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The diet of the blue-eyed shag, *Phalacrocorax atriceps bransfieldensis* feeding in the Bransfield Strait

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Abstract: The diet of the Antarctic blue-eyed shag *Phalacrocorax atriceps bransfieldensis* was analysed based on the identification of the prey items in 50 regurgitated casts collected at Duthoit Point, Nelson Island, in February 1991. Fish remains occurred in 100% of the casts and represented 68% by number and 90% by weight of the total prey items. From a total of 2112 otoliths found, 1176 fish specimens were identified belonging to four demersal-benthic species: *Harpagifer antarcticus*, *Notothenia neglecta*, *Nototheniops nudifrons* and *Trematomus newnesi*. Equations to estimate total length and weight from otolith length are provided. *H. antarcticus* and *N. neglecta* were the most frequent (92%) and important by weight (66%) respectively. Cephalopod beaks found indicate benthic octopods as the second group in importance after fish. Other invertebrates such as polychaetes, gastropods, bivalves and crustaceans were only occasional. The presence of algae and stones in the casts is attributed to accidental ingestion. Our results are in general agreement with those published for other Antarctic localities which indicate that *P. atriceps* is a benthic coastal feeder, with fish as its main food.

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Key words: Antarctica, cormorant, fish, diet, prey remains

Introduction

The blue-eyed shag *Phalacrocorax atriceps* has a circumpolar distribution, south of 45°S (Watson 1975). This species is reported to include eight subspecies, yet the taxonomic status of the group is still in question.

Shags are often observed foraging alone but also exhibit a social feeding behaviour, frequently in flocks of over 200 individuals diving to the bottom close inshore. Dive depth and duration was thought to range from 25–50 m (Conroy & Twelves 1972, Brothers 1985, Cooper 1986) and from 0.5–3.5 min (Bernstein & Maxson 1985) respectively. Recently registers of deep dives averaging 80–90 m and down to 116 m (Croxall *et al.* 1991) for periods up to 6.5 min (Wanless *et al.* 1992) have been experimentally demonstrated, thus indicating diving abilities hitherto unrecognized in the family. Within breeding pairs, partners alternate foraging twice per day, each parent foraging once while the other remains at the nest (Maxson & Bernstein 1982).

The diet of these birds have been the subject of several studies, usually by the identification of the prey items in regurgitated casts. Benthic organisms such as polychaetes, gastropods, bivalves, cephalopods, crustaceans and fish are known to be the main components. Substantial information has been reported for *P. atriceps* subspecies from the southern Indian Ocean, at Marion and Heard islands (Blankley 1981, Espitalier-Noel *et al.* 1988, Green *et al.* 1990b) and from the southern Pacific Ocean at Macquarie Island (Brothers 1985, Green *et al.* 1990a). For the Antarctic sector of the southern Atlantic Ocean, the studies on the diet of *P. atriceps* are by Wanless *et al.* (1992) at South Georgia, and on *P. a. bransfieldensis* by Shaw (1984) at Signy Island, South Orkney Islands and by Schlatter & Moreno (1976) at Green Island, west Antarctic Peninsula area.

Our paper provides data on the diet of breeding *P. a. bransfieldensis* from Nelson Island, South Shetland Islands, pointing out the importance of fish as prey.

Material and methods

Fifty regurgitated casts of *P. a. bransfieldensis* were collected in a colony (*c.* 160 pairs and 320 chicks) at Duthoit Point, Nelson Island (62°18'S, 58°47'W) in February 1991 (Fig. 1). The samples were weighed (to 0.01 g), frozen and dried to constant weight at 60°C. The contents were sorted into prey classes under a binocular microscope and each item was weighed again. The otoliths (all sagittal) were cleaned and identified, where possible, to species using descriptions and

