DIET COMPOSITION OF ADELIE PENGUINS *PYGOSCELIS ADELIAE* AT HOPE/ESPERANZA BAY DURING 2014–2019

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ABSTRACT

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In this study, we obtained samples through stomach lavage to determine the diet of Adelie Penguins *Pygoscelis adeliae* during the guard and crèche periods at Hope/Esperanza Bay, Antarctica, during four breeding seasons (2014–2019, except 2016). Antarctic krill was the dominant prey, contributing > 99.6% of the diet by mass. The remainder of prey were fish, amphipods, and mollusks. Among fish, the nototheniid *Pleuragramma antarcticum* was the most frequent while the bathydraconid *Parachaenichthys charcoti* dominated by mass. Mollusks and fish increased their contribution during the crèche period in accord with seasonal patterns elsewhere.

Key words: diet composition, *Pygoscelis adeliae*, Antarctic Peninsula, breeding periods, diet during chick rearing

INTRODUCTION

The Adelie Penguin *Pygoscelis adeliae* is a circumpolar species distributed between 54° and 77°S. It occurs in ice-covered seas, but it breeds in ice-free coastal areas on the Antarctic continent and on surrounding islands (Williams 1995, Ainley 2002). The main prey of this species in the Antarctic Peninsula and Scotia Arc regions is the Antarctic Krill *Euphausia superba* (hereafter krill). Fish and amphipods are part of their diet as well, although diet composition can differ depending on the breeding location (*cf.* Ainley & Schlatter 1972, Volkman *et al.* 1980, Gorman 2015). In Hope/Esperanza Bay, the first study of Adelie Penguin diet using stomach lavage was in 1987 (Coria *et al.* 1995b), followed by another analysis using isotopic methods in 2013 (Colominas-Ciuró *et al.* 2018).

Diet composition, based on the mass contribution of prey combined with other variables, can provide information on the trophic ecology of a penguin and ultimately indicate changes in the availability, quality, and quantity of the food resource (Fraser *et al.* 1992, Fraser & Hofmann 2003, Sailley *et al.* 2013, Cimino *et al.* 2014, Ainley *et al.* 2015). This study was conducted to increase the knowledge of Adelie Penguin diet in Hope/Esperanza Bay.

MATERIALS AND METHODS

During the 2014/15 (hereafter 2014), 2015, 2017, and 2018 breeding seasons, we obtained samples to reveal the diet of Adelie Penguins at Hope/Esperanza Bay (63°24′S, 057°01′W). During the guard and the crèche periods within the breeding season, we obtained the stomach contents (five samples every five days) of different parents returning to the colony from feeding trips, using the stomach pumping technique (Wilson 1984, Gales 1987). The samples were sieved through 0.10 mm mesh in the field, and they were analyzed at the laboratory according to the method described in Coria *et al.* (1995b). The total mass of krill per sample was estimated using the methodology described by Morris *et al.* (1988). To estimate the contribution of fish, otoliths were analyzed according to the method of Casaux *et al.* (1995) and Karnovsky (1997). To determine fish size and mass, we measured otoliths and used the regression equations in Hecht (1987), Williams & McEldowney (1990), and Casaux *et al.* (1997). Amphipods were represented by exoskeleton remains, and their masses were estimated by considering the mass of entire specimens. Gastropods and bivalves were represented by shells, and their mass was estimated by considering entire specimens.

All procedures were conducted under appropriate international, national, and institutional guidelines for sampling, care, and experimental use of animals for study. All necessary approvals were obtained. Each year, sampling was completed under the permit granted by the Dirección Nacional del Antártico (Environmental Management Office).

RESULTS

Krill, fish, amphipods, and mollusks (gastropods and bivalves) were found in the samples (Table 1). Overall, krill was the most frequent (100%) prey, followed by amphipods, mollusks, and fish (Table 1). Krill also dominated by mass, followed by fish, amphipods, and mollusks. Among fish, the nototheniid Antarctic Silverfish *Pleuragramma antarcticum* (hereafter silverfish) was the most frequent over the entire study period, whereas the bathydraconid Antarctic Dragonfish (hereafter dragonfish) *Parachaenichthys charcoti* dominated by mass. Amphipods were a frequent prey, mollusks were absent from the diet in 2015, and fish were most prevalent in the diet during 2015 and 2018.

As expected, krill was the most frequent and important prey by mass in both breeding periods considered. Mollusks and fish increased their contribution to the diet during the crèche period (Table 2).

