Species diversity and size ranges of cephalopods in the diet of jackass penguins from Algoa Bay, South Africa

R.M. Randall, B.M. Randall and E.W. Klingelhoeffer
Department of Zoology, University of Port Elizabeth, Port Elizabeth

An analysis of cephalopod remains collected from jackass penguin *Spheniscus demersus* regurgitations and stomachs at St Croix Island, Algoa Bay, in 1976 and 1977 revealed the presence of three cephalopod species. Most common was *Loligo reynaudi*, with *Heterotuthus* sp. and *Argonauta argo* constituting trace items. Beak measurements were used to estimate dorsal mantle lengths and wet masses of cephalopods taken by penguins. The dominant cephalopod taken by penguins was the same species as that harvested by commercial fisheries. Despite an overlap in the size range of squid taken by penguins and trawlers, penguins tended to take smaller squid and did not take the larger squid landed by trawlers. The seasonal occurrence of squid in the penguin diet in 1976 and 1977 was the opposite of the abundance of squid in the area as reflected by trawler landings. This is explained in terms of the abundance and preference for other prey items. It is suggested that penguins take fish in preference to squid because of the relatively higher energy content and food value of fish.

S. Afr. J. Zool. 1981, 16: 163 – 166

'n Analise van die Cephalopoda-oorblyfsels versamel direk uit die mae van Kaapse pikkewyne *Spheniscus demersus* en van die kos wat opgebring word vir die voer van hul kleintjies is gedurende 1976 en 1977 op St Croix Eiland, Algoabaai gedoen. Drie spesies Cephalopoda is gevind waarvan die inkvis *Loligo reynaudi* die meeste was, terwyl *Heterotuthus* sp. en *Argonauta argo* min voorgekom het. Die mantellengte en nat massa van die Cephalopoda wat deur pikkewyne geëet word, is van die snawel afmetings bereken. Pikkewyne vreet dieselfde spesie inkvis wat deur kommersiële treilers gevang word en ofskoon die groottereeks wat hul vreet oorvleuel met dié wat die treilers vang, vreet hulle meesal die kleiner inkvisse en benut hulle nie die groter inkvisse wat die treilers vang nie. Die seisoenale voorkoms van inkvis in die dieet van pikkewyne gedurende 1976 en 1977 is die teenoorgestelde van die voorkoms van inkvis in die omgewing soos weerspieël deur treilervangste. Dit word verklaar in terme van die rykdom en voorkeur aan ander voedselbronne. Die voorkeur vir hierdie ander voedsel mag toegeskryf word aan die hoër energie-inhoud en voedingswaarde daarvan teenoor inkvis.

S.-Afr. Tydskr. Dierk. 1981, 16: 163 – 166

R.M. Randall*, B.M. Randall and E.W. Klingelhoeffer
Department of Zoology, University of Port Elizabeth,
P.O. Box 1600, Port Elizabeth 6000
*To whom correspondence should be addressed

Received 25 September 1980; accepted 4 February 1981

Cephalopods, and in particular squids, are important prey items for many oceanic animals including the toothed whales, seals, game fish, penguins and a variety of pelagic seabirds. A cephalopod is usually represented in the stomach of a predator by its two mandibles, most often called beaks. These chitinous structures are extremely durable, being largely resistant to enzymes and mechanical attrition in the stomach. Clarke (1962) realised the importance of being able to classify cephalopods on the basis of their beaks, and after an extensive review of the Cephalopoda derived useful relationships between beak dimensions and body weights.

Cephalopods have been recorded in the diets of many penguin species (Stonehouse 1967). Stonehouse (1967) found that cephalopods formed the bulk of the king penguin *Aptenodytes patagonica* diet at South Georgia, and Murphy (1936) concluded that they were the principal food of Magellanic penguins *Spheniscus magellanicus* during the breeding season in Patagonia. Davies (1956), Rand (1960), Mathews (1961) and Maclean (1966) recorded squid beaks in the stomachs of jackass penguins *S. demersus*.

During a study of the biology of jackass penguins at St Croix Island a seasonally high incidence of cephalopod remains was noted in penguin regurgitations. Since squid are harvested by commercial fisheries operating in the area we decided to ascertain if penguins and trawlers were taking the same squid species, and if so, whether they were competing for the same size classes. In addition the seasonal occurrence of cephalopods in the penguin regurgitations was examined in relation to a major fish resource exploited by the penguins.