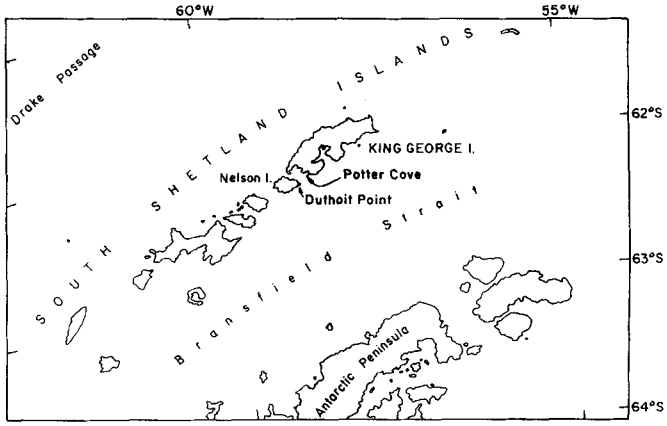

Fig. 1. The location of Duthoit Point at Nelson Island, South Shetland Islands.

illustrations in North *et al.* (1984), Hecht (1987), 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 cast. Total length (TL) in cm and weight in g of these fish were calculated by means of equations estimated from measurements of otolith length (OL). The comparison between regurgitated and unworn otoliths (from our collection) showed, in general, little erosion by digestion. Our values were corrected by assuming a reduction of 5% in the otolith length (see also Croxall *et al.* 1988). Equations were:

Harpagifer antarcticus [1]

$TL = 3.268603+1.812654*OL$ (n = 124)

$MASS = -123.1464*TL^{-0.5804228}+45.39072$ (n = 124)

Notothenia neglecta [1]

$TL = -11.4918+11.31757*OL$ (n = 161)

$MASS = 0.0032*TL^{3.4407}+25.439$ (n = 501)

Trematomus newnesi [1]

$TL = 1.568699+4.166653*OL$ (n = 84)

$MASS = 0.146477*TL^{2.127549}$ (n = 77)

Nototheniops nudifrons [2]

$TL = 32.95*OL^{1.05}$ (n = 46)

$SL = 33.78*OL^{0.96}$ (n = 11)

$MASS = 4.01*10^{-7}*SL^{3.81}$ (n = 11)

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

Results

Mean values of wet and dry weights of the casts were 13 ± 1.31 and 4.3 ± 0.34 g respectively. Fish remains (bones and otoliths) occurred in all of the 50 casts analysed and represented 67.7% by number and 89.9% by weight of the total prey items (Table I). Algae (mainly *Desmarestia* sp. and *Iridea* sp., F = 78%) and small octopod beaks , (F = 26%) only represented 2.2% and 0.9% by number respectively. Occasional items were polychaete mandibles (of nereids about 3–4 cm long, M. Stiller, pers. comm.); shells of trochiids, limpets (*Nacella concinna*) and bivalves (*Dacrydyum* sp.); crustacean exoskeletons; eye lens; and feathers. All the casts contained stones (mean weight 0.39 g), whose origin is discussed below (Table I).

Table I. Diet composition of *Phalacrocorax atriceps bransfieldensis* at Duthoit Point, Nelson Island as shown by the contents of 50 castings.

	Freq.	Freq. %	No.	No. %	Mass (g)	Mass %
Fish (bones-otoliths)	50	100	1219	67.68	195.62	89.93
Octopods (beaks)	13	26	17	0.94	0.28	0.13
Polychaetes (mandibles)	1	2	2	0.11	0.00	0.00
Trochidae (shell)	4	8	4	0.22	0.01	0.01
Limpets (shell)	2	4	2	0.11	0.23	0.11
Bivalves (shell)	1	2	1	0.06	0.00	0.00
Crustacea (exoskeleton rest)	1	2	1	0.06	0.00	0.00
Algae	39	78	39	2.17	1.96	0.90
Eye lens	1	2	1	0.06	0.00	0.00
Feathers	6	12	6	0.33	0.08	0.04
Stones	50	100	509	28.26	19.34	8.89

A total of 2112 otoliths was found, apparently from 1219 fish; 1176 were identified and belong to four demersal-benthic fish species (Table II). *H. antarcticus* was the most frequent fish (92%), representing 87% by number and 28.7% by weight. *N. neglecta* (64%) was the most important by weight (66 %). Otoliths from 43 fish were unidentified. The calculated size range (TL) of the fish was 3–33 cm, with *N. nudifrons* and *N. neglecta* the smallest and largest species respectively (Fig. 2). Published age length relationships were used to derive age (Table I). The maximum number of fish represented in a cast was 111 (106 *H. antarcticus*, 3 *N. nudifrons*, 1 *T. newnesi* and 1 unidentified), with an estimated mass of about 560 g; the heaviest cast weighed 983 g (15 *H. antarcticus*, 3 *N. neglecta* and 1 *T. newnesi*).

