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Inter-annual variability in Chinstrap penguin diet at South Shetland and South Orkneys Islands

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Abstract Inter-annual variability in the diet of Chinstrap penguins (*Pygoscelis antarctica*) at Laurie Island (South Orkney Islands) and 25 de Mayo/King George and Nelson Islands (South Shetland) was examined based on stomach contents of adults during the 2002/2003–2006/2007 and 2002/2003–2004/2005 breeding seasons, respectively. Krill (*Euphausia superba*) dominated the diet as frequency of occurrence (in 100% of samples), number (>99%), and percentage contribution in weight (>94.8%). Other prey items were minor and varied between years. The weight of stomach contents was significantly different. The percentage in weight of whole krill was used to compare the feeding conditions across seasons. It differed significantly at the three sites studied. Distribution of krill size varied among years and localities, showing different krill availability for penguins.

Keywords Chinstrap penguin · Diet · *Euphausia superba*

Introduction

Marine predators vary considerably in their responses to changes in the abundance and distribution of their prey. Specialized predators exhibit changes in reproductive performance, foraging behaviour and the size of their populations that reflects the status of their food supply (Croxall et al. 1988; Clarke et al. 2002). Chinstrap penguins (*Pygoscelis antarctica*), one of the major consumers of Antarctic krill in the Southern Ocean marine ecosystem (Croxall and Lishman 1987; Williams 1995; Woehler 1995), have been included by Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), in the CCAMLR Ecosystem Monitoring Programme (CEMP), aimed to detect changes induced by resource extraction.

Together with reproductive success and other parameters, the diet of Chinstrap penguin chicks and from other species are used to monitor seabird performance in the Antarctic ecosystem, (Croxall et al. 1988a, b; Irvine et al. 2000; Lynnes et al. 2004; CEMP 2004; Rombolá et al. 2006) with a view to detect changes induced by the krill fishery.

Changes in the size and composition of the diet reflect changes in prey availability (Murphy 1995; Rombolá et al. 2006, Miller and Trivelpiece 2008), which depends not only on prey density but also on variations in environmental factors (Rombolá et al. 2003).

We report here the results of the study of diet composition in the breeding colony of Chinstrap penguins monitored by the CEMP at Laurie Island, South Orkney Islands; Antarctica over a 5-year period and two other colonies in South Shetland Islands, Barton Peninsula (25 de Mayo/King George Island) and Harmony Point (Nelson Island). We investigated inter-annual and between reproductive period variability in each locality in species composition, size of prey distribution and other variables analyzed from the stomach contents. Regular sampling of stomach contents also provided estimates of krill population parameters, albeit biased by the selectivity of penguins (Marschoff and Gonzalez 1992; Hill et al. 1996; CEMP 2004).

Materials and methods

Fieldwork was carried out at Laurie Island, South Orkney Islands, during the summer seasons of 2002/2003–2006/

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2007, which will be referred to hereafter by the last year (e.g. 2003, 2007). The colony sampled is located at Point Martin (60°46S, 44°42W). During the 5 years, stomach contents of reproductive adults of Chinstrap penguins were collected within the whole reproductive period in 2004–2006. During 2003, 40 samples were taken during late crèche period and in 2007 only 13 samples of guard period could be processed. The colonies sampled at South Shetland were Harmony Point (62°15′S, 59°37′W), Nelson Island in 2003 and 2004 and Barton Peninsula (62°18′S, 59°14′W), 25 de Mayo/King George Island during the 2003–2005 breeding seasons. Diet samples of adults that were feeding chicks in guard and crèche periods except in 2004 at Harmony Point and in 2005 at Barton when samples were obtained only during guard.

Samples were collected by the stomach-flushing method of Wilson (1984) and Gales (1987) and frozen, following CEMP standard method (Parameter A8, for details see Rombolá et al. 2003). The flushing technique has been under development since the early 1980s and finally standardized for use in the CEMP. If applied according to this protocol, it provides consistent results equivalent to the complete removal of the stomach applied by older studies such as Lishman (1985).

