FEEDING TRIAL ON AN IMPERIAL CORMORANT *PHALACROCORAX ATRICEPS*: PRELIMINARY RESULTS ON FISH INTAKE AND OTOLITH DIGESTION

RICARDO J. CASAUX[1], MARCO FAVERO[2], ESTEBAN R. BARRERA-ORO[1] & PATRICIA SILVA[2]

[1]*Instituto Antártico Argentino, Cerrito 1248, 1010 Buenos Aires, Argentina*

[2]*Universidad Nacional de Mar del Plata, Laboratorio de Vertebrados, Funes 3350, 7600 Mar del Plata, Argentina*

Received 27 December 1994, accepted 16 May 1995

SUMMARY

CASAUX, R.J., FAVERO, M., BARRERA-ORO, E.R. & SILVA, P. 1995. Feeding trial on an Imperial Cormorant *Phalacrocorax atriceps*: preliminary results of fish intake and otolith digestion. *Marine Ornithology* 23: 101–106.

To assess the extent which the otoliths of different fish species may be differentially retained in pellets regurgitated by Imperial Cormorants or Blue-eyed Shags *Phalacrocorax atriceps*, a feeding experiment was carried out at Jubany Station, King George Island, South Shetland Islands. For 45 days a captive cormorant was fed seven local fish species, regurgitated pellets collected and otoliths counted and measured. A total of 16 pellets was produced. All fish species except *Gobionotothen gibberifrons* and *Nototheniops nudifrons* were under-represented numerically; no otoliths of *Notothenia rossii* were recovered. Losses in otolith size were substantial for most species but least for *G. gibberifrons.* These data provide preliminary factors for correcting estimates of number and mass of ingested fish, derived from otolith lengths. During the feeding study the cormorant's average daily consumption was 31% of body mass, a higher value than those recorded in studies of non-Antarctic cormorants. All remains of polychaetes in the pellets came from fish stomachs; previous studies may, therefore, have overestimated their importance in cormorant diets.

INTRODUCTION

Most studies of the diet of the Imperial Cormorant or Blue-eyed Shag *Phalacrocorax atriceps* have indicated coastal demersal-benthic fish as their main prey (Schlatter & Moreno 1976, Blankley 1981, Shaw 1984, Brothers 1985, Espitalier-Noel *et al.* 1988, Green *et al*. 1990a,b, Wanless *et al*. 1992, Casaux & Barrera-Oro 1993, Barrera-Oro & Casaux 1994). Analysis of regurgitated pellets or casts is very effective for qualitative studies, because it provides diet information with little effort in a short time, without disturbance to the birds. However, some biases are associated with the use of this technique, as for example, the erosion by digestion or loss of otoliths through the gastrointestinal track and lack of data from prey which do not leave indigestible hard parts (Jobling & Breiby 1986).

Feeding experiments with captive birds are the key to evaluating the accuracy of results obtained by the analysis of pellets in diet studies. 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 differentially affected by the digestive process. Consequently, there is evidence indicating that the number, lengths and masses of fish ingested by cormorants will, at least for some species, be underestimated by the method.

We conducted a feeding trial to provide preliminary correction factors to improve estimates of the number and size of fish based on pellets regurgitated by the Imperial Cormorant.

METHODS

An adult male Imperial Cormorant was caught at Low Rocks, King George Island, South Shetland Islands and transported to Jubany Station, King George Island, where it was kept in captivity from 11 December 1993 to 25 January 1994.

The bird was weighed when caught and on release. It was maintained in a pen (2.0 x 0.8 x 0.8 m) and provided with water and stones to perch on. To prevent the presence in regurgitation casts of otoliths ingested before capture, the bird was stomach-flushed until the flushed water was clear. During the first six days the bird was fed headless fish.

The diet consisted of fish species commonly taken by cormorants in the area: *Notothenia coriiceps* (previously known as *N. neglecta), Harpagifer antarcticus, Trematomus newnesi, Gobionotothen gibberifrons, N. rossii, Pagothenia bernacchii and Nototheniops nudifrons* (Barrera-Oro & Casaux 1994). They were caught by means of trammel-nets and kept frozen until needed, although some were fed live. The meals were constituted by a single or by mixed species according to availability and experimental design. At the beginning, the bird was force fed; by the 10th day it started to feed itself and during the last 12 days it fed from a small tank containing live fish.

Fish eaten were identified to species, weighed (to 1 g) and total length measured (TL) (to 0.1 cm). From day 7 of the experiment, pebbles were added to the diet to encourage pellet formation.

Pellets produced were collected and dried at 60°C to constant mass and sorted into prey species. The otoliths were identified, where possible, to species using descriptions and illustrations in North *et al.* (1984), Hecht (1987), Williams & McEldowney (1990) and reference material from our own collection. Otoliths were separated into right and left; whichever was the most abundant was considered to represent the total number of fish present by species in each pellet. Otolith length (OL) was used to estimate fish size (TL, total length; SL, standard length) and mass. The equations were:

Nototheniops nudifrons[1]

$TL=32.95*OL^{1.05}$ mm (n=46)
$SL=33.78*OL^{0.96}$ mm (n=11)
$Mass=4.01*10^{-7}*SL^{3.81}$ g (n=11)

Harpagifer antarcticus[2]

$TL=3.268603+1.812654*OL$ cm (n=124)
$Mass=-123.1464*TL^{-0.5804228}+45.39072$ g (n=124)

Trematomus newnesi[2]

$TL=1.568699+4.166653*OL$ cm (n=84)
$Mass=0.146477*TL^{2.127549}$ g (n=77)

Notothenia coriiceps[2]

$TL=-11.4918+11.31757*OL$ cm (n=161)
$Mass=0.0032*TL^{3.4407}+25.439$ g (n=501)

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 data from Potter Cove.

RESULTS

The cormorant weighed 2500 g when caught and 2650 g on release. Initially the daily ration of whole fish fluctuated around 400 g, but the bird did not produce pellets. On the 12th day fish was offered to the cormorant *ad libitum* and 1090 g were ingested willingly. Two days later, the first regurgitated pellet was obtained. Throughout the experiment, the mean mass of fish ingested per day was 659 g (45 days), whereas the mean eaten willingly was 771 g (maximum 1348 g) (over 35 days). The largest and the heaviest fish consumed were two *N. coriiceps* specimens of 30.5 cm and 413 g, respectively; a maximum of 33 fish was given in a single meal (five *N. coriiceps*, 27 *H. antarcticus* and one *G. gibberifrons*).

Throughout the experiment, 16 pellets were regurgitated by the cormorant at different hours of the day. Excluding the six-day starting period during which only headless fish were used as food, the frequency of pellet production was around one every 2.5 days. On two occasions, the cormorant regurgitated when it was about to start feeding. Twelve pellets provided otoliths; despite being fed exclusively with fish, algae appeared in 11 pellets and mandibles of polychaetes in two.

In the pellets, all fish species except for *G. gibberifrons* and *N. nudifrons* were underestimated in number; *N. rossii* was completely absent from the pellets (Table 1). For all species but *N. rossii* the back-calculated values of fish length and mass indicated erosion of the otoliths during digestion. *Gobionotothen gibberifrons* was by far the least affected both in number and size of otoliths (Table 2).

On the basis of the recovery rate of otoliths belonging to the fish species used to feed the cormorant, it was possible to correct the estimated number of fish represented in pellets (Table 1). This value was combined with the observed percentage of loss in mass (Table 2) to obtain correction factors aimed to approach better the real mass of ingested fish. Preliminary correction factors are: *N. coriiceps*, 13.4x; *H. antarcticus*, 3.5x; *T. newnesi*, 13.1x and *G. gibberifrons*, 1.3x. For the other species, the data were too few to allow such calculation.

DISCUSSION

One of the goals of our research programme on cormorant diet is the potential use of these birds as biological samplers capable of reflecting changes in the diversity and abundance of littoral fish populations (Ainley *et al.* 1981, Duffy & Laurenson 1983, Duffy *et al.* 1987, Barrett 1991, Wanless *et al.* 1991, Casaux & Barrera-Oro 1993a, 1993b). The original idea was based on the similarity existent in nearshore marine communities, between the fish species sampled by means of conventional gear (hook and lines, trammel/gill-nets, mid-water trawls) and those represented in pellets of cormorants occurring in the same area, including Imperial Cormorants (Casaux & Barrera-Oro 1993a, Barrera-Oro & Casaux 1994). Moreover, in Antarctica, the depth distribution of littoral fish is co-extensive with the foraging depth range (down to 116 m, according to Croxall

TABLE 1

LENGTH, MASS AND RECOVERY RATE OF FISH INGESTED BY A CAPTIVE IMPERIAL CORMORANT *PHALACROCORAX ATRICEPS*

	Ingested fish				Recovered fish		Recovery rate
Fish species	N	T.L.(cm)*	Mass(g)*	N	T.L.(cm)*	Mass(g)*	
Notothenia coriiceps	82	22.0±0.6	170.8±12.1	20	10.7±1.3	53.5± 8.3	24.4
Harpagifer antarcticus	27	8.8±0.2	9.4± 0.5	17	6.8±0.3	4.4± 0.8	62.9
Trematomus newnesi	7	19.3±1.3	83.6±13.5	4	6.8±1.9	11.2± 4.6	57.1
Gobionotothen gibberifrons	5	22.1±1.0	90.6±14.3	5	20.6±0.9	72.4±20.7	100.0
Notothenia rossii	5	26.0±0.5	214.6±23.9	0	——	——	0.0
Pagothenia bernacchii	2	27.4±0.3	255.0±16.0	1	11.2	10.8	50.0
Nototheniops nudifrons	1	16.4	53.0	1	9.2	9.5	100.0

* Mean ± standard deviation

et al. 1991) of Imperial Cormorants. However, in view of the biases associated with pellet analyses, this study was undertaken to establish their quantitative validity (see Hartley 1948).

Our preliminary results from the feeding trial on an Imperial Cormorant confirm those reported by Duffy & Laurenson (1983) and Johnstone *et al.* (1990) for Cape Cormorants and European Shags, respectively. Examination of the pellets regurgitated in captivity showed that the otoliths of the fish species were differentially lost and eroded during digestion. Therefore, correction factors must be used to give an accurate quantitative estimation of the diet of the Imperial Cormorant based on analysis of regurgitation pellets.

The erosion of otoliths depends on their shape, size, thickness and time exposed to digestion. *Gobionotothen gibberifrons*, whose otoliths are large and thick, was fully represented in number and only slightly underestimated in size (Table 2). The otoliths of *N. coriiceps* and *N. rossii* are similar in shape, thin and with a high area/volume ratio. Due to these characteristics they are easily eroded and this presumably resulted in a low recovery rate. *Trematomus newnesi*, *N. nudifrons* and *P. bernacchii* were substantially underestimated in mass. This is, however, partially due to the equations used to estimate mass, which do not fit well for the smaller sizes of fish.

The feeding behaviour of the cormorant changed during the experiment. During the last 16 days it was allowed to eat *ad libitum* whenever it chose. This strategy better reproduced natural conditions, since Imperial Cormorants undertake three to five foraging trips per day (Coria *et al.* 1995). The frequency of pellet production for this period was one every two days and the correction factor estimated for *N. coriiceps* was 9.2x. This gradual adaptation of the bird to captivity suggests the need for a minimum period of around 40 days for such an experiment. In feeding trials, the otoliths are probably differentially affected by the feeding behaviour, and this should be taken into account in the analysis of the results. No pellets were produced with an initial daily intake of whole fish of 16% of the cormorant's mass. After daily intake increased and the bird ingested 40% of its mass, regurgitated pellets were obtained two days later. Subsequently, pellet production occurred around every 2.5 days, which is still less than the frequency recorded in the wild (one every 1.4 days, R.J. Casaux *et al.* unpubl. data). Johnstone *et al.* (1990) recovered pellets from captive European Shags with a daily fish intake of 16–18% of body mass. These values agreed with those observed in Reed *P. africanus* and Whitebreasted *P.*

TABLE 2

THE UNDERESTIMATION IN NUMBER, LENGTH AND MASS OF FISH FED TO A CAPTIVE IMPERIAL CORMORANT *PHALACROCORAX ATRICEPS* BY THE BACK-CALCULATION FROM OTOLITHS RECOVERED IN REGURGITATED CASTS

Fish Species	Loss in number	Loss in length	Loss in mass	Correction factors
Notothenia coriiceps	75.6%	47.8%	68.7%	13.4x
Harpagifer antarcticus	37.0%	22.9%	53.8%	3.5x
Trematomus newnesi	42.9%	64.3%	86.6%	13.1x
Gobionotothen gibberifrons	0.0%	6.7%	20.1%	1.3x
Notothenia rossii	100.0%	—	—	*
Pagothenia bernacchii	50.0%	59.2%	97.8%	*
Nototheniops nudifrons	0.0%	44.1%	82.2%	*

* Few fish used in the experiment.

carbo Cormorants (16–17% of body mass) (Meinertzhagen 1959, Junor 1972, quoted in Johnstone *et al*. 1990). The mean daily intake of fish ingested willingly in this study was 31% of body mass (3290 kJ/day, according to data from FAO/OMS/UNU 1985 and Marquez *et al.* 1994), which indicates a higher energy requirement than those observed in the other species. This could be explained by the extreme weather conditions in Antarctica. The existence metabolism for a non-passerine bird of 2700 g of mass at 30°C and 0°C was estimated as 877 and 1278 kJ/day respectively (using equations in Kendeigh 1970 and Kendeigh *et al.* 1977).

The correction factors obtained in this study are aimed to improve the accuracy of the mass estimations of fish ingested, calculated by means of equations based on otolith lengths. However, for several fish species these values were higher than expected, probably because natural conditions were not appropriately reproduced in this first experiment.

Despite stomach-flushing carried out at the beginning of the experiment, mandibles of polychaetes were found in two pellets and one of them was produced on the 28th day. Likewise, algae were found in 11 of the 16 pellets obtained. Algae and polychaetes probably came from fish stomachs and therefore their importance may have been overestimated in previous studies of cormorant diets.

The results presented here are preliminary because the experiment was carried out on one bird only, some of the fish species were little used and the frequency of regurgitation of pellets was low. Besides, because the production of pellets is strongly dependent on the quality and quantity of food ingested, captive meals must closely emulate those obtained in the wild. R. Price (unpubl. data, quoted in Johnstone *et al*. 1990) reported that Imperial Cormorants fed on an inadequate diet failed to produce pellets. Information coming from studies of foraging rhythms and stomach contents will allow us to reproduce wild conditions more closely in future feeding trials.

ACKNOWLEDGEMENTS

We thank P. Alagia, N. Poblet, F. Scagliola and J.B. Tarapow for assistance with field work. We are particularly grateful to J.P. Croxall, D.C. Duffy and an anonymous referee who critically commented on the manuscript.

REFERENCES

AINLEY, D.G., ANDERSON, D.W. & KELLY, P.R. 1981. Feeding ecology of marine cormorants in southwestern North America. *Condor* 83: 120–131.

BARRERA-ORO, E.R. & CASAUX, R.J. 1994. Fish as diet of the Blue-eyed Shag, *Phalacrocorax atriceps bransfieldensis* at Half-moon Island, South Shetland Islands. Document WG-CEMP–94/32. CCAMLR: Cape Town, South Africa. 15 pp.

BARRETT, R.T. 1991. Shags (*Phalacrocorax aristotelis* L.) as potential samplers of juvenile Saithe (*Pollachius virens* (L.)) stocks in northern Norway. *Sarsia* 76: 153–156.

BLANKLEY, W.O. 1981. Marine food of Kelp Gulls, Lesser Sheathbills and Imperial Cormorants at Marion Island (Subantarctic). *Cormorant* 9: 77–84.

BROTHERS, N.P. 1985. Breeding biology, diet and morphometrics of the King Shag, *Phalacrocorax albiventer purpurascens*, at Macquarie Island. *Austr. Wildl. Res.* 12: 81–94.

CASAUX, R.J. & BARRERA-ORO, E.R. 1993a. The diet of the Blue-eyed Shag, *Phalacrocorax atriceps bransfieldensis* feeding in the Bransfield Strait. *Antarct. Sci.* 5: 335–338.

CASAUX, R.J. & BARRERA-ORO, E.R. 1993b. Blue-eyed Shags as indicators of changes in littoral fish populations. Document WG-CEMP–93/25. CCAMLR: Seoul, South Korea. 6 pp.

CORIA, N.R., CASAUX, R.J., FAVERO, M. & SILVA, P. 1995. Analysis of the stomach content in the Blue-eyed Shag *Phalacrocorax atriceps bransfieldensis* at Nelson Island, South Shetland Islands. *Polar Biol.* 15: 349–352.

CROXALL, J.P, NAITO, Y., KATO, A., ROTHERY, P. & BRIGGS, D.R. 1991. Diving patterns and performance in the Antarctic Blue-eyed Shag *Phalacrocorax atriceps*. *J. Zool*., *Lond.* 225: 177–199.

DUFFY, D.C. & LAURENSON, L.J. 1983. Pellets of Cape Cormorants as indicators of diet. *Condor* 85: 305–307.

DUFFY, D.C., WILSON, R.P. & WILSON, M.-P. 1987. Spatial and temporal patterns of diet in the Cape Cormorant off southern Africa. *Condor* 89: 830–834.

ESPITALIER-NOEL, G., ADAMS, N.J. & KLAGES, N.T. 1988. Diet of the Imperial Cormorant *Phalacrocorax atriceps* at sub-Antarctic Marion Island. *Emu* 88: 43–46.

FAO/OMS/UNU 1985. Necesidades de energía y de proteínas. *Serie de Informes Técnicos*, 724, FAO/OMS/UNU, Ginebra.

GREEN, K., WILLIAMS, R. & SLIP, D.J. 1990a. Diet of the Macquarie Island Cormorant *Phalacrocorax atriceps purpurascens. Corella* 14: 53–55.

GREEN, K., WILLIAMS, R., WOEHLER, E.J., BURTON, H.R., GALES, N.J. & JONES, R.T. 1990b. Diet of the Heard Island Cormorant *Phalacrocorax atriceps nivalis*. *Antarct. Sci.* 2: 139–141.

HARTLEY, P.H. 1948. The assessment of the food of birds. *Ibis* 90: 361–381.

HECHT, T. 1987. A guide to the otoliths of Southern Ocean fishes. *S. Afr. J. Antarct. Res.* 17: 1–87.

JOBLING, M. & BREIBY, A. 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. *Sarsia* 71: 265–274.

JOHNSTONE, I.G., HARRIS, M.P., WANLESS, S. & GRAVES, J.A. 1990. The usefulness of pellets for assessing the diet of adult Shags *Phalacrocorax aristotelis*. *Bird Study* 37: 5–11.

KENDEIGH, S. 1970. Energy requirements for existence in relation to size of bird. *Condor* 72: 60–65.

KENDEIGH, S., DOL'NIK, V. & GAVRILOV, V. 1977. Avian energetics. In: Pinowski, J. & Kendeigh, S. (Eds). Granivorous birds in ecosystems. Cambridge: Cambridge University Press. pp. 127–204.

MARQUEZ, M.E., CASAUX, R.J. & MAZZOTTA, A.S. 1994. Variación estacional de la composición química del tejido muscular del Bacalao Antártico (*Notothenia neglecta*). *Proceedings of the VIº Congreso Argentino de Ciencia y Tecnología de Alimentos y Iº Encuentro de los Técnicos de Alimentos del Cono Sur*: 383–385.

NORTH, A.W., BURCHETT, M.S., GILBERT, C.J. & WHITE, M.G. 1984. Identification of fish from the Southern Ocean by means of otoliths. *Brit. Antarct. Surv. Bull.* 62: 83–94.

SCHLATTER, R.P. & MORENO, C.A. 1976. Hábitos alimentarios del cormorán antártico, *Phalacrocorax atriceps bransfieldensis* (Murphy) en Isla Green, Antártida. *Ser. Cient. Inst. Antárt. Chileno* 4: 69–88.

SHAW, P. 1984. Factors affecting the breeding performance of the Antarctic Blue-eyed Shag (*Phalacrocorax atriceps bransfieldensis*). Ph.D thesis, University of Durham.

WANLESS, S., HARRIS, M.P. & MORRIS, J.A. 1991. Foraging range and feeding locations of Shags *Phalacrocorax aristotelis* during chick rearing. *Ibis* 133: 30–36.

WANLESS, S., HARRIS, M.P. & MORRIS, J.A. 1992. Diving behaviour and diet of the Blue-eyed Shag at South Georgia. *Polar Biol.* 12: 713–719.

WILLIAMS, R. & McELDOWNEY, A. 1990. A guide to the fish otoliths from waters off the Australian Antarctic Territory, Heard and Macquarie Islands. *ANARE Res. Notes* 75: 1–173.