Discussion

The analysis of shag diet from regurgitated casts presents difficulties because of the limited material and problems in the identification and quantification of the contents. This methodology has been extensively used (Schlatter & Moreno 1976, Blankley 1981, Espitalier-Noel *et al.* 1988, Green *et al.* 1990a and 1990b, Barrett 1991, Wanless *et al.* 1992), since it gives diet information with little effort in a short time, without disturbance to the colony. However, it is of limited applicability if biased. Jobling & Breiby (1986), among others, discussed in detail the errors arising when using otoliths in diet investigations. Moreover, recent feeding trials on captive Scottish shags (*Phalacrocorax aristotelis*) showed that the analysis of pellets underestimated the number and the sizes of fish taken (Johnstone *et al.* 1990). Although this study deals with other shag/fish-prey species, the technique must be used with caution. Biases could arise from differential evacuation rate through the gastrointestinal tract of unregurgitated otoliths from different sizes and species of fish, or lack of information on prey which not leave indigestible hard parts. The erosion of otoliths during digestion, seemed to be a minor problem in our study.

Quantification of fish prey by dividing by two the number of otoliths found in the casts gave 1056 fish. Sorting of the otoliths into rights and lefts gave 1219 fish. This latter value is probably still an underestimate, but a better approximation to the actual number of fish ingested.

P. a. bransfieldensis at Nelson Island was a benthic coastal feeder, with fish as its main food item (F = 100%) (Table I). Similar findings were reported for shags at other localities: *P. a. bransfieldensis* at Green Island (Schlatter & Moreno

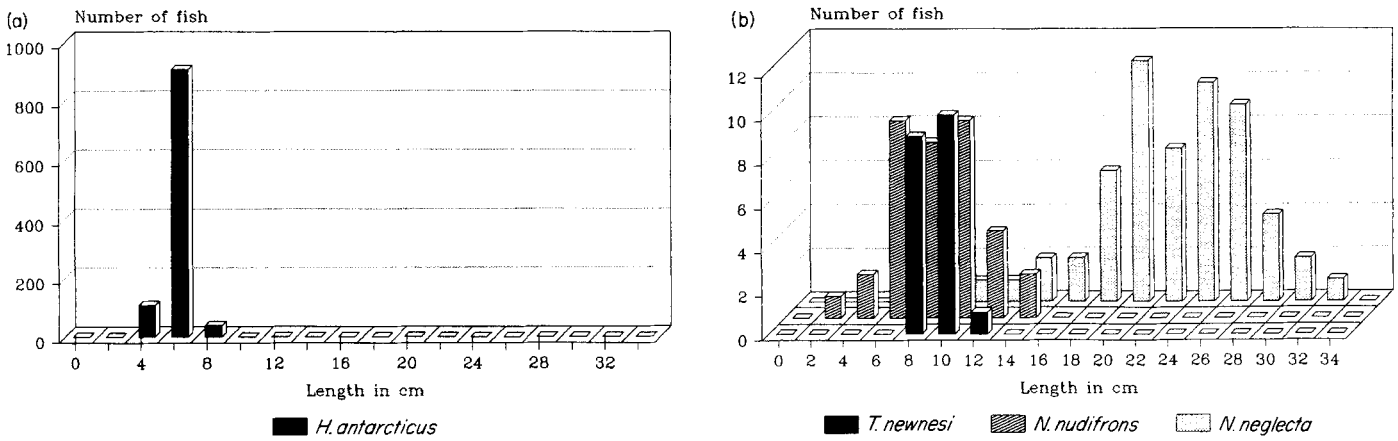

Fig. 2. Length frequency distribution (calculated from otolith lengths) of fish prey: **a.** *Harpagifer antarcticus*; **b.** *Notothenia neglecta*, *Nototheniops nudifrons* and *Trematomus newnesi*.

