown, by number, of the fish and cephalopod fractions are also given.

TABLE 2

COMPOSITION OF DIET SAMPLES COLLECTED FROM MAGELLANIC PENGUINS AT THE FALKLAND ISLANDS

Site & Dates	Mean Mass ± sd (g) (n)	L. Krill Aggregate Mass %	L. Krill Aggregate No. %	Squid Aggregate Mass %	Squid Aggregate No. %	Species composition Gon. No. %	Species composition Lol. No. %	Species composition Oct. No. %	Oth No. %	Fish Aggregate Mass %	Fish Aggregate No. %	Not. No. %	Per. No. %	Species composition SBW No. %	Species composition Spr. No. %	Agn. No. %	UID No. %
NI	73±117.5	17.5	30	585.5	2532	2213	14	143	63	276.5	803	303	37	61	0	1	2
Nov '86	(9)	2.0	0.9	66.6	75.2	90.9	0.6	5.9	2.6	31.4	23.9	75.0	9.2	15.1	0.0	0.2	0.5
NI	380±255.9	2075.2	2873	4090.4	4416	3381	53	55	66	7479.5	6795	782	4	253	256	22	6
Dec '86-Feb '87	(31)	15.2	20.4	30.0	31.4	95.1	1.5	1.5	1.9	54.8	48.2	59.1	0.3	19.1	19.3	1.7	0.5
VP	515±258.0	2161.0	1907	4255.1	1184	1438	218	367	27	180.7	848	52	0	0	0	21	6
Dec '89	(12)	32.8	48.4	64.5	30.1	70.2	10.6	17.9	1.3	2.7	21.5	65.8	0.0	0.0	0.0	26.6	7.6
VP	564±210.9	11.7	70	6280.9	2865	1284	225	2	55	591.3	176	25	0	0	0	0	9
Jan '91	(12)	0.2	0.1	91.2	92.1	82.0	14.4	0.1	3.5	8.6	5.7	73.5	0.0	0.0	0.0	0.0	26.5
NI	241±162.0	135.7	80	2343.9	8595	3038	6	7	14	787.2	5134	310	0	1	0	0	1
Dec '90	(14)	4.2	0.6	71.7	62.2	99.1	0.2	0.2	0.5	24.1	37.2	99.,4	0.0	0.3	0.0	0.0	0.3
WI	203± 86.0	2674.8	3405	259.4	163	547	82	26	5	215.1	296	67	0	3	4	0	1
Dec '90	(14)	84.9	88.1	8.2	4.2	82.9	12.4	3.9	0.8	6.8	7.7	89.3	0.0	4.0	5.3	0.0	1.3

Notes:
1) All masses are in grams; 2) Site codes: NI: New Island; VP: Volunteer Point; WI: Westpoint Island; 3) Cephalopod species codes: Gon.: *Gonatus antarcticus;* Lol.: *Loligo gahi*; Oct.: Octopods; Oth.: Other, mainly *Illex argentinus, Martialia hyadesi, Moroteuthis ingens*, sepiolidae and unidentified; 4) Fish species codes: Not.: Nototheniids; Per.: non-nototheniid perciformes; SBW.: Southern Blue Whiting; Spr.: *Sprattus fuegensis;* Agn.: *Agonopsis chiloensis*; UID.: Unidentified

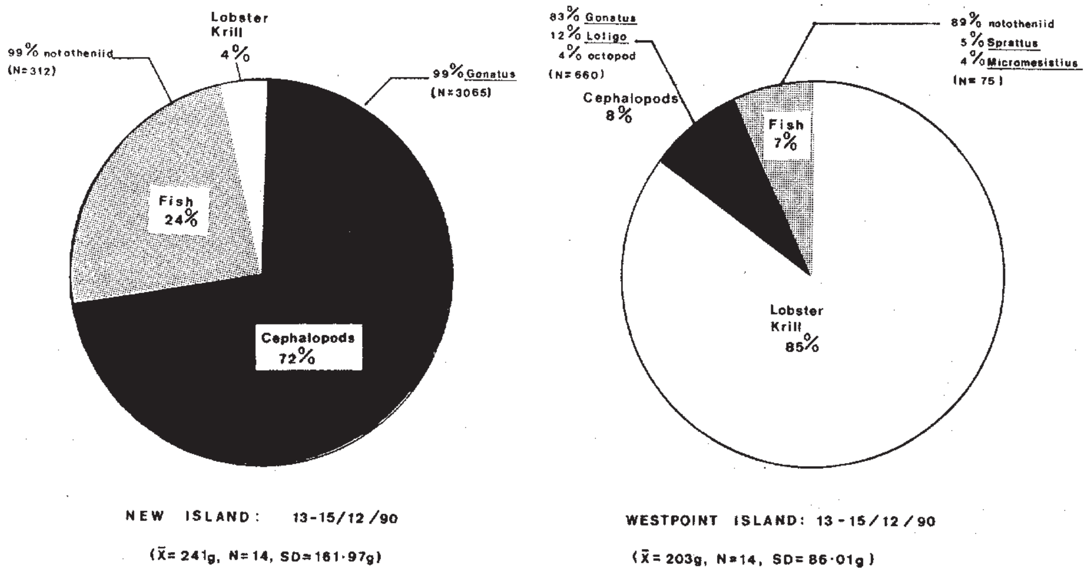

Figure 4

Composition of diet samples from Magellanic Penguins collected between 13 and 15 December 1990 at New Island and Westpoint Island. Pie charts show the relative contributions by wet mass of fish, cephalopods and lobster krill to the pooled samples. Species breakdown, by number, of the fish and cephalopod fractions are also given.