Methods

Over a 17-month period between July 1976 and November 1977 at St Croix Island (33°48′S, 25°46′E) jackass penguin regurgitations and the stomach contents of dead penguins were collected. The collections were made during visits to the island lasting about six days at a time with about 10 days between visits. All regurgitations or stomachs containing cephalopod remains were collected and stored in 70% alcohol. In addition, large, almost undigested pieces of cephalopods were collected from penguin nests. These pieces became available when penguins tried to feed their chicks pieces of food which were too large for the chicks to swallow and consequently

the pieces fell into the nests where they were ignored by the penguins.

For analysis the cephalopod beaks were separated into upper and lower beaks. The minimum number of individual cephalopods represented by the beaks in any one regurgitation or stomach was estimated by counting the upper and lower beaks separately and taking whichever number was higher. One measurement from each lower beak was made using dial calipers, and the measurements made were those specified by Clarke (1962). For the cephalopod families Loliginidae and Sepiolidae the rostral length of the lower beak was measured, while for the family Argonautidae the crest length of the lower beak was measured (Figure 1). If the mantle of the pieces of squid collected from the nests was fresh and showed little sign of digestion then the dorsal mantle length was measured.

Body size estimates, as reflected by dorsal mantle length, were obtained from a lower beak rostral length versus dorsal mantle length regression recalculated from the data of Wessels (1977). Body mass estimates were obtained by extrapolating from published accounts relating lower beak rostral length to body mass (Clarke 1962, Cooper 1979). Means are given throughout ± 1 standard deviation.

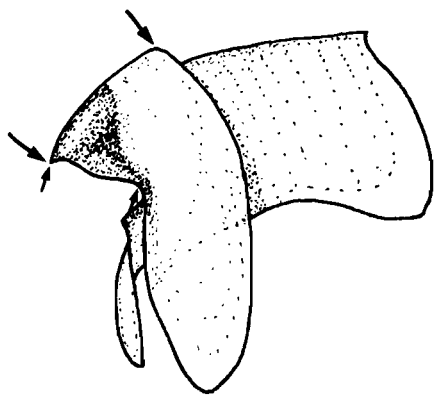

Figure 1 Illustration of the lower beak of *Loligo reynaudi*. The distance between the small arrows represents the rostral length and that between the large arrows the crest length.

Results

Three types of cephalopod beaks representing at least three species were identified in penguin regurgitations and stomachs. These were the common *Loligo reynaudi* (Loliginidae), and the rarer *Heterotuthus* sp. (Sepiolidae) and *Argonauta argo* (Argonautidae). The overwhelming predominance of the Loliginidae indicates that the other two families constituted trace items in the diet (Table 1).

Jackass penguins are unable to digest cephalopod beaks, eye lenses and to a lesser extent the pen. The result is that these parts accumulate at the pyloric end of the stomach, and are eventually regurgitated. Large numbers of beaks may accumulate and become bound into a compact mass, and a maximum of 54 upper plus lower beaks was found in a stomach and 66 in a regurgitation. The variation in the number of beaks represented in either a regurgitation or stomach was considerable, varying between one upper or lower beak and 66 upper plus lower

Table 1 The relative abundance of the three cephalopod families found in jackass penguin regurgitations and stomachs at St Croix Island. This is expressed as the number of regurgitations or stomachs in which the families were represented, and as the minimum number of individual cephalopods represented

	Regurgitations and stomachs		Minimum number cephalopods	
Family	Number	Frequency occur.(%)	Number	Representation (%)
Loliginidae	131	98,4	792	96,0
Sepiolidae	1	0,8	26	3,0
Argonautidae	4	3,0	9	1,0

beaks. Although the mean minimum number of individual cephalopods represented by beaks in the regurgitations [6,30 ± 6,76 (n = 111)] was less than in the stomachs [9,00 ± 10,69 (n = 8)] the difference was not statistically significant ($P < 0,10$, t-test). No penguin regurgitations or stomachs containing cephalopod beaks were found in the months December 1976 to February 1977 inclusive.

Loliginidae

Penguins took a wide range of squid size classes (Figure 2). The mean lower beak rostral length was 0,25 ± 0,07 cm (n = 684) with a range of 0,08 to 0,43 cm. The monthly size frequency distributions of the beaks in all months in which they were obtained indicates that with the exception of March and April 1977 similar size squid were taken throughout (Figure 3).

