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DIET OF THE IMPERIAL CORMORANT *PHALACROCORAX ATRICEPS*: COMPARISON OF PELLETS AND STOMACH CONTENTS

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SUMMARY

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A total of 45 pellets from the Imperial Cormorant or Blue-eyed Shag *Phalacrocorax atriceps* was collected in January 1994 at Duthoit Point, Nelson Island, South Shetland Islands. The analysis showed fish as the main prey, followed by octopods, polychaetes and gastropods. *Notothenia coriiceps* formed the bulk of the diet, but *Harpagifer antarcticus* was the most frequent and important fish in number. The prey items represented in the pellets were consistent with those observed in stomach contents sampled simultaneously in the same colony; however, they differed in importance. A daily mean of 0.7 pellets per bird was collected, representing 255 g of fish. Correction factors previously estimated in a feeding trial were applied to this value, and suggested that the average daily amount of food ingested by an adult cormorant during the sampling period was 1325 g, which falls within the range observed by stomach content analysis. Other aspects related to the feeding behaviour of the species are also discussed.

INTRODUCTION

Due to the similarity found between demersal fish species sampled in coastal waters using conventional gears and those represented in pellets of cormorants occurring in the same area (Duffy & Laurenson 1983, Duffy *et al*. 1987, Wanless *et al*. 1992, Casaux & Barrera-Oro 1993a) the Imperial Cormorant or Blue-eyed Shag *Phalacrocorax atriceps* has been considered as a potential indicator of changes in the diversity and abundance of Antarctic littoral fish populations (Casaux & Barrera-Oro 1993a,b). However, due to the erosion of otoliths and their loss through the gastrointestinal tract, the analysis of pellets may give biased results if no preliminary trials are carried out to establish their quantitative and qualitative adequacy (see Hartley 1948). Duffy & Laurenson (1983) and Johnstone *et al*. (1990) carried out feeding trials with Cape Cormorants *P. capensis* and European Shags *P. aristotelis*, respectively, and observed that the otoliths of several fish species were affected differentially by the digestive process. In a similar experiment on an Imperial Cormorant, Casaux *et al*. (1995) succeeded in obtaining pellets from an individual fed with known quantities of local fish species allowing species-specific correction factors to be estimated to compensate for the loss and digestion of otoliths.

Recently, the examination of stomach contents of Imperial Cormorants collected when birds returned to the colony from foraging trips was used to obtain reliable information on the number and size of the fish species ingested, thus minimising the errors which arose from pellet analysis (Coria *et al*. 1995). The aim of this study is to compare the diet of the Imperial Cormorant by the analysis of pellets and stomach contents collected concurrently. Likewise, the accuracy of correction factors already estimated is tested.

METHODS

Forty-five regurgitated pellets were collected from 5–8 January 1994 in an Imperial Cormorant colony at Duthoit Point (62°18' S, 58°47' W), Nelson Island, South Shetland Islands, Antarctica. At that time the chicks weighed a mean of 1382 g (n = 35, S.D. 508 g), which means they were approximately 22 days of age (range 15–27 days) (M. Favero unpubl. data).

Pellets were obtained by visiting 11 marked nests every 12 hours (10h00 and 22h00 local time). The activity of the Greater Sheathbill *Chionis alba* in the colony during the sampling period was negligible. The samples were dried to constant mass at 60°C. The contents were sorted into prey classes under a binocular microscope. The otoliths (all sagittal) were cleaned and identified, where possible, to species using descriptions and illustrations in North *et al*. (1984), Hecht (1987) and Williams & McEldowney (1990) and our own reference collections. They were separated into right and left, the most abundant being considered as the approximate number of fish present by species in each pellet. Total length (TL) in cm and mass in grams of these fish were calculated by means of equations estimated from measurements of otolith length (OL).

