

PELLETS OF CAPE CORMORANTS AS INDICATORS OF DIET

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ABSTRACT.—Pellets of Cape Cormorants (*Phalacrocorax capensis*) are cast daily and can be used to determine prey species through identification of otoliths and other indigestible parts. Experiments in captivity indicate that some otoliths may be partially or entirely digested, making it impossible to estimate the original size or number of fish ingested per meal or per day.

Birds of various species regurgitate casts or pellets of indigestible material (Knight 1964). Pellets of cormorants could be useful for studying diets of these birds because sampling is non-destructive and large samples can be obtained with little disturbance to the birds (Ainley et al. 1981). Crystals of fish eyes taken from pellets might be counted to estimate daily food intake (Jordan 1959, Schlatter and Moreno 1976), and otoliths could be useful in identifying the species and sizes of fish consumed by the birds.

However, certain aspects of pellet production require investigation before pellets can be used for either quantitative or qualitative studies. How frequently are pellets cast? Does a pellet (accurately) reflect a meal or a bird's daily consumption of food? Do otoliths remain unchanged while residing in a bird's stomach, so that otoliths can be used to estimate the sizes of the fish eaten? How long do otoliths persist in a bird's stomach? We report here on studies designed to answer these questions, using information obtained from pellets produced by captive Cape Cormorants (*Phalacrocorax capensis*).

METHODS

Seven adult Cape Cormorants were taken from Dyer Island (34°41'S, 19°15'E), Cape Province, South Africa, on 19 November 1981. The birds were transported overnight by sea to Cape Town and placed in cages. They were kept in the cages for six weeks until their weights stabilized and they became accustomed to captivity. Birds were grouped in two cages of two individuals and one cage of three, because they refused to eat if kept separately. During the experimental period, the birds were fed commercially obtained horse mackerel (*Trachurus capensis*; 140 mm) and cape anchovy (*Engraulis capensis*; 120 mm). Birds were fed twice daily (10:00 and 16:00) by throwing them fish, until satiated. Cages were carefully searched

for pellets at 08:00, after which the birds were weighed.

Recovered pellets were measured to the nearest millimeter for maximum length and their volumes determined by displacement in water. Each pellet was then cut open and any otoliths and eye crystals extracted and counted. Three experiments were carried out:

Experiment one. Does the composition of pellets accurately reflect daily food intake? We counted the number of otoliths and eye crystals in pellets in relation to the number of fish consumed. The size and number of fish fed to each bird in each cage were noted. The number of pellets produced one day later was recorded for each cage. We combined the number of fish fed and number of pellets produced within each cage, since we did not know which bird produced each pellet within a cage. If pellets perfectly reflected fish intake, and if pellets are produced daily, the number of otoliths and eye crystals should have been twice the number of fish consumed the day before.

Experiment two. Can otolith size be used to estimate the length or mass of the original fish? Do otoliths become reduced by residence in the digestive tract or are different sizes of otoliths affected differently? We measured otoliths from 100 horse mackerel picked from a sample being fed to the birds and compared these with 100 otoliths extracted from cormorant pellets. Otoliths were measured by means of an ocular grid in a microscope. We also compared 50 otoliths of anchovy extracted from pellets with 40 otoliths extracted from a sample of fish used to feed the birds. Finally, we compared the sizes of otoliths from 37 anchovies regurgitated on Dyer Island on 19 November 1981 with 36 anchovy otoliths extracted from pellets collected on Dyer at the same time.

Experiment three. How long do otoliths persist in cormorant stomachs? We fed the birds horse mackerel, switched to anchovy for three days, then switched back to horse mackerel.

The otoliths in pellets were monitored for the three days following each change.

RESULTS

Pellets varied greatly in size and composition. Of 81 examined, 30% contained no apparent indigestible remains and appeared to be just thick mucous. The mean length of all pellets was 19.4 mm (SD = 0.65; $n = 81$) and for pellets with contents was 21.0 mm (SD = 5.8; $n = 56$). The mean displacement for all pellets was 1.08 ml (SD = 0.62; $n = 83$) and for those with hard contents, 1.25 ml (SD = 0.63; $n = 58$).

Cages with two birds produced a mean of 3.5 pellets per day (SD = 1.87; $n = 22$), of which those with fish remains had a mean frequency of 2.23 per day (SD = 1.27; $n = 22$). In the cages with three birds, the mean for all pellets was 4.91 per day (SD = 2.02; $n = 11$), of which those with contents averaged 2.91 (SD = 1.51; $n = 11$). The total number of pellets per bird per day was 1.64–1.75, and for pellets with indigestible contents, the rate was 0.97–1.11.

EXPERIMENT ONE

The number of otoliths and eye crystals ingested (number of fish \times 2) was significantly correlated with the number produced in pellets the next day (otoliths: $r = 0.45$; $P < .05$; $n = 33$; crystals: $r = 0.47$; $P < .05$; $n = 33$). However, intake explained only about 20% of the variation in otolith ($r^2 = 0.20$) or eye crystal ($r^2 = 0.22$) production.