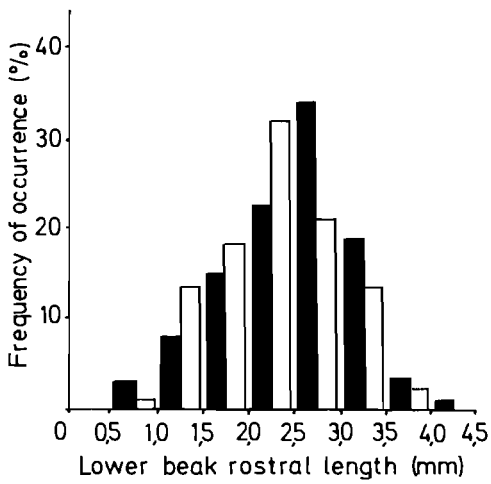

Figure 2 Size frequency histogram of squid *Loligo reynaudi* beaks occurring in the penguin diet. Solid bars represent data from the present study and open bars those from Maclean (1966).

The mean dorsal mantle length of pieces of squid collected at penguin nests was 11,60 ± 1,99 cm (n = 10). From Wessels (1977) we derived a regression relating lower beak rostral length to dorsal mantle length in *L. reynaudi* caught by trawlers in the Algoa Bay area (Figure 4):

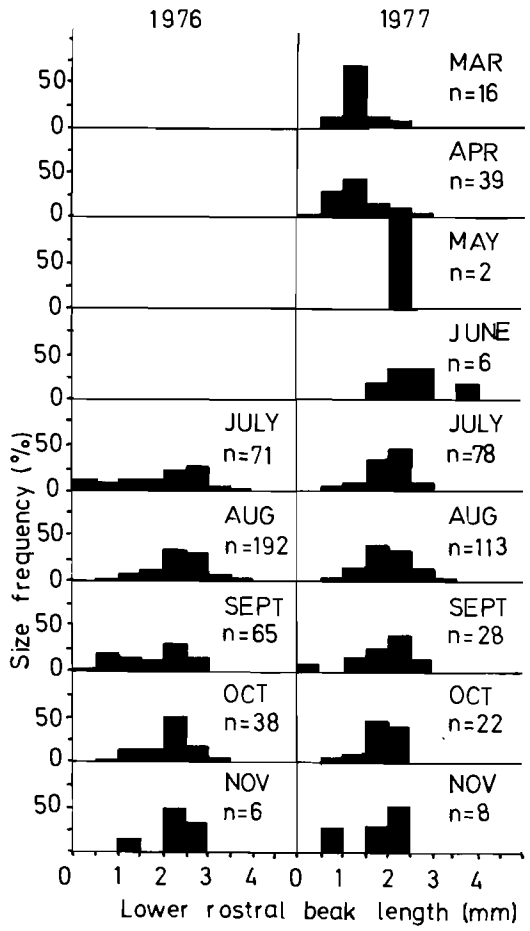

Figure 3 Monthly size frequency histograms of *Loligo reynaudi* beaks in the penguin diet.

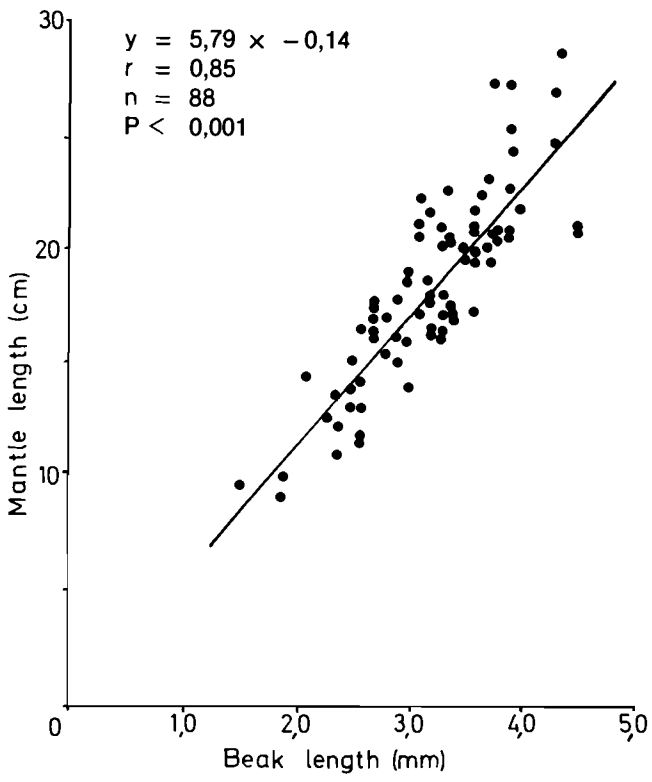

Figure 4 Scatter diagram of mantle length versus lower beak rostral length for *Loligo reynaudi* from the Port Elizabeth area (recalculated from Wessels 1977).

$$Y = 5{,}79\,x - 0{,}14$$

where Y = dorsal mantle length (cm), x = lower beak rostral length (mm). By extrapolation the mean dorsal mantle length of loliginid squid taken by penguins was 14,5 ± 3,9 cm (n = 684).

