DIET OF THE FIORDLAND CRESTED PENGUIN DURING THE POST-GUARD PHASE OF CHICK GROWTH

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ABSTRACT

The stomach contents of 50 adult Fiordland Crested Penguins were collected during the post-guard phase of chick growth. Twenty-two food species were identified from 19 families. The composition of the diet, expressed as percentages of calculated weight, was 85% cephalopods, 13% crustaceans and 2% fish. The sexes did not differ in their diets. The cephalopods and fish were juvenile and larval forms, indicating that the penguins were feeding on pelagic macro-zooplankton and micro-nekton. The main cephalopod taken was *Nototodarus* sp., and so the penguins were foraging mainly over the continental shelf, which extends no more than 10-15 km from the shore.

INTRODUCTION

Eudyptid penguins characteristically feed offshore on small shoaling species of euphausiids, cephalopods and small fish. The proportions of these three groups in the penguin diet vary between localities, but crustaceans and cephalopods usually make up at least 85% of the diet (Duroselle & Tollu 1977, Croxall & Furse 1980, Croxall & Prince 1980, Williams & Siegfried 1980, Williams & Laycock 1981, Croxall *et al.* 1985, Brown & Klages 1987).

The Fiordland Crested Penguin *(Eudyptes pachyrhynchus)* breeds on the south-west coast of the South Island. Its distribution extends southwards to include Stewart Island, the Solander Islands, and Codfish Island. General features of their growth, breeding cycle, moult and display behaviour have been described by Warham (1974), but very little is known about their diet. In this study I examined the diet of adult Fiordland Crested Penguins during the post-guard phase of chick growth.

METHODS

I visited two colonies in Fiordland: Jackson's Bay on 9-11 October 1984 and Martin's Bay on 4-7 November 1984. At dusk I captured penguins returning from foraging as they made their way up the beach, measured them to sex them (Warham 1974) and weighed them. I was not able to differentiate between breeders and non-breeders.

By water-offloading (Wilson 1984) I collected nine vomits at Jackson's Bay and 41 at Martin's Bay. I decanted off excess fluid and preserved the rest in alcohol in sealed plastic bags.

The vomits were sorted for otoliths, cephalopod beaks, and crustacean remains. I weighed the crustaceans after blotting off surface moisture. Very few fish were entire, and so I sorted, identified and weighed the otoliths and applied allometric equations of Lalas (1983) to calculate both fish length (total length) and weight. Cephalopod beaks were identified as far as possible. I measured upper rostral lengths on squid beaks and upper hood lengths on

TABLE 1 — Species composition of the diet of 50 Fiordland Crested Penguins in Fiordland, South Island

SPECIES		FAMILY	%WT	%OCCUR (n=50)
Cephalopods				
Arrow Squid	Nototodarus sloanii	Ommastrephidae		
Warty Squid	Moroteuthopsis ingens	Onychoteuthidae	71	94
Octopus	Ocythoe tuberculata	Octopodidae		
Octopus	Octopus maorum	Octopodidae	14	52
Crustaceans				
Krill	Nyctiphanes australis	Euphausiidae		
Squillid shrimp		Stomatopoda	13	94
Crab megalopa	Ommatocarcinus macgillveryi	Goneplacidae		
Fish				
Hoki	Macruronus novaezelandiae	Merlucciidae	<1	74
Sprat	Sprattus antipodum	Clupeidae	<1	30
Red cod	Pseudophycis bachus	Moridae	<1	82
Long-snouted pipefish	Stigmatophora macropterygia	Syngnathidae	<1	16
Warehou	Seriolella brama	Centrolophidae	<1	4
Ahuru	Auchenoceros punctatus	Moridae	<1	28
Tarakihi	Nemadactylus macropterus	Cheilodactylidae	<1	2
Monkfish	Kathestoma giganteum	Uranoscopidae	<1	6
Lantern fishes		Myctophidae	<1	8
Common roughy	Paratrachichthys traillii	Trachichthyidae	<1	16
Cockabully	Trypterygion spp.	Trypterygidae	<1	2
Grenadier cod	Tripterphycis gilchristi	Moridae	<1	4
Sole	Peltorhamphus tenuis	Pleuronectidae	<1	10
Maori chief /Black cod	Notothenia angustata	Nototheniidae	<1	2
Silversides	Argentina elongata	Argentinidae	<1	2

beaks and then calculated weight estimates of the animals (Lalas 1983). Because appropriate allometric equations are not available for all of the cephalopod species encountered, I used the equation for *Nototodarus* also for *Moroteuthopsis*, both of which belong to the order Decembrachiata, and I used the equation for *Robsonella australis* (Lalas 1983) also for *Octopus maorum* and *Ocythoe tuberculata*, all three belonging to the family Octopodidae. As they were all small juveniles, any error was probably small. For dorsal mantle lengths I measured only intact mantles. However, I could not weigh entire animals because the tentacle mass and the mantle appear to separate very quickly after ingestion, and were seldom intact. Finally, I calculated the total weights for each species in each stomach sample and the length-frequency distributions for the two most common species of fish.