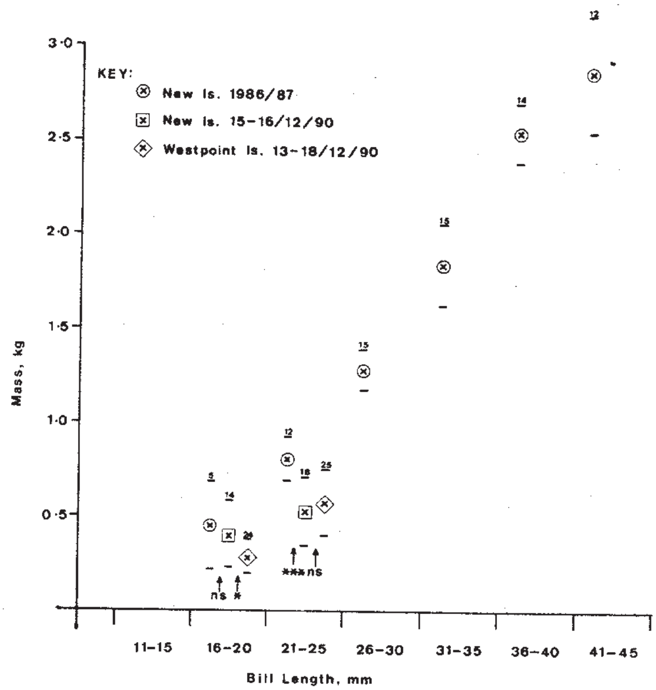

Figure 5

Chick masses of Magellanic Penguins in relation to bill length at New Island in 1986/87 and at Westpoint and New Island in December 1990.

were collected on different dates in the two seasons, these results are suggestive of considerable interannual variation in diet.

New Island and Westpoint Island, December 1990

Figure 4 illustrates the composition of diet samples collected on exactly the same days (13-15 December 1990) during the early chick-rearing period on New and Westpoint Islands (Table 2). These sites are 60 km apart (Fig. 1). At New Island, squid, predominantly *G. antarcticus*, accounted for just over 70% of pooled sample mass with nototheniid fish and lobster krill making up just under 25% and 5%, respectively. By contrast, at Westpoint Island, lobster krill made up 85% of the samples with *Gonatus* and *Loligo* squid plus nototheniid fish comprising the majority of the remaining 15%. The estimated mean DML of the *Gonatus* present was 26.3±2.81 mm (n=988, range 19.3-41.0 mm) on New Island and 27.3±5.86 mm (n=41, range 18.3-41.9 mm) on Westpoint Island (d=1.088, NS). The estimated mean length, from otoliths, of Southern Blue Whiting in the Westpoint Island samples was 18.8±5.47 mm (n=27, range 11.0-30.6 mm). Too few otoliths were present in the New Island samples to assess whiting lengths.

Chick growth

Figure 5 is a mass growth curve plotted against bill length for 15 chicks measured on New Island in 1986/87. Also plotted are mean chick masses in the 16-20-mm and 21-25-mm bill length categories for random samples of chicks measured on New and Westpoint Islands in December 1990. There was no significant difference in mean bill length of the chicks measured at these two sites on 15 and 16 December 1990 ($t=0.870$, d.f.=45, $p>0.10$), suggesting similar mean hatching dates. Among the 16-20-mm bill length chicks, the New Island 1990 birds were significantly heavier than those from Westpoint, but there was no significant mass difference in the larger bill length group (Table 3). However, the 21-25-mm bill length chicks from New Island were significantly lighter than were those in the same bill length class in 1986/87.

TABLE 3

CHICK MASSES OF MAGELLANIC PENGUINS AT NEW ISLAND (N.I.) IN 1986/87 AND AT WESTPOINT (W.I.) AND NEW ISLANDS IN DECEMBER 1990

Bill (mm)	Chick mass in kg (n, s.d.) N.I. 1986/87	P	N.I. 1990	P	W.I. 1990
16-20	0.45 (5, 0.237)	NS ($t=0.482$)	0.40 (14, 0.173)	* ($t=2.169$)	0.29 (24, 0.091)
21-25	0.82 (12, 0.113)	*** ($t=4.530$)	0.55 (18, 0.181)	NS ($t=0.851$)	0.59 (25, 0.176)

DISCUSSION

Overall composition of the diet

Relatively little has to date been published on the diet of the Magellanic Penguin. Scolaro & Badano (1985) investigated diet at Punta Clara, Argentina as did Venegas & Sielfeld (1981) at Magdalena Island, Chile. Together with anecdotal reports in Boswall & McIver (1975), these studies indicate that Magellanic Penguins breeding on the South American mainland feed predominantly on small fish, including anchovies *Engraulis anchoita* and silversides *Austroatherina smitti*, and cephalopods, including loliginids and ommastrephids. Lobster krill is reported only from the southern part of the species' range. In the Falklands, anchovies and silversides are replaced by nototheniids, Southern Blue Whiting and sprats. *Gonatus antarcticus* has not been recorded in the diet outside the Falklands.