Comparing the numbers of otoliths and crystals in fish ingested with the number produced in pellets one day later, we recovered only 33.2% of the otoliths (SD = 20.3; $n = 32$) and 51.4% of the crystals (SD = 25.8; $n = 32$).

EXPERIMENT TWO

The mean length of otoliths extracted from intact horse mackerel was 5.185 mm (SD = 0.3631; $n = 100$) while the mean length of otoliths extracted from pellets of birds fed the same-sized fish was 3.699 mm (SD = 0.760; $n = 100$). The difference was significant ($x_1 - x_2 = 1.49$; 95% confidence limits = -0.165 to $+0.165$; $df = 154.7$; t -test with correction for unequal variance). Otoliths from pellets had a significantly greater variance of size than those taken directly from fish (F -test = 4.43; $P < .01$).

The mean length of anchovy otoliths extracted directly from fish was 3.119 mm (SD = 0.258; $n = 40$) while the mean length from pellets was 2.333 mm (SD = 0.548; $n = 50$). This difference was also significant ($x_1 - x_2 = 0.786$; 95% confidence limits = -0.185 to $+0.185$; $df = 70.60$; t -test with correction for unequal

variances; F -test = 4.55; $P < .01$). The mean size of otoliths extracted from anchovy regurgitated by cormorants on Dyer Island on 19 November 1981 was 5.21 mm (SD = 0.56; $n = 37$) but the mean length from pellets was only 3.90 mm (SD = 0.47; $n = 36$). The two means are significantly different at the 0.05 level ($t_{\text{calc}} = 10.82$; $t_{\text{crit, } \alpha = 0.05} = 1.980$; s^2 equal at 0.05 level, F -test).

EXPERIMENT THREE

The day following the change from one kind of fish to another, all four collections of pellets showed only otoliths of the new species (otoliths in four samples examined = 56, 45, 29, 41). Otoliths of the original species did not appear on the second day (otoliths in four samples = 20, 48, 6, 13) or on the third (otoliths in two samples = 54, 36).

DISCUSSION

Regurgitated pellets provided little information on the daily intake of fish by Cape Cormorants, based on the recovery of either otoliths or eye crystals. Two-thirds of the former and half of the latter were lost, either through being dissolved or being defecated. In addition, because a bird may produce more than one pellet per day, it is unlikely that pellets contain a consistent proportion of otoliths or eye crystals of each day's intake of food. Similarly, the birds were fed twice a day yet produced less than two pellets per day; hence, it is also unlikely that the contents of pellets reflect individual meals.

Otoliths recovered from pellets do not seem to be a valid indication of the size of the original fish. Otoliths were reduced by at least 25% in length between ingestion of the fish and production of the pellet. Correction factors to compensate for shrinkage of otoliths could perhaps be derived but would probably have to be determined separately for individual species. Such specific corrections would themselves be useless if decrease in otolith size varied seasonally or with the stage of the bird's reproductive cycle. Eye crystals may be more resistant to abrasion (Jordan 1959, Schlatter and Moreno 1976) but do not allow identification to species or determination of size of the original fish (Schlatter and Moreno 1976).

The percentage of otoliths recovered in pellets and their degree of shrinkage may depend on several factors. Calcium demands and absorption can vary from day to day (Simkiss 1975). High uptake of calcium may result in fewer and smaller otoliths in pellets. The size of the meal may also be important. Otoliths in the middle of the food bolus may be more likely to pass through the digestive tract. Those

on the outside might become embedded in the cuticular lining during contractions of the gizzard. Finally, the size of the fish may be a factor. Many small fish would have a proportionally greater mass of otoliths than a similarly-sized meal of a few large fish, with the consequence that less calcium might be digested from the meal of smaller fish. On the other hand, the smaller otoliths would have more surface in proportion to their volume, and hence be more subject to digestive processes. Experimental work with marked and known-size otoliths, diets supplemented with calcium, and varied meal sizes might help to explain variations in pellet contents.

Despite limitations, pellets can still be useful in studies of cormorants and their diets. Most otoliths survive passage through the gut and pellet with enough structure to enable determination of the fish species. Squid beaks and other hard parts, such as carapaces of crustacea, also occur in pellets (pers. observ.). If not scavenged by gulls or other birds, accumulations of pellets can be sampled annually, at the end of the breeding season (e.g., Ainley et al. 1981), or more frequently. They are thus ideal for long-term, inexpensive studies of changes in the marine environment. Based on knowledge of the general characteristics of a cormorant species' foraging behavior (distance foraged, depth foraged, size of foraging group), data from a network of collection points would present a general picture of distribution of prey species at a cost far below other methods such

as mid-water trawls from oceanographic vessels.

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