RESULTS

Number of species

Altogether, 22 species from 19 families were identified from the 50 vomits collected (Table 1). Two vomits contained nothing and were stained green from bile. All stomachs with more than about seven pairs of squid beaks contained both *Nototodarus* and *Moroteuthopsis*. In those stomachs, an average of 61% by number of these two cephalopod species were *Nototodarus* and 39% *Moroteuthopsis*. Of the Octopodidae, 94% of all individuals were *Ocythoe*.

Relative importance of species

Of the 22 species recorded, cephalopods and crustaceans contributed 98% of the total weight of food ingested. Of the cephalopods, squid *(Nototodarus* and *Moroteuthopsis)* constituted 71% and Octopodidae 14% of the total (Table 1).

The bulk of the weight of crustaceans was made up of the euphausiid *Nyctiphanes australis*, but occasionally crab megalopa *(Ommatocarcinus macgillveryi)* and squillid shrimps were also present. The remaining 2% by weight was made up of 15 species of fish belonging to 13 families. Red cod *(Pseudophycis bachus)*, hoki *(Macruronus novaezelandiae)*, sprat *(Sprattus antipodum)* and ahuru *(Auchenoceros punctatus)* were in many of the stomachs, whereas the remaining species were in few stomachs.

Percentage frequency of occurrence

In general, frequently occurring species also contributed largely to the bulk of the diet. However, red cod and ahuru were present in 82% and 28% of the stomachs respectively, but they were too small to be significant in terms of weight. Being small, they are digested rapidly, which introduces a potential error in reconstructing the penguin's diet. Both the flesh and otoliths of larval fish consumed early in a foraging trip may well have disappeared by the end of the foraging trip, reducing the apparent contribution of fish in the diet. However, even when such errors are compensated for by multiplying the fish component in the diet by a factor of, say, three, its percentage contribution increases only from 2% to 9%. To get a more accurate correction factor I would need to know the duration of the foraging trip as well as the rate of digestion of larval fish.

Size

The measurements of mantle lengths indicated that only juvenile squid were being taken (Fig. 1). Calculations of fish lengths and weights indicated that the penguins were taking only small larval and post-larval fish which contributed very little to the bulk of the diet. Mean total lengths of hoki and red cod were 35.2 mm (SD = 5.5) and 28.0 mm (SD = 7.3) respectively (Fig. 1).

Sexual differences in diet

Of the 50 penguins captured, 35 were females and 15 males. Their diets were almost identical, cephalopods and crustaceans comprising 98% and 97% respectively of their intake. Patterns of intake of the fish species were essentially similar ($X^2 = 0.56$, $d = 2$, $X^2 = 0.82$, $df = 2$, $p > 0.05$, grouping crustaceans, cephalopods and fish together, for % weight and % occurrence respectively).

Stomach content weights

The mean calculated weight of all stomach contents except the empty ones was 348 g (n = 48, SD = 330, range = 46 - 1608 g). The mean body weight of the penguins was 3.05 kg (n = 48, SD = 0.40, range = 2.1 - 3.9 kg). Total calculated stomach weights were < 10% body weight in 32 birds, < 20% in 13 birds, and 23, 25, 42, 50 and 62% in the remaining birds.

DISCUSSION

With their diet being mainly cephalopods, small crustaceans and post-larval fish, adult Fiordland Crested Penguins in Fiordland in 1984, both male and female, were probably feeding on the macro-zooplankton.

In samples of spilt food and stomach contents from dissected chicks collected between 1966 and 1971, Warham (1974) also found that the identifiable prey