The wet body mass of squid taken by penguins was obtained by extrapolating from a regression established for *L. reynaudi* on the west coast of South Africa (Cooper 1979):

$$Y = 7{,}33\,x^{2{,}80}$$

where Y = body mass (g), x = lower beak rostral length (mm). On this basis loliginid squid represented in jackass penguin regurgitations and stomachs on St Croix Island had a mean mass of 116,3 ± 73,2 g (n = 684).

Sepiolidae

One stomach containing 46 small beaks, 20 upper and 26 lower, identified as *Heterotuthus* was found in September 1977. The mean lower beak rostral length was 0,13 ± 0,03 cm (n = 26).

The wet body masses were estimated by extrapolating from the generalised regression for the family Sepiolidae established by Clarke (1962):

$$\log y = 3{,}01 \log x + 3{,}41$$

where y = body mass (g), and x = lower beak rostral length (cm). This indicated a mean sepiolid body mass of 6,7 ± 5,1 g (n = 26).

Argonautidae

The highly characteristic *Argonauta argo* beaks were found in two regurgitations and two stomachs. These were found in July 1976, September 1977 and two in November 1977. *A. argo* was represented by 14 beaks, six of which were upper beaks and eight lower.

The lower beak crest length was 0,55 ± 0,15 cm (n = 8). The sample available to Clarke (1962) was inadequate for regressing body mass against lower beak crest length, but by comparison with his scatter diagram the mean body mass of argonauts taken by penguins was less than 10 g.

Discussion

Loligo reynaudi which forms the bulk of the jackass penguin cephalopod diet is the same species as that taken by commercial fisheries operating in the area (Hecht 1976, Wessels 1977). An analysis of squid caught by trawlers in the Port Elizabeth area during 1977 revealed that the mean lower beak length of *L. reynaudi* was 0,32 ± 0,06 cm (n = 88) with a range of 0,11 to 0,46 cm (Wessels 1977). Although there was overlap in the size of loliginid squid taken by penguins and trawlers, 91% of those taken by fisheries were above the mean size occurring in the penguin diet. Based upon a comparison of lower beak rostral lengths loliginid squid represented in the penguin diet were found to be significantly smaller than those taken by trawlers ($P < 0{,}001$, t-test).

Squid taken by jackass penguins on the west coast of South Africa have also been identified as *L. reynaudi* (Davies 1956, Mathews 1961). In addition small numbers of sea-cats (Octopodidae) and cuttlefish (Sepiidae) have

been identified in penguin stomachs from the west coast (Rand 1960). The maximum number of 66 beaks recorded in a regurgitation from St Croix Island is considerably less than the 243 found in a stomach by Rand (1960) and the 327 found by Maclean (1966). However, the mean of six per stomach recorded by Rand (1960) is similar to that observed at St Croix Island.

The abundance of squid *L. reynaudi* in the Port Elizabeth area as reflected by trawler landings over a nine year period shows a marked seasonal pattern (Hecht 1976). Based on a catch-per-unit-effort basis Hecht showed that squid abundance declines from April to reach a low point in July, and then increases gradually to reach a peak in the summer months. This is the exact opposite of the occurrence of squid in the penguin diet in 1976 and 1977, when squid was not frequently encountered in the winter months and was absent in the summer months (December to February). We believe this can be explained in terms of the abundance and greater food value of other prey species. The South African pilchard *Sardinops ocellata* can be used to illustrate the point. The pilchard is one of the most important prey items in the penguin diet, both on the west coast and in Algoa Bay (Davies 1956, Rand 1960, Mathews 1961, present study unpublished). Pilchard abundance increases seasonally in the area every year when pilchards pass Port Elizabeth on their annual migration from the southern Cape to Natal, culminating in the 'sardine run' (Crawford & Shelton 1978). Both 1976 and 1977 were paticularly bad years for the sardine run (van der Byl 1979). It may be inferred from this that pilchards were scarcer in those years in Algoa Bay as well. Penguins would therefore have been compelled to concentrate on other food sources, including squid. The scarcity of squid in the penguin diet in 1978 and 1979, both good years for the sardine run (van der Byl 1979), supports this hypothesis.