TABLE 1

Diet composition of the Imperial Cormorant *Phalacrocorax atriceps* at Duthoit Point, Nelson Island as shown by the analysis of regurgitated pellets and stomach contents

	Regurgitated pellets			Stomach contents		
	Freq. % N = 45	N %	Mass %	Freq. % N = 40	N %	Mass %
Fish (bones – otoliths)	100.0	88.5	97.3	100.0	96.3	99.6
Octopods (beaks)	88.9	9.8	2.6	7.5	1.1	0.4
Polychaetes (mandibles)	20.0	1.7	0.1	2.5	1.1	0.0
Snails (shell)	4.4	0.1	0.0	—	—	—
Gammarids (exoskeletons)	—	—	—	2.5	1.5	0.0
Algae	33.3	—	—	—	—	—
Stones	97.8	—	—	—	—	—
Feathers	7.8	—	—	—	—	—
Eye lens	22.2	—	—	—	—	—

The equations were:

Notothenia coriiceps [2]
$TL = -11.4918 + 11.31757*OL$ cm (n = 161)
$MASS = 0.0032*TL^{3.4407} + 25.439$ g (n = 501)
Harpagifer antarcticus [2]
$TL = 3.268603 + 1.812654*OL$ cm (n = 124)
$MASS = -123.1464*TL^{-0.5804228} + 45.39072$ g (n = 124)
Nototheniops nudifrons [1]
$TL = 0.37 + 3.19*OL$ cm (n = 46)
$SL = 33.78*OL^{0.96}$ mm (n = 11)
$MASS = 4.01*10^{-7}*SL^{3.81}$ g (n = 11)
Trematomus newnesi [2]
$TL = 1.568699 + 4.166653*OL$ cm (n = 84)
$MASS = 0.146477*TL^{2.127549}$ g (n = 77)
Gobionotothen gibberifrons [1]
$TL = 17.64*OL^{1,468}$ mm (n = 85)
$MASS = 2.98*10^{-6}*TL^{3.2}$ g (n = 78)
Pagothenia bernacchii [1]
$TL = 53.52*OL^{0.979}$ mm (n = 32)
$MASS = 9.76*10^{-7}*TL^{3.44}$ g (n = 20)

[1] Taken from Hecht (1987). Data from fish collected at Elephant Island, South Shetland Islands and South Georgia Islands.
[2] Calculated using unpublished fish data from Potter Cove.

The results were compared to those obtained by Coria *et al.* (1995) from stomach contents (N = 40) collected simultaneously in another area of the colony applying the “shaking” technique used by Cooper (1985) and Coria *et al.* (1995). To compensate for the loss and digestion of the otoliths found in pellets, correction factors estimated in a previous feeding trial on a captive Imperial Cormorant fed with known quantities of fish were used (Casaux *et al.* 1995). These factors were calculated for species comparing the mass ingested by the cormorant to the mass estimated from the pellets recovered; the values were: *Harpagifer antarcticus* 3.5 ×, *Gobionotothen gibberifrons* 1.3 ×, *Notothenia coriiceps* 9.2 × and *Trematomus newnesi* 5 ×.

RESULTS

A total of 45 pellets was recovered from the 11 marked nests, representing a daily average of 0.7 pellets produced per adult. Because there was no evidence of pellets being produced by chicks we assumed that all pellets were produced by adults. Since the cormorants made between three and five foraging trips per day during the sampling period (Coria *et al.* 1995), the fish ingested in four to seven foraging trips were represented in one regurgitated pellet.

TABLE 2

Comparison between the fish species represented in pellets and stomach contents of the Imperial Cormorant *Phalacrocorax atriceps* from Duthoit Point, Nelson Island

Species	Regurgitated pellets			Stomach contents		
	Freq. %	N %	Mass %	Freq. %	N %	Mass %
Notothenia coriiceps	39	3	40	58	12	65
Nototheniops nudifrons	49	20	21	25	47	23
Harpagifer antarcticus	85	59	33	20	25	5
Trematomus newnesi	17	1	2	13	7	4
Pagothenia bernacchii	2	0	0	—	—	—
Gobionotothen gibberifrons	42	2	4	—	—	—
Pleuragramma antarcticum	—	—	—	3	0	0
Unidentified	71	14	—	50	9	4