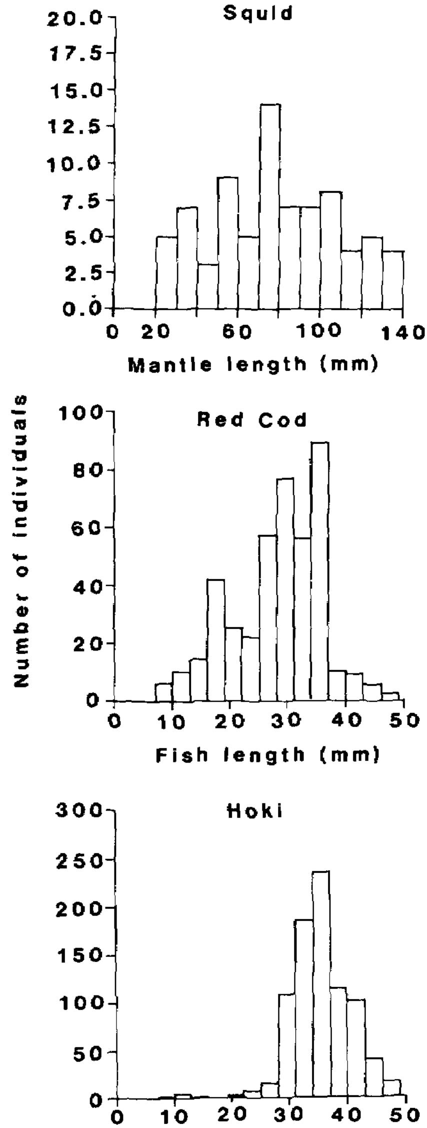

FIGURE 1 — Size-frequency distributions of squid, red cod and hoki found in the stomachs of Fiordland Crested Penguins

of Fiordland Crested Penguins were predominantly cephalopods and sometimes small euphausiids described as being probably *Nyctiphanes australis*. Warham (1974) also found squid beaks up to 10 mm long, far larger than any in this study. Warham (1974) found no identifiable fish remains, but Reischek (1884) claimed young blue cod *(Parapercis colias)* to be the main prey species. I found no blue cod in this study, or in the diet of Fiordland Crested Penguins at another locality (van Heezik 1988) where blue cod were known to be abundant at the time of sampling.

The proportion of cephalopods in the diet compared with crustaceans and fish may be exaggerated by the more rapid digestion of flesh and diagnostic remains (Blake *et al.* 1985, Gaston & Noble 1985, Jackson & Ryan 1986, Adams & Klages 1987). Chitinous cephalopods beaks are likely to remain in the stomach much longer than crustacean remains and fish otoliths. The fish remains in this study were mainly tiny larval fish and hence were rapidly digested. If these fish are totally digested within two hours after ingestion (van Heezik & Seddon, in press), if we assume a foraging trip to last 12 hours, and if fish are taken as much at the beginning as at the end of a trip, and we multiply the weight of the fish by even a factor of 6, the precentage contribution of fish would increase only to 16% of the total weight, compared with 61% squid, 12% octopods and 11% crustaceans.

A further possible bias is that the squid and octopus beaks in the stomach contents had accumulated over more than one day, resulting in an overestimation of cephalopods in the diet. However, the calculated values for weights of squid in individual stomachs are not very high ($n = 46$, $\bar{x}$ = 254 g, SD = 265 g, range = 5 - 1436 g), 43 of these values being less than 600 g. These values are not an unrealistic meal size for an adult which is also feeding a chick (i.e. 8% adult body weight). Meals of King Penguins *(Aptenodytes patagonicus)* varied between 8.5% and 12% of adult body weight, depending on how meal mass was calculated (Adams & Klages 1987). Moreover adults regurgitate loose beaks along with food to their chicks and so regularly pass loose beaks from their stomachs to those of their chicks, as also observed in the King Penguin (Adams & Klages 1987). Almost all the beaks I recovered in each stomach were small and unstained, apparently at the same stage of digestion, i.e. wings intact with little or no sign of abrasion or wear. Therefore it seems likely that most of the beaks in the stomachs of adults feeding chicks had been accumulated during a single foraging trip.

When comparing feeding ranges of Macaroni and Gentoo Penguins, Croxall & Prince (1980) suggested that certain features of the breeding biology of Macaroni Penguins comply with those characteristics described for offshore feeders: only one chick raised per clutch, long incubation stints rather than daily changeovers, fewer and longer foraging trips, and breeding in vast colonies. They made a rough estimate of foraging ranges, based on length of foraging trip and assumed swimming speed. However, when actual foraging ranges are determined by radio telemetry, for several species of penguin they turn out to be smaller than theoretical ranges calculated on the basis of time at sea and average swimming speed (Wilson 1985, Trivelpiece *et al.* 1986). Although the Fiordland Crested Penguin raises only one chick and spends more than one day at sea at a time during incubation (Warham 1974), and possibly throughout fledging also, the relatively large numbers of *Nototodarus* in the diet indicate that foraging is confined to a distance no further than the width of the contenental shelf (Mattlin *et al.*

1985), which extends only about 10 km off the coast near the study sites. This short foraging range implies a distributionally predictable prey (Frost *et al.* 1976). Although little is known about squid and fish off the coast of Fiordland, the diet of the Fiordland Crested Penguin shows that squid and crustacea are abundant and predictable foods during the post-guard chick-feeding phase of the breeding cycle.

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