At the laboratory, all samples were thawed and drained through a sieve (0.91 mm mesh size). The stomach contents were separated into the digested fraction (mush, weighed to 0.1 g) and the identifiable remains. The latter were sorted into the different food items: krill, amphipods and fish and weighed separately. Identification of taxonomic groups was made using keys and reference collections (Argentine Antarctic Institute), to the family or species level whenever possible.

The importance of each prey item was evaluated using the index of relative importance (IRI) (Pinkas et al. 1971; Hyslop 1980), modified by Castley et al. (1991): calculated as: $\text{IRI} = \text{FO} \times 50 \times (N + \text{WW})$, where FO is the frequency of occurrence, N the number of prey item and WW the wet weight (g), as described in Rombolá et al. (2006) and this index was used for inter-annual and inter-breeding periods comparisons.

Krill was identified using Kirkwood (1982) and size was measured in all whole specimens (cephalothorax attached to pleon and telson), from the anterior tip of the rostrum to the posterior tip of the telson (Hill 1990; CEMP 2004) using a digital caliper (0.01 mm error) and the total weight of the measured specimens was determined to 0.1 g. Amphipods were identified using Bowman and Gruner (1973) guide, individuals were counted and measured. Fish otoliths were recovered from the whole sample and identified, using Hecht (1987), Williams and Mc Eldowney (1990) keys and reference collections (Argentine Antarctic Institute). Weight and total length were calculated from otolith length using the regression equations reported in the keys.

The proportion of whole krill in each sample (Rombolá et al. 2003) was obtained dividing the weight of whole specimens by the total weight of krill in the stomach (mush fraction, krill remains and whole krill). This proportion depends on the duration of the feeding trip, which in turn depends on the feeding conditions (abundance of prey, spatial disposition, weather, etc.) and the total weight of the krill captured (Rombolá et al. 2003; 2006). Thus, the proportion of whole krill at a given stomach contents weight, allows the comparison of the feeding conditions between samples.

The non-parametric tests of Mann–Whitney (U) and Kruskal–Wallis (H) (Siegel and Castellan 1995) were used to test inter-annual variations in the weights of stomach contents and in the proportion of whole krill. The statistical analysis of the differences between IRI's were conducted using bootstrap techniques (Efron and Tibshirani 1993) as the sampling distribution of the index is unknown. Comparisons of the index were obtained resampling (999 resamples) the whole samples of stomach contents in each of the groups to be compared under the null hypothesis that the difference between years is zero for the items analyzed (fish and amphipods).

Results

Euphausia superba was the main prey in frequency of occurrence, number and weight in every season, more than 98% of the IRI in all seasons and sites (Table 1). The other items were never above 1.4% with respect to number and weight of stomach contents. The relative importance of these items was below 5% in all seasons. The inter-annual comparisons of the IRI for amphipods at Point Martin were significant only when the 2003 season was included. Comparisons for fish were significant except for comparisons involving 2007.

The guard period had the highest frequency of occurrence of amphipods in 2005 and this occurred in the crèche period in 2006 (75%, Table 2). The frequency of occurrence of fish was also higher during guard in 2005 and 2006; the IRI of fish and amphipods was below 0.2%. Significant differences were found only between amphipods in some comparisons involving 2004 when this item was not present, and between guard and crèche in 2006, and guard in the 2005–2006 seasons.

Antarctic krill was the main prey item at Harmony Point during 2003, while the IRI for fish was <0.01%. In 2004, krill was the only item present in all samples (Table 1).