1976); at Signy Island (Shaw 1984); *P. a. nivalis* at Heard Island (Green *et al.* 1990b); *P. a. purpurascens* at Macquarie Island (Brothers 1985, Green *et al.* 1990a); *P. atriceps* at Marion Island (Blankley 1981, Espitalier-Noel *et al.* 1988).

Blue-eyed shags appear to require between 600 (Shaw 1984) and 1209 g (Bernstein 1982) of fish per day. Thus, the maximum mass of fish estimated in a cast in this study (983 g), would represent between 1–2 days food. Although the entirely benthic nature of fish in the diet has been indicated (Blankley 1981, Brothers 1985, Espitalier-Noel *et al.* 1988), the size and age of a few individuals of *N. neglecta* and *T. newnesi* suggest that they may have been pelagic. It is probable that shags take such fish in the whole intertidal zone, including tide-pools.

Among the *N. neglecta* eaten, those about 20 cm long were the most frequently represented (Fig. 2). This size corresponds to fish of age group 3 (Barrera-Oro & Casaux unpublished), which already belong to the demersal phase (Everson 1970, Kellermann 1991). Everson (1970), reported *N. neglecta* of 30–500 g weight to be taken by *P. atriceps* at Signy Island and Shaw's (1984) data on age ranges of *N. neglecta* (1–6 years) and *T. newnesi* (1–3 years) represented in regurgitated samples, were similar to those reported here (Table II).

The fish species identified in the diet agree with those regularly sampled with trammel-nets (excepting *H. antarcticus*, which escape from the net) at Potter Cove (Fig. 1; see Casaux *et al.* 1990). This locality is very close to Duthoit Point, and the fish are collected in water 5–50 m deep, (Barrera-Oro & Casaux 1990) all of which is within the blue-eyed shag foraging depth range. Among the species caught by the nets only *Notothenia rossii* and *N. gibberifrons* were absent in the casts. This is not surprising, since these species have practically disappeared in the trammel-net catches of the last five years in the area, presumably due to commercial exploitation (Barrera-Oro & Marschoff 1991). Moreover, at the onset of the last decade in waters around South Orkney Islands, a fishing ground still affected by the commercial fishery, *N. rossii* was a frequent prey of *P. a. bransfieldensis* (see Shaw 1984).

The cephalopod beaks were found to belong to benthic octopods, presumably juveniles (Z. Castellanos, pers. comm.). This group was second in importance to fish; its relevance in the diet of blue-eyed shags has been indicated (Schlatter & Moreno 1976, Espitalier Noel *et al.* 1988, Green *et al.* 1990b). Other invertebrates were occasional (Table I). Interestingly, polychaetes have been reported to be the most common prey in the diet of the non-breeding *P. a. nivalis* at Heard Island (Green *et al.* 1990b).

Several authors have indicated utilization of algae by shags for nest building (Schlatter & Moreno 1976, Bernstein & Maxson 1982). However, only Schlatter & Moreno (1976) and Green *et al.* (1990) reported its presence in the casts. K. Green (pers. comm.) observed recently at Heard Island that the

Table II. Fish species identified from otoliths found in casts of *Phalacrocorax atriceps bransfieldensis* at Duthoit Point, Nelson Island.

	Freq. %	No. of Otol.	No. of Fish	No. %	Mass in g.	Mass %	Size range	Age range
Harpagifer bispinis	92%	1919	1061	87	5350	29	5.2–9.2	1–4 (1)
Notothenia neglecta	64%	78	60	5	12361	66	6.2–33.1	1–6 (2)
Nototheniops nudifrons	22%	48	35	3	525	3	3.0–15.1	0–8 (3)
Trematomus newnesi	24%	21	20	2	417	2	8.1–12.5	1–2 (4)
Unidentified	28%	46	43	4	—	—	—	—

(1) Tomo & Cordero Funes 1972; (2) Barrera-Oro & Casaux, unpublished data; (3) Radtke & Hourigan 1990; (4) Radtke *et al.* 1989.

occurrence of algae was significantly higher ($P < 0.005$) in casts of breeders than in non-breeders. It is probable that algae are ingested accidentally during transport to the nest.

Two explanations have been suggested for the presence of stones in casts of shags: 1) the stones are ingested to reduce buoyancy, facilitating diