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Utilization Efficiency of a Squid Diet by Adult King Penguins (*Aptenodytes patagonicus*)

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Published values for the utilization efficiency of seabirds have come entirely from work on chicks and juveniles fed exclusively on fish (Dunn 1975; Cooper 1977, 1978, 1980). Squid is an important component of the diet of many species, however, comprising up to 90% of prey taken by King Penguins (*Aptenodytes patagonicus;* Stonehouse 1960, Croxall and Prince 1980, Croxall 1984). Because the utilization efficiency of birds is known to vary depending on the food consumed (Uramoto 1961), the applicability of the published data to such species is uncertain. This study presents the first measurements of the assimilation efficiency of a predominately squid-eating adult seabird fed on squid.

The study was conducted at sub-Antarctic Marion Island (46°54'S, 37°55'E) during September 1981 and April 1982. Four nonbreeding adult King Penguins were housed indoors, individually confined to small cages, and fasted for 48 h before commencement of the experiment. Room temperature varied between 5°C and 15°C, within the thermoneutral zone of King Penguins (Groscolas et al. 1981). The penguins were then fed for 5 days on a diet consisting exclusively of the South Atlantic cool-water squid *Loligo reynaudi.* Each bird was weighed daily before being fed a known mass of food sufficient for it to maintain constant mass over the period of the experiment. A preweighed plastic sheet underneath a wire mesh floor allowed for the daily collection of excretory products, which were then dried to constant mass at 60°C. Homogenized portions of oven-dried squid and excretory products were analyzed individually for energy content with a Phillips micro-bomb calorimeter. Utilization efficiency was calculated as gross energy intake minus excretory energy expressed as a percentage of gross energy intake.

Gross energy intake, excretory energy, and utilization efficiency were calculated per bird over the 5 days and the averaged results for the four birds are given in Table 1. The wet mass of food consumed daily averaged 6.1% of total body mass. The daily squid intake of 699 g/d was close to the 675 g/d of fish fed to King Penguins maintained at the Montreal Aquarium (Penfold 1979). The energy value of squid was 22.1 ± 0.5 kJ/g dry mass (n = 8; 5.23 kJ/g wet mass), a value 14% higher than that obtained by Cooper (1979) for the same species. Excretory output was similar to that measured by Burger et al. (1978), averaging 8.4% higher. The energy value of excretory products was 13.2 ± 0.7 kJ/g dry mass (n = 23), a value 8.3% lower than that obtained by Burger et al. (1978). The mean efficiency of utilization of four birds was 81.3%.

The calculated utilization efficiency of captive adult King Penguins fed squid is near the upper limits of the range observed for young piscivorous seabirds fed on fish (Table 2). Estimates of food consumption by squid-eating species based on these data (e.g. Prince et al. 1981, Croxall and Prince 1982a) will therefore be substantially correct. This confirmation has considerable ecological significance for bioenergetics modelling (see Croxall and Prince 1982a), because King Penguins and other squid-eating species comprise a large proportion of the total seabird biomass in the sub-Antarctic region.

Published values for the energy content of squid, mainly from the northern hemisphere, are appreciably lower than those for the energy content of Antarctic krill and fish (Croxall and Prince 1982b). The energy value of squid meals fed to Black-browed (*Diomedea melanophris*) and Grey-headed albatross (*D. chrysostoma*) chicks at South Georgia, however, fall within the range measured for Antarctic fish (Clarke and Prince 1980) and krill (*Euphausia superba;* Clarke

TABLE 1. Gross energy intake, excretory energy, and utilization efficiency of King Penguins.

	Bird mass (kg)	Energy input (kJ/d)	Energy excreted (kJ/d)	Utilization efficiency (%)
Mean	11.53	3,605.6	677.3	81.3
Range	11.3–11.75	4,495.0–2,955.3	469.2–873.6	79.8–84.3

TABLE 2. Efficiency of utilization of squid and fish by seabirds.

Species	Age class	*n*	Diet	Utilization efficiency (%)	References
Great White Pelican (*Pelecanus onocrotalus*)	Juvenile	1	Fish	73.0	Cooper 1980
Cape Gannet[a] (*Sula capensis*)	Chick	2	Fish	74.2	Cooper 1978
Jackass Penguin[a] (*Spheniscus demersus*)	Chick	2	Fish	75.3	Cooper 1977
Cape Gannet (*Sula capensis*)	Juvenile	2	Fish	76.1	Cooper 1978
Adélie Penguin (*Pygoscelis adeliae*)	Chick	?	?	80.0	D. P. Da Costa in Kooyman et al. 1983
King Penguin (*Aptenodytes patagonicus*)	Adult	4	Squid	81.3	This study
Double-crested Cormorant[a] (*Phalacrocorax auritus*)	Chick	>6	Fish	85.0	Dunn 1975

[a] Utilization-efficiency values are averages over the growth period.

1980). These data re-emphasize the need for compositional analyses of individual prey items available to Antarctic and sub-Antarctic predators and for further investigation into whether or not variation in energy content of prey may be reflected in avian utilization efficiencies.

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Egg Retrieval by Canada Geese: Apparent Interspecific Retrieval and Tests of Egg Displacement

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Egg retrieval, an innate behavioral pattern in which birds roll displaced eggs into their nests by using their bills, was first described in detail in the Greylag Goose (*Anser anser*) (Lorenz and Tinbergen 1939). Prevett and Prevett (1973) reported that egg retrieval occurred in numerous species of ground-nesting birds, including a number of species of Anseriformes, but made no reference to this behavior in Canada Geese (*Branta canadensis*). Kossack (1950: 644) thought it unlikely that Canada Geese retrieved eggs, because he found eggs lying outside and yet near their nests. This note reports: (1) an incident in which a Canada Goose apparently "retrieved" the eggs from a nearby Northern Pintail (*Anas acuta*) nest, and (2) the results of tests to confirm egg retrieval in Canada Geese and to determine the distance over which they would retrieve eggs.

On 24 April 1982, a pintail nest with four eggs was found 45 cm from the edge of a Canada Goose nest containing three eggs. The nests were on an island about 35 km southeast of Brooks, Alberta. Two days later, the pintail nest contained six eggs and the goose nest contained five. When the nests were checked 4 days later, the goose was incubating five goose eggs and five pintail eggs, having apparently rolled the pintail eggs into her nest. Only a small ball of nest material remained where the pintail nest had been. On 17 May the goose nest contained only the five goose eggs. A few small fragments of eggshell were found around the nest, and I surmise that the pintail eggs were either depredated by gulls [I observed California Gulls (*Larus californicus*) and Ring-billed Gulls (*Larus delawarensis*) eating duck eggs but very seldom goose eggs] or were accidentally broken and subsequently removed by the goose. In light of Prevett and Prevett's (1973) hypothesis that egg retrieval may occur only after incubation has begun, it is interesting to note that the pintail eggs were not "retrieved" until after the goose had completed laying.

To investigate egg retrieval behavior in Canada Geese, egg displacement tests were conducted between 13 and 17 April 1983 on geese nesting in the area of the observation. One egg per nest was taken from 34 nests and placed at one of the following distances from the nest: 25, 50, 75, or 100 cm. The distance was measured from the center of the displaced egg to the outer edge of the nest bowl. The displaced eggs were marked with indelible ink and positioned so as to be readily visible from the nest. About 50% of the geese were laying at the time of egg displacement; virtually all, however, had finished laying when the eggs were checked 4–6 days later. Of the 32 geese that continued incubation, all 27 with eggs placed at 25–75 cm from the nest retrieved the egg (10 from 25 cm, 8 from 50 cm, and 9 from 75 cm). In one case the egg was rolled to the edge of the nest but not into the nest bowl. Four of the 5 eggs placed 1 m from the nest were retrieved. Prevett and Prevett (1973) found that 95 cm was about the maximum distance that eggs were retrieved by Snow Geese (*Chen caerulescens*). The tests reported here suggest that 1 m may be approaching the limit from which Canada Geese will retrieve eggs. They may not, however, retrieve eggs at much over 1 m; in 1983 a Mallard (*Anas platyrhynchos*) nest, located 110 cm from a Canada Goose nest, remained undisturbed by the goose. Kossack's (1950) impression that Canada Geese do not retrieve eggs may have been based on observations of eggs that were lying beyond the egg retrieval limit. The retrieval limit indicated here for