At Barton Peninsula, the frequency of occurrence of fish and amphipods was the same in 2003 (10.81%) while in the following years fish was present in more than 50% of the samples. The IRI values for fish and amphipods (Table 1)

Table 1 Composition of *Pygoscelis antarctica*'s diet at Point Martin, Barton Peninsula and Harmony Point based on stomach contents

Item	2003				2004				2005				2006				2007			
	%FO	%*N*	%WW	IRI	%FO	%*N*	%WW	IRI	%FO	%*N*	%WW	IRI	%FO	%*N*	%WW	IRI	%FO	%*N*	%WW	IRI
Point Martin																				
Krill	100	99.49	99.13	99.71	100	99.83	99.82	99.81	100	94.87	99.11	96.99	100	98.47	99.68	99.1	100	98.90	99. 74	99.32
Fish	10	0.01	0.01	<0.01	30	0.06	0.01	0.02	36.54	0.16	0.24	0.07	38.89	0.14	0.14	<0.01	0	0	0	0
Amphipods	45	0.49	0.06	0.12	0	0	0	0	9.62	0.04	<0.01	<0.01	50	0.62	0.08	0.17	53.86	1.10	0.27	0.37
Others	0	0	0	0	0.11	0.09	0.09	nc	3.85	4.93	0.18	0	27.78	0.77	0.01	nc	0	0	0	0
Barton Peninsula																				
Krill	100	99.91	99.81	99.47	100	99.84	97.6	98.72	100	99.44	99.86	99.65								
Fish	10.81	0.01	0.13	<0.01	54.29	0.13	2.4	0.69	90	0.13	0.13	0.12								
Amphipods	10.81	0.02	<0.1	<0.01	2.86	<0.01	<0.01	<0.01	10	0.02	<0.01	0.12								
Others	<0.01	0.06	<0.01	nc	17.14	0.02	<0.01	nc	30	0.41	<0.01	nc								
Harmony Point																				
Krill	100	99.99	99.97	99.98	100	99.83	99.99	99.98												
Fish	8	0.01	0.03	<0.01	0	0	0	0												
Amphipods	0	0	0	0	0	0	0	0												
Others	0	0	0	0	16	0.17	0.01	nc												

%FO frequency of occurrence, *%N* percentage by number, *ww* percentage by wet weight, *IRI* index of relative importance, for "other items" has not been calculated. "*Bold others*" item include the euphausiid *Thyssanoessa macrura*

were always very low (maximum of 0.69% for fish in 2004).

Amphipods were absent at Harmony. Out of the 283 specimens found in Point Martin, 277 were the hyperiid *Themisto gaudichaudii*, 114 of these could be measured. Length varied between 8.11 and 23.74 mm ($X = 17.54$; SD = 3.17). Only one gammaridean specimen (Lysianassidae) was found.

At Barton, eight hyperiids were identified: one *Hyperia macrocephala*, six *T. gaudichaudii* in 2003 and one in 2004.

In 2005 at Point Martin, 16 of 18 otoliths that belonged to 9 fish of 3 species, could be measured (two belonged to the asteriscus or lapillus pairs). In 2006, the notothenid *Trematomus newnessi*, was found in six of the eight samples with otoliths, contributing 53% of the frequency of occurrence (Table 3). Of 21 otoliths recovered, one was a larval notothenid. The myctophid *Electrona antarctica* was the main species, with four otoliths in 2005 and five in 2004. *E. carlsbergi* was found only in 2003 and *Gobionotothen gibberifrons* in 2005. The total length of the fish varied between 4.65 and 155.27 cm ($X = 50.22$ cm; SD = 45.18; $N = 26$).

At Barton Peninsula, the main myctophid prey item was also *E. antarctica* (19.05%, 7 otoliths and 4 fish, Table 3). *Pleuragramma antarcticum* was the main fish item; 15 otoliths (9 specimens) were recovered in 2004 and 2005. In 2004 all species identified were present, with the exception of *Protomyctophum bolini*. The range of total length of fish was 8.48–304.66 ($X = 133.88$ mm; SD = 71.49; $n = 21$).

At Harmony Point, 12 otoliths of three myctophid species were recovered, 8 of them pertaining to 5 specimens of *Gymnoscopelus nicholsi* (mean length = 165.4 cm) and there were 6 larval forms (Table 3).