Analysis of pellets showed that fish were by far the main prey, followed by octopods, polychaetes and gastropods (Table 1). A total of 3243 otoliths was found and assigned to 1931 fish; 1656 of them were identified to six demersal-benthic species: *H. antarcticus, Nototheniops nudifrons, G. gibberifrons, Notothenia coriiceps, T. newnesi* and *Pagothenia bernacchii*. *Harpagifer antarcticus* was the most frequent fish (F = 85%) and important by number (59%), whereas *N. coriiceps* prevailed in mass (40%) (Table 2). The smallest and largest specimens represented were *G. gibberifrons* (TL = 2.7 cm) and *N. coriiceps* (TL = 32.0 cm), respectively (Table 3). The mean number of fish per pellets was 47 (range 1–120, SD = 42); and 10 pellets (22%) were composed of a single species, most of them containing large *N. coriiceps* specimens. The mean total mass of fish represented per pellet was 364 g (range 2–1242 g, SD = 240.7 g). Because the cormorants produced an average of 0.7 pellets per day, the mean mass of fish represented in pellets per day was 255 g. Considering the percentage in mass in pellets (Table 2), we calculated the proportion in grams corresponding to each species. Applying to these values the correction factors obtained in the feeding trial by Casaux *et al*. (1995) we calculated an average of 1325 g as the daily consumption of fish per cormorant.

The mean mass of 40 stomach contents was 282 g (S.D. 142 g, range 4–680 g). Fish was by far the most important item in the diet, followed by octopods, polychaetes (nereids) and gammarids (Table 1). A total of 261 fish was present in the samples; 237 of them were assigned to five species: *N. coriiceps, N. nudifrons, H. antarcticus, T. newnesi* and *Pleuragramma antarcticum*; 24 remained unidentified. *Notothenia coriiceps* was the most frequent (F = 58%) and also predominated by mass (65%), whereas *N. nudifrons* was the most important by number (47%) (Table 2). The smallest and biggest specimens were *H. antarcticus* (6.8 cm) and *N. coriiceps* (34.6 cm), respectively (Table 3). The mean number of fish per sample was 6.5 (SD = 5.6, range 1–27). Thirty-five of the 40 stomach contents analysed were composed of a single fish species. In 14 stomachs a single specimen was found, 13 of them were *N. coriiceps*.

DISCUSSION

As in many other diet studies on the Imperial Cormorant, fish were by far the main prey (Schlatter & Moreno 1976, Espitalier-Noel *et al*. 1988, Blankley 1981, Shaw 1984, Brothers 1985, Green *et al*. 1990a, 1990b, Wanless *et al*. 1992, Casaux & Barrera-Oro 1993, Coria *et al*. 1995, Barrera-Oro & Casaux 1996), followed by octopods and polychaetes (Table 1). In general, our results are similar to those obtained by the analysis of stomach contents collected simultaneously (Coria *et al*. 1995). However, the frequency and the importance by number and by mass of the secondary items were higher in pellet results. Two possible explanations are suggested: 1) the number of meals represented in the 45 regurgitated pellets (180 to 315) is higher than in the 40 stomach contents and the remains of some alimentary items (e.g. octopods or polychaetes) obtained in different foraging trips were accumulated; 2) part of the remains of secondary items found in pellets could come from fish stomachs. In a recent feeding trial, a captive Imperial Cormorant specimen fed exclusively with fish produced pellets in which algae and mandibles of polychaetes were found (Casaux *et al*. 1995), thus supporting the second hypothesis.

Coincidentally with Harris & Wanless (1993) and Coria *et al*. (1995) we observed that stones are frequently present in pellets but absent in stomach contents. Although several hypotheses related to their presence in pellets have been suggested (Van Tets 1967, Schlatter & Moreno 1976, Casaux & Barrera-Oro 1993a), only their provenance from fish stomachs or ingestion for pellet formation are supported by our findings.

