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Short note

Seasonal importance of oceanic myctophids in king penguin diet at Crozet Islands

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Commercial fisheries of lanternfishes (Myctophidae: Osteichthyes) began a few years ago in the Atlantic sector of the Southern Ocean and exploitable stocks of myctophids probably also occur in the Indian and Pacific sectors. The Scientific Committe for the Conservation of Antarctic Marine Living Ressources (CCAMLR 1991) recommended to collect informations on potential competition between these fisheries and populations of predators. The king penguin (*Aptenodytes patagonicus*) is the most specialized subantarctic seabird preying upon mesopelagic myctophids (Adams and Klages 1987; Hindell 1988; Klages et al. 1990; Ridoux 1992), and more than 50% of the bird's world population is located in Crozet Archipelago (Jouventin et al. 1984). Since only limited king penguin diet data from Crozet Islands are available (Cherel and Ridoux 1992; Ridoux 1992), we investigated the food of king penguin chicks during their extended fledging period (about 11 months; Stonehouse 1960), to test for seasonal variation and the significance of their main prey in relation to the bird's breeding cycle.

Methods

This study was carried out at La Baie du Marin, Possession Island (46°25'S; 51°45'E) during the 1990 breeding season. Adult king penguins were randomly chosen among birds on arrival at the colony, before they feed their offspring. Using a water off-loading technique, 3 sets of 5 samples (15 samples per season) were collected at one week interval in the middle of 1) the first period of chick growth (autumn: February–March), 2) the winter (June–July) period of growth curtailment, and 3) the second period of growth (spring: September–October). Wet mass of the samples refers to the sample mass minus the mass of accumulated items (squid beaks without flesh, and stones). Sampling, and determination and quantification of the main prey were made according to Cherel and Ridoux (1992).

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Results and discussion

Strong seasonal differences occurred in the size, prey number and species composition of king penguin stomach contents (Tables 1 and 2). Meal mass and prey number were lower in winter than in fall and spring. Fish (mainly myctophids) predominated during chick growth whereas the importance of squid in the diet substantially increased in winter (Table 1). Similar results were reported from Marion Island which is also located in the Southern Indian Ocean (Adams and Klages 1987), whereas squid was a minor component of the diet at Macquarie Island, in the Southern Pacific Ocean (Hindell 1988).

Only 3 species of lanternfish formed the bulk of the food in autumn and spring at both Possession (Table 2) and Marion (Adams and Klages 1987) islands. These are *Krefftichthys anderssoni*, *Protomyctophum tenisoni* and *Electrona carlsbergi*. In previous studies, *P. tenisoni* was either not identified (Hindell 1988) or not distinguished from *K. anderssoni* (Adams and Klages 1987). Our data clearly showed that *P. tenisoni* was a main item in spring, *E. carlsbergi* in autumn, and *K. anderssoni* during both seasons. Only few interannual differences probably occur in the chick diet at that time because the results in autumn were identical in 1989 (Cherel and Ridoux 1992) and 1990 (this study). Among fish prey, winter diet was marked by only one main species (*P. tenisoni*) and a large number of minor items.

A new finding of this study was the importance of the onychoteuthid squid *Moroteuthis ingens* in the winter chick diet (Table 2). The large size of this species (dorsal mantle length: 171 ± 7 mm, body mass: 164 ± 8 g; $n = 10$) explains the higher percentage by mass than by number of squid prey in winter (Table 1).

Is the king penguin life cycle synchronised with myctophid availability?

During the 2 phases of chick growth, the king penguin chick diet always consists in large meals containing

Table 1. Seasonal variation in meal size, prey number and composition of identifiable material in king penguin stomach contents from Possession Island

	Autumn ($n=15$)	Winter ($n=15$)	Spring ($n=15$)
Wet mass (g)	1592 ± 122^a	623 ± 84^b	1245 ± 117^a
Prey number	367 ± 50^a	55 ± 13^b	395 ± 59^a
Fish (% wet mass)	98.9 ± 0.3^a	42.6 ± 8.6^b	97.2 ± 1.3^a
(% prey number)	98.5 ± 0.3^a	74.6 ± 7.7^b	98.1 ± 0.5^a
Squid (% wet mass)	1.1 ± 0.3^a	57.4 ± 8.6^b	2.8 ± 1.3^a
(% prey number)	1.5 ± 0.3^a	25.4 ± 7.7^b	1.9 ± 0.5^a