The mean weights of stomach contents in each breeding season and reproductive period from Point Martin are shown in Table 4.

Differences in total weight were non-significant between 2004, 2005 and 2006 ($H = 3.19$, $df = 2$, $p = 0.20$), but significant against the 2003 season ($H = 13.56$, $df = 3$, $p = 0.04$). Guard and crèche periods in 2004–2006 also show significant differences, ($U = 1{,}194$, *df* 58, 80, $p < 0.001$).

The mean weight of stomach contents increased at Point Martin along the breeding season until chicks reached their final fledging weight during crèche (Fig. 1; Table 4). The linear regression model: mean weight = 129.51 + 2.66 age, yielded a significant slope ($F = 15.15$, $p = 0.03$, $R^2 = 0.47$) but the fit resulted poor, showing an increase along the season.

Table 4 also shows mean weights in the South Shetland localities.

Table 2 Guard and crechè periods diet of Chinstrap penguin at Point Martin

Item	Guard				Crèche			
	%FO	%*N*	%WW	IRI	%FO	%*N*	%WW	IRI
2004								
Krill	100	99.83	99.28	98.56	100	99.83	99.80	99.81
Fish	30	0.07	0.09	0.02	30	0.06	0.10	0.03
Amphipods	0	0	0	0	0	0	0	0
Other	40	0.1	0.02	0.02	30	0.11	0.10	0.04
2005								
Krill	100	89.39	99.55	94.47	100	97.39	98.82	98.11
Fish	36.36	0.19	0.01	0.06	40	0.15	0.26	0.08
Amphipods	13.63	0.06	0.01	<0.01	6.66	0.04	<0.01	<0.01
Other	0.45	10.36	0.34	0.02	6.66	2.43	0.11	0.08
2006								
Krill	100	99.2	99.65	99.43	100	98.04	99.68	98.86
Fish	43.75	0.16	0.25	0.09	35	0.13	0.08	0.04
Amphipods	18.75	0.05	0.01	<0.01	75	0.95	0.12	0.4
Other	25	0.59	0.08	0.08	15	0.87	0.11	0.07

%FO Frequency of occurrence, *%N* percentage by number, *ww* percentage by wet weight, *IRI* index of relative importance

Table 3 Fish in the diet of *Pygoscelis antarctica* in the 2003–2006 breeding seasons at Laurie Island, in the 2003–2005 breeding seasons at 25 de Mayo/King George Island and the 2003–2004 breeding seasons at Nelson Island, South Shetland

Species	Fish number	%FO	%*N*	%WW	Mean weight (g)	Mean length (mm)
Point Martin						
Myctophidae						
Electrona antarctica	9	37	34.62	23.54	3.91	65
E. carlsbergi	2	11	7.69	12.58	9.4	83
Notothenidae						
Gobionotothen gibberifrons	2	21	7.69	17.33	25.9	147
Trematomus newnessi	11	53	42.31	44.16	6	6
Pleuragramma antarcticum	2	5.3	7.69	2.39	79.84	4
Barton Peninsula						
Myctophidae						
E. antarctica	4	18.84	19.05	3.77	3.37	63
Gymnoscopelus nicholsi	1	6.3	4.76	8.70	31.01	170
Protomyctophum bolini	1	6.3	4.76	0.11	0.39	30
Notothenidae						
G. gibberifrons	2	12.5	9.52	5.54	9.90	109
T. newnesi	1	6.3	4.76	3.88	13.85	8
P. antarcticum	10	37.5	47.62	71.36	25.5	156
Paralepididae						
Notolepis coatsi	2	6.3	9.52	6.64	11.85	284
Harmony point						
Myctophidae						
E. antarctica	25	1	14.29	1.88	2.9	60
E. carlsbergi	25	1	14.29	4.52	6.98	74
G. nicholsi	50	5	71.43	93.61	28.93	165

%FO frequency of occurrence, *%N* percentage by number, *ww* percentage by wet weight

Table 4 Mean weight of stomach contents for each breeding season and reproductive period at Point Martin, Harmony Point and Barton Peninsula (standard deviation and number of samples are shown)

Year	Guard	Créche	Total	*N*
Point Martin				
2003	No data	268.65 ± 104.3 (97–551.98)	268.65 ± 104.3 (97–551.98)	40
2004	187.37 ± 93.2 ($N = 20$)	235.33 ± 75.98 ($N = 30$)	216.15 ± 99.58 (41.57–422.9)	50
2005	127.19 ± 100.57 ($N = 22$)	224.25 ± 140.3 ($N = 30$)	183.18 ± 85.24 (20.94–381.33)	52
2006	188.53 ± 63.08 ($N = 16$)	245.49 ± 75.22 ($N = 20$)	220.18 ± 111.05 (54.1–598.4)	36
Total	164.86 ± 102.1 ($N = 58$)	233.72 ± 85.22 ($N = 80$)	219.13 ± 103.03 (20.94–551.98)	178
Harmony Point				
2003	293.3 ± 85.3	418.85 ± 148.4	356.1 ± 132.35	50
2004	331.3 ± 111.88	No data	331.3 ± 111.88	25
Total	312.3 ± 100.31	418.85 ± 148.4	347.81 ± 125.69	75
Barton Peninsula				
2003	207.2 ± 75.6	200.1 ± 63.3	205.77 ± 72.54	36
2004	250.44 ± 100.27	287.96 ± 113.73	259.27 ± 103.06	34
2005	429.14 ± 117.77	No data	429.14 ± 117.77	10
Total	258.6 ± 119.85	246.99 ± 101.18	256.42 ± 116.07	80

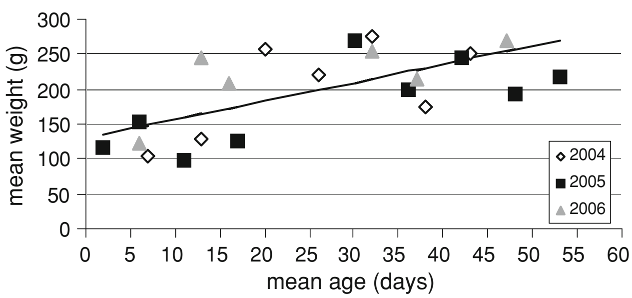

Fig. 1 Mean weight of stomach contents versus mean age at Point Martin

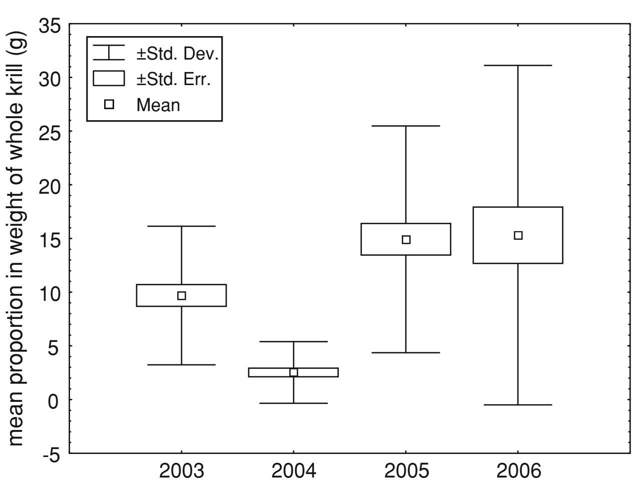

Fig. 2 Box plots of mean proportion in weight of whole krill at Point Martin, South Orkneys

Fig. 3 Box plots of mean proportion in weight of whole krill at Barton Peninsula, South Shetland

There were significant differences between seasons in stomach content weights at Barton ($H = 19.14$, $df = 2$, $p < 0.01$) but not at Harmony Point ($U = 591$, df 50, 25, $p = 0.71$).

At Point Martin no significant differences in the proportion of whole krill were found between the guard and crèche periods. Interannual comparisons showed significant differences ($H = 71.23$, $df = 2$, $p = 0.00$); the proportion was very low in 2004, while for 2005 and 2006 the proportion of whole krill was higher (Fig. 2).

At Barton 2003 (Fig. 3), the proportion of whole krill was lower than in 2004 ($U = 378$, $df = 31, 34$, $p = 0.05$). Not enough data from Harmony Point were available for a similar comparison.

Table 5 Means and SD of krill size at Point Martin, Barton Peninsula and Harmony Point in the years studied

Year	Point Martin	Barton Peninsula	Harmony Point
2003	42.44 ± 3.93 ($N = 2{,}748$)	36.06 ± 5.69 ($N = 3{,}066$)	42.48 ± 6.19 ($N = 3{,}398$)
2004	46.44 ± 4.1 ($N =$ (565)	40.51 ± 5.58 ($N = 3{,}374$)	41.26 ± 5.10 ($N = 988$)
2005	48.98 ± 4.46 ($N = 1{,}736$)	45.42 ± 3.77 ($N = 615$)	No data
2006	46,55 ± 5.20 ($N = 1{,}715$)	No data	No data
2007	37.28 ± 6.91 ($N = 507$)	No data	No data

Mean yearly krill lengths at Point Martin were always greater than in the Shetland localities. At Point Martin in 2004 and 2005, the range of krill lengths was 32–60 mm, in 2003, 2006 and 2007 the lower end was smaller, including juvenile krill (<22 mm). At Harmony Point and Barton, the lower end was smaller than 20 mm in 2003 and 20 mm in 2004. Means and standard deviations of all seasons and sites are shown in Table 5.

Discussion

Antarctic krill has been reported as the main item of Chinstrap penguin's diet both in the South Orkneys (Lishman 1985; Lynnes et al. 2004; Rombolá 2006) and South Shetland Islands (Croxall and Furse 1980; Volkman 1980; Jablonski 1985; Jansen et al. 1998; Trivelpiece et al. 1990; Trivelpiece et al. 2003).

Minoritary items in Chinstrap chick diet are also preyed by other species occurring in the area, either as minoritary or main items. *T. gaudichaudii*, the most abundant amphipod found in the Southern Ocean (Jazdzewski 1981), is taken by Chinstrap and other penguin species such as Adélie, macaroni and rockhopper (Croxall and Furse 1980; Lynnes et al. 2004; Raya-Rey 2005) and in seabirds such as Antarctic prions and common diving petrels (Bocher et al. 2001).

Myctophids are an important prey item for marine mammals (Daneri et al. 2005; Casaux et al. 1998) and Cape Petrels, *Daption capense*, (Coria et al. 1997), while nototheniids are the main prey of gentoo penguins *P. papua* (Coria et al. 2000) and blue-eyed shag (Casaux and Barrera-Oro 1996; Casaux and Ramón 2002). *P. antarcticum* was the main fish taken by Chinstrap penguin at South Shetland in the present study and is in agreement with Volkman et al. (1980) and Trivelpiece et al. (2003). A common characteristic of amphipods (*T. gaudichaudii*) and pelagic fish (myctophids and *P. antarcticum*) found as minoritary items in chinstrap diet is their relation with euphausiid concentrations (Tarling et al. 1995; Barrera-Oro 2002).

With regard to fish in the diet, it should be noted that being highly digestible (Jackson and Ryan 1986), fish could be underrepresented by weight in Chinstrap penguin samples; they only appear as bone fragments and otoliths.

The benthic nothoteniids *T. newnessi* and Gobionotothen gibberifrons were also found at Signy Island (Lishman 1985; Lynnes et al. 2004) in Chinstrap penguin diet. Since the small-sized specimens (Table 3) are usually found in inshore waters (Barrera-Oro 2002), they might be an opportunistic prey caught by Chinstrap penguins in shallow waters.

All studies mentioned below, except that from Lishman (1985) have been conducted using stomach-flushing method.