It appears therefore that given a variety of prey species penguins take fish in preference to squid, and although this might be related to availability it can also be explained in terms of energy content and food value if *S. ocellata* and *L. reynaudi* are compared. On a wet mass basis *S. ocellata* has an energy content of 7,1 kJ/g compared to 3,9 kJ/g for *L. reynaudi* (Coetzee 1978). An analysis of body composition revealed that *S. ocellata* was 20,1% protein, 7,9% fat, 3,2% ash and 69,2% water; as against *L. reynaudi* which was 15,8% protein, 1,3% fat, 1,6% ash and 81,3% water (Coetzee 1978). The selective advantages of *S. ocellata* as opposed to *L. reynaudi* as a food source are immediately apparent, particularly in terms of energy, fat and protein content. Evidence of selectivity by seabirds for prey species of higher food value has been demonstrated by Harris & Hislop (1978). They showed that the fish species fed by puffins *Fratercula arctica* to their chicks were not a true reflection of the relative abundance of those species in the area, and that the puffins were selecting species with a higher calorific value and protein content.

Acknowledgements

This work formed part of a study on the biology of jackass penguins on St Croix Island and was made possible by a grant from the Department of Water Affairs, Forestry and Environmental Conservation. Dr G.J.B. Ross, Port Elizabeth Museum, and Dr M.J. Imber, Wildlife Service New Zealand, are thanked for their assistance with identification. Professor Erasmus commented on the manuscript and Mrs M.F. Olivier assisted with its preparation.

References

CLARKE, M.R. 1962. The identification of cephalopod beaks and the relationship between beak size and total body weight. *Bull. Br. Mus. Nat. Hist.* 8: 419–480.

COETZEE, A.N. 1978. Die retensiedoeltreffendheid van verskeie voedselsoorte by die Kaapse Pikkewyn (*Spheniscus demersus*). Unpubl. B.Sc. Hons. project. University of Port Elizabeth, Port Elizabeth, South Africa.

COOPER, J. 1979. Length-mass relationships, water content and energy values for two species of squid, *Loligo reynaudi* and *Todanopsis eblanae* off the south-western Cape. *Fish. Bull. S. Afr.* 11: 43–45.

CRAWFORD, R.J.M. & SHELTON, P.A. 1978. Pelagic fish and seabird interrelationships off the coasts of South West and South Africa. *Biol. Conserv.* 14: 85–109.

DAVIES, D.H. 1956. The South African pilchard (*Sardinops ocellata*) and maasbanker (*Trachurus trachurus*). Bird predators, 1954–1955. *Investl Rep. Div. Fish. Un. S. Afr.* 23: 1–40.

HARRIS, M.P. & HISLOP, J.R.G. 1978. The food of young Puffins *Fratercula arctica*. *J. Zool., Lond.* 185: 213–236.

HECHT, T. 1976. The general biology of six major trawl fish species of the eastern Cape coast of South Africa, with notes on the demersal fishery, 1967–1975. Unpubl. Ph.D. thesis, University of Port Elizabeth, South Africa.

MACLEAN, G.L. 1966. Cephalopod beaks from the stomach of a jackass penguin *Spheniscus demersus* Linnaeus. *Zool. Afr.* 2: 27–30.

MATHEWS, J.P. 1961. The pilchard of South West Africa (*Sardinops ocellata*) and the maasbanker (*Trachurus trachurus*). Bird predators, 1957–1958. *Investl Rep. mar. Res. Lab. S. W. Afr.* 3: 1–35.

MURPHY, R.C. 1936. Oceanic birds of South America. Vol. 1 and 2, American Museum of Natural History, New York.

RAND, R.W. 1960. The biology of guano producing sea-birds. The distribution, abundance and feeding habits of the Cape penguin, *Spheniscus demersus*, off the south-western coast of the Cape Province. *Investl Rep. Div. Fish. S. Afr.* 41: 1–28.

STONEHOUSE, B. 1967. The general biology and thermal balances of penguins. *Adv. Ecol. Res.* 4: 131–196.

VAN DER BYL, P. 1979. The Natal sardine run, annual report no. 2. Int. rep. Sea Fish. Branch, Durban, South Africa.

WESSELS, E.D. 1977. Squid — an energy source to penguins. Unpubl. B.Sc. Hons. project, University of Port Elizabeth, Port Elizabeth, South Africa.