Values are means ± SE. Values in the same horizontal row not sharing a common superscript letter are significantly different ($P<0.05$; Peritz' F test; percentages were corrected by an arcsine transformation)

Table 2. Seasonal variation in the frequency of occurrence (FO) and the percentage by number (N) of the main prey items in king penguin stomach contents from Possession Island

	Autumn ($n=15$)		Winter ($n=15$)		Spring ($n=15$)	
	FO	N	FO	N	FO	N
Fish	15	98.9	14	89.3	15	98.5
Family Myctophidae	15	98.6	14	67.5	15	97.5
Krefftichthys anderssoni	15	71.7	4	2.0	10	41.7
Protomyctophum tenisoni	0	0.0	7	27.7	15	46.1
Electrona carlsbergi	15	24.9	3	0.7	11	6.4
Other Myctophids	9	2.0	14	37.1	3	3.3
Other fish	5	0.3	11	21.8	13	1.0
Squid	15	1.1	15	10.7	14	1.5
Moroteuthis ingens	0	0.0	13	4.8	0	0.0

numerous individuals of only 2–3 myctophid species, whereas the cessation of chick growth in winter is associated with decreases in meal size and feeding rate, and a shift in dietary composition (Stonehouse 1960; Adams and Klages 1987; Hindell 1988; Cherel and Ridoux 1992, this study). Adult king penguins accumulate large energy reserves in the few weeks before the molting fast, and they begin to arrive ashore for molting in late September. Thus, 2 processes (second period of chick growth and premolting storage of energy reserves in adults) that require the availability at sea of large amounts of food, begin at about the same time, in spring. Interannual differences were found in the timing of the beginning of both the second period of chick growth and prebreeding adult molt in spring, and also in the start of chick winter fast (Weimerskirch et al. 1992). These data strongly suggest a nutritional synchronisation of the king penguin life cycle, the accumulation of nutrient reserves before adult molt and chick growth occurring only when food of high nutritional value (Cherel and Ridoux 1992) is plentiful. The duration of the period of food scarcity is thus determined by the disappearance and appearance of the main myctophid prey in late autumn and early spring, respectively. The unavailability of these prey types for king penguins is probably due to their deeper migration in winter, as observed for *E. carlsbergi* and *K. anderssoni* in the South Atlantic Ocean (Sabourenkov 1991).

Commercial fishing catches around South Georgia were mainly *E. carlsbergi* but they also included *K. anderssoni* in small quantities (CCAMLR 1991). Since these 2 species are the main prey of the king penguin throughout its range, both myctophid and king penguin monitoring studies must therefore be conducted before and during myctophid stock exploitation.

Is the king penguin only an oceanic predator?

King penguin is usually considered as an oceanic predator throughout chick rearing (Adams and Brown 1989). Accordingly, *K. anderssoni*, *E. carlsbergi* and *P. tenisoni* were identified as the main penguin prey in autumn and spring. The 2 former species are among the most abundant mesopelagic fish in the Southern Ocean where they form dense concentrations in the Antarctic Polar Frontal Zone (Sabourenkov 1991), *K. anderssoni* being also found in oceanic waters surrounding the subantarctic islands (Perissinotto and McQuaid 1992). Prey distribution therefore indicates that birds from Possession Island may forage at that time in 2 distinct areas; 1) in oceanic waters close to the breeding colony, as previously suggested from time-depth recorder data (Kooyman et al. 1992), and 2) 300–400 km in the south of the archipelago (where the Polar Front is located; Park et al. 1991). Long and distant hunting areas were also indicated by the highly digested nature of the stomach contents in both autumn and spring. On the other hand, most of the winter samples contained hardly digested fish and cephalopods. The main winter prey by mass, the squid *Moroteuthis ingens*, is a benthopelagic species that was caught in bottom trawls around Crozet and Kerguelen Islands (Duhamel, personal communication). Moreover, myctophid prey in winter included *Gymnoscopelus nicholsi*, *G. piabilis*, *Electrona subaspera* and *Metelectrona ventralis* that are found over continental shelves (Hulley et al. 1989). Both the undigested items and prey location suggest that the bulk of the food given to the

chicks in winter was caught over the shelf. This shift in the foraging areas from oceanic to neritic waters to feed the chicks does not preclude that nonbreeding birds and breeding adults hunt for themselves far from the islands, as indicated by the longer absence of adult birds and the low chick feeding rate in winter.

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