TABLE 1
Composition of the Adelie Penguin *Pygoscelis adeliae* diet in Hope/Esperanza Bay, Antarctica, during the 2014, 2015, 2017 and 2018 breeding seasons[a]

	Overall		2014		2015		2017		2018	
	FO%	M%	FO%	M%	FO%	M%	FO%	M%	FO%	M%
Antarctic Krill	100.00	99.80	100.00	99.89	100.00	99.64	100.00	99.99	100.00	99.69
Amphipods	16.18	0.03	13.33	0.05	11.4	0.00	26.00	0.02	14.00	0.03
Mollusks										
Bivalves	6.17	0.01	6.67	0.03	-	-	12.00	0.00	6.00	0.01
Gastropods	2.00	0.00	-	-	-	-	4.00	0.00	4.00	0.00
Fish										
Pleuragramma antarcticum	1.71	0.04	-	-	2.86	0.09	-	-	4.00	0.07
Trematomus newnesi	1.00	0.05	-	-	-	-	-	-	4.00	0.20
Parachaenichthys charcoti	1.43	0.06	-	-	5.71	0.22	-	-	-	-
Unidentified	3.70	-	2.22	-	8.57	-	2.00	-	2.00	-

[a] Frequency of occurrence (FO%) and mass (M%) of each type of prey

DISCUSSION

Antarctic Krill was found to be the main prey of the Adelie Penguin during the breeding period in the northern Antarctic Peninsula–Scotia Arc region (Karnovsky 1997, Gorman 2015). The information we obtained in this study indicates this to be true at our study site as well. In agreement with the findings of Juáres *et al.* (2018) at the South Shetland Islands (SSI), amphipods and mollusks contributed little to the diet by mass. As also observed by Coria *et al.* (1995a) at SSI and at Anvers Island and vicinity, silverfish was the most frequent fish in our samples. On the other hand, Coria *et al.* (1995b), Juáres *et al.* (2016), and Karnovsky (1997) indicated that among fish, pelagic species were the most common prey at Hope/Esperanza Bay and at SSI, respectively. Fish in our samples included those of mid-water (silverfish), mid-water/demersal (Dusky Rockcod *Trematomus newnesi*), and demersal (dragonfish) habits. Mid-water fish dominated the diet by frequency of occurrence, and dragonfish led by mass.

TABLE 2
The composition of the Adelie Penguin *Pygoscelis adeliae* diet in Hope/Esperanza Bay, Antarctica, during guard and crèche periods[a]

	Guard period		Crèche period	
	FO%	M%	FO%	M%
Antarctic Krill	100.00	99.94	100.00	99.69
Amphipods	15.00	0.02	17.00	0.02
Mollusks				
Bivalves	3.75	0.00	10.00	0.00
Gastropods	-	-	3.00	0.00
Fish				
Pleuragramma antarcticum	2.50	0.03	1.00	0.03
Trematomus newnesi	-	-	2.00	0.08
Parachaenichthys charcoti	-	-	2.00	0.16
Unidentifiable	3.75	-	5.00	-

[a] Frequency of occurrence (FO%) and mass (M%) of each type of prey

The composition of the diet remained stable throughout the study with one exception: greater consumption of fish occurred in 2015 and 2018, which could be interpreted as a decrease in the availability of krill (see Waluda *et al.* 2017). An alternative explanation for the greater consumption of fish in 2015 and 2018 is a higher availability of fish in those years. According to Chapman *et al.* (2010, 2011), Adelie Penguin chicks raised on fish, especially silverfish, fledge at more robust weights, and thus parents should be seeking them as prey. In this sense, fish found in the water column (silverfish in particular) have a much higher energy density than krill (Ichii *et al.* 2007, Ruck *et al.* 2014, Jennings *et al.* 2016, Ainley *et al.* 2018). Therefore, when pelagic fish are present and abundant within foraging areas, penguins would be foraging more on them than on krill (McDaniel & Emslie 2002, Ainley *et al.* 2003, Chapman *et al.* 2011, Ruck *et al.* 2014). Studies by La Mesa *et al.* (2015) indicate that silverfish abundance and distribution has been decreasing around the Western Antarctic Peninsula, and Sailley *et al.* (2013) hypothesized that this is a factor behind the decrease in this penguin species in the area (see also Gorman *et al.* 2021).

Ainley (2002; more recently Ainley *et al.* 2018) observed that fish consumption by Adelie Penguins increases progressively throughout the breeding season, which is consistent with the higher proportion of fish in our samples from the crèche stage in all years studied. Polito *et al.* (2011) observed that during the breeding period, fish were better represented in stable isotope samples than in stomach contents. Since fish are digested faster than krill, and since small otoliths can be completely digested (Karnovsky *et al.* 2012) or lost through the gastrointestinal tract (Casaux *et al.* 1995), this prey is likely underestimated by stomach contents analysis. Despite this possible underestimation, the results obtained during our study show the importance of krill in the diet of Adelie Penguins during the reproductive stage.

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