As reflected by both methods, *N. coriiceps* predominated in mass; however, the contribution to the diet of the other species varied (Table 2). The fish prey spectrum observed in regurgitated pellets and stomach contents was different. This is partially due to the fact that otoliths of fish species are differentially accumulated in pellets. *Pagothenia bernacchii* and *G. gibberifrons* were represented in pellets but were absent in stomach contents. Their otoliths are large and thick which implies that they have lower probabilities of passing throughout the gastrointestinal tract so that they are more frequently found in pellets. The fact that a higher number of meals is represented by the 45 pellets (see above) could also contribute to these differences. On the other hand, *P. antarcticum* was only represented in the stomach contents. This species was never reported in the diet of the Imperial Cormorant by the analysis of pellets. Coria *et al*. (1995) suggested that its presence in stomach contents could be considered as an occasional intake or suggest a high loss rate of otoliths. *Pleuragramma antarcticum* was absent in 139 stomach contents collected in the 1994/95 summer season at the same colony, thus supporting the first hypothesis (Favero *et al*. 1995).

TABLE 3

Means and size ranges of fish represented in pellets and stomach contents of the Imperial Cormorant *Phalacrocorax atriceps* from Duthoit Point, Nelson Island

Species	Regurgitated pellets		Stomach contents		*t* value	
	Size range (g)	Mean	Size range (g)	Mean	(df)	
Notothenia coriiceps	4.0–32.0	15.9	12.8–34.6	23.6	5.08*	(83)
Nototheniops nudifrons	3.5–13.9	8.1	7.3–13.4	10.6	11.67*	(475)
Harpagifer antarcticus	3.2–8.7	6.4	6.8–9.2	7.9	14.61*	(1203)
Trematomus newnesi	6.1–13.1	9.3	8.1–12.8	10.8	2.38#	(28)
Pagothenia bernacchii	13.5	13.5	—	—	—	
Gobionotothen gibberifrons	2.7–26.2	8.6	—	—	—	
Pleuragramma antarcticum	—	—	13.2	13.2	—	

* $P < 0.0001$
# $P < 0.05$

For all the fish species the upper limits of the size ranges estimated by both methods were similar, but from pellet analysis the lower limit resulted in smaller sizes (Table 3). Consequently, the mean lengths estimated from pellets were significantly shorter than those obtained from stomach contents (Table 3), which suggests a high degree of otolith erosion during digestion.

The mean number of fish represented per pellet (47) was higher ($t = 6.66$, $P < 0.0001$, df = 75) and the percentage of pellets composed by a single species (22%) was lower (Sign Test $z = 4.81$, $P < 0.0001$) than in stomach contents (6.5 and 90%, respectively). The presence of a single fish specimen was represented in one pellet only (2%), but was found in 14 (35%) stomach contents. These findings suggests that the remains of more than one meal are accumulated in pellets. Consequently, some alimentary items appears as more frequent and could be interpreted as more important than they really are. Stomach contents reflect more appropriately the feeding habits of the Imperial Cormorant, which frequently preyed on a single fish species in each foraging trip with *N. coriiceps* as its most important prey in the study area.

Applying correction factors to the estimated mass from pellets analysis, the mean mass of fish ingested daily per bird was estimated as 1325 g (45% of body mass). Although somewhat high, this value falls into the range calculated by stomach contents analysis (846–1410 g, Coria *et al*. 1995). It is possible that the correction factors used in this study are overestimated due to biases produced in the feeding trial (Casaux *et al*. 1995) and therefore the mean intake by this method could be better estimated in future experiments.

Feeding trials on Imperial Cormorants are difficult to undertake, particularly in Antarctica. Some of the problems found are related to the capture of enough specimens of the fish species used to feed the cormorants during the experiment and to difficulties in reproducing natural conditions. However, our results confirm that feeding captive birds is an appropriate method to obtain correction factors necessary to estimate the food intake of cormorants by the analysis of pellets. The comparison of a large number of stomach contents with pellets collected simultaneously over a breeding season would lead to an improvement in the accuracy of such factors.

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