The range of mean weights of stomach contents at Point Martin, Harmony Point and Barton Peninsula was (183–429 g). However, with the exception of Harmony Point samples, weights are close to the lower end of the range. Compared with data from the previous decade in the same sites, stomach contents are lower (Cemp-Index Data Report, WG-EMM 07/04, appendix 3, Rombolá et al. 2006).

Detailed data at Point Martin show an increase on stomach content weights along the breeding season until a maximum is attained (Ferreti 1998; Rombolá et al. 2003) as shown in Fig. 1. No obvious differences between years were found in this pattern.

The higher weights found in crèche samples are in agreement with previous results obtained in the South Orkneys (Lishman 1985), although this author did not use stomach flushing technique, and some recent works (Ferreti 1998; Lynnes et al. 2004), and the South Shetland Islands (Volkman 1980; Jablonski 1985; Trivelpiece 1990). In the course of the breeding season, as chicks grow, the quantities of food brought by parents become larger; resulting in a weight at fledging almost equal to parent's weight. (Williams 1985; Trivelpiece et al. 1987; Culik 1990; Jansen et al. 2002).

The quantity necessary to maintain the chicks in the guard period was estimated from published results to be approximately 160–200 g/day (Rombolá et al. 2003). About 55% of the samples analyzed are well below this quantity.

The fraction of fragmented krill was also studied by Trivelpiece et al. (2003) who found high percentages of stomachs with digested food in 20 years of diet research: a mean of 54% Adélie penguin and 42% for Chinstraps. These percentages in both species increased with the increment in stomach contents weights as the breeding season progressed.

At Point Martin, the low proportion of whole krill in the 2004 samples are indicative of longer foraging trips (Rombolá et al. 2006; Fig. 2), and points to low availability of food.

In the South Orkneys region, the Antarctic krill, *Euphausia superba* is highly concentrated (Miller and Hampton 1989). It is transported from the South Shetland Islands and from the Weddell Sea (Miller and Hampton 1989; Marschoff 1996; Siegel et al. 2004), while in the South Shetland Islands krill originates mainly in the Bellingshausen Gyre. These different origins may explain the differences in the observed differences in the size of krill preyed by penguins in both areas. Krill captured by penguins at South Orkney Islands are larger than those captured at South Shetlands (Table 5).

Information from the fishery

No data are available from the fishery in the South Orkneys region in 2004, which could be used to decide whether low availability was caused by a decline in krill abundance or by changes in krill distribution (e.g. krill was far from shore, distributed in large or small swarms, etc.).

Bibik and Zhuk (2007) reported that northeast of Coronation Island, South Orkneys, the recruitment of small sizes of krill was higher in 2006, compared with the previous year. In the South Shetlands, the fishery caught mean sizes greater than in the South Orkneys. Size ranges were between 25 and 60 mm (mainly 39–45 mm) near Coronation Island, and between 33 and 61 mm in the South Shetland (mainly 46–52 mm).

In 2006, penguins captured the smallest sizes, mainly between 42 and 46 mm but with lower frequencies than in previous years (Rombolá et al. 2006) and from the period considered. This confirms the recruitment of smaller krill informed by Bibik and Zhuk (2007) at South Orkneys. In good or normal years this pattern is reversed, with larger krill found at South Orkneys.

Conclusions

The CEMP main objective is to monitor the impact of the krill fishery on krill predator populations. It is proving to be difficult to separate the effects of fishing from environment variability (SC-CAMLR 2008).

The detailed analysis of diet might be useful to detect events of low availability of krill to Chinstrap penguins and to help to identify the driving factors (Rombolá et al. 2003; 2006; present study). The incorporation of other variables in the dietary analysis like the proportion of whole krill and their size distribution, entire or fragmented (Marschoff et al. 2008), is essential to understand the availability of krill. However, independent information, either from the fishery or research sampling, on krill abundance, biological parameters and distribution is needed.

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