Temporal and spatial variation in diet

Scolaro & Bandano (1985) noted seasonal variations in Magellanic Penguin diet at Punta Clara, although the percentage relative abundance of anchovies remained fairly constant at around 50%. Seasonal changes in the diet of the related Jackass Penguin *S. demersus* in Africa have been recorded by Randall & Randall (1986). Other penguin species in which such seasonal variation in diet have been recorded include Macaroni *Eudyptes chrysolophus*, Southern Rockhopper *E. chrysocome chrysocome*, and Gentoo *Pygoscelis papua* Penguins at Marion Island (Brown & Klages 1987, Adams & Klages 1989) and Yelloweyed Penguins *Megadyptes antipodes* (Van Heezik 1990). The studies of the *Eudyptes* and Yelloweyed Penguins also found interannual variations in diet at the same study sites.

Spatial variation in diets has been noted in Jackass Penguins (Randall & Randall 1986) in association with the depletion of pilchard stocks in some areas. Van Heezik (1990) also found marked variation in Yelloweyed Penguin diet among seven study sites, although the relative percentage occurrence of the four main prey species was relatively consistent. This contrasts with the simultaneous study of Magellanic Penguin diets on New and Westpoint Islands reported here, where lobster krill made up less than 5% of the diet at New Island but over 85% at Westpoint Island.

Biological significance of dietary variation

Several studies have linked variations in penguin chick growth rates and survival to diet in both natural and experimental situations (Heath & Randall 1985, Van Heezik 1990). In general, it appears that oily fish, such as sprats, provide high quality food for penguin chicks whereas cephalopods are of lower nutritional value. Hence a shift in diet in favour of fish over squid during the chick-rearing period, as observed on New Island in 1986/87, may be adaptive. In the current study, the lower mass of chicks on New Island in 1990/91 as compared to 1986/87 was associated with a reduced proportion of fish and increased proportion of squid in the diet. However, average stomach content masses were also significantly lower in 1990/91 (Table 4).

The high consumption of lobster krill on Westpoint Island, as compared to other sites, is of interest. The island's owner, Mr. R. Napier, reports a marked decrease in Magellanic Penguin breeding success in recent years. This has apparently coincided with the appearance of casts of undigested lobster krill exoskeletons around burrow entrances, suggestive of a change in diet. No information is currently available on the energetic content of lobster krill, so its nutritional value relative to squid or fish is unknown. However, personal observations suggest that lobster krill may be an inappropriate food for young chicks. Recently dead chicks have been found with stomachs congested with lobster krill carapaces, suggesting that young chicks may have difficulty in digesting or regurgitating them. The comparative growth data also suggest that younger (smaller) chicks grow less well on a diet of lobster krill.

TABLE 4

MASSES OF COMPLETE DIET SAMPLES OF MAGELLANIC PENGUINS AT NEW ISLAND IN DECEMBER 1986 AND DECEMBER 1990

Dates	Mean mass (g)	n	s.d.	t	P
7-26 Dec 1986	516.8	5	149.414	3.150	<0.005
13-15 Dec 1990	241.2	14	161.969		

Implications for monitoring and ecosystem studies

The extreme temporal and spatial variation in diet exhibited by Magellanic Penguins in the Falkland Islands raises practical difficulties in assessing the species' role in the region's marine ecosystem. Sampling diets, chick growth rates and other parameters at only a few sites could result in erroneous conclusions being drawn about the Falklands population as a whole. For example, a "typical" meal delivered to chicks at New Island might consist of 60 g fish, 170 g squid and 10 g lobster krill. At Westpoint Island the meal could comprise 15 g fish, 15 g squid and 175 g lobster krill. Assuming an average of 1.5 feeds per brood per day over a 60-d chick-rearing period, and a breeding population in the order of 100 000 pairs (Thompson 1989), gives estimates of total consumption ranging from 135 to 540 t of fish, 135 to 1530 t of squid and 90 to 1575 t of lobster krill. These estimates span one or two orders of magnitude.

There are also conservation implications because Magellanic Penguins, and other seabirds breeding in the Falkland Islands, may potentially be affected by offshore fisheries (Thompson 1989). Two of the commercially fished species, *Loligo gahi* and Southern Blue Whiting, are preyed upon by Magellanic Penguins. The birds may also potentially be indirectly affected by as yet unknown effects of the fisheries on marine community structure. The variation in diet and other aspects of ecology exhibited by the Magellanic Penguin necessitates conservation monitoring studies being conducted at a range of sites in order to gain an overall picture for the species in the Falklands. However, more positively, this variability may be helpful in gaining insights into possible linkages between diet, chick growth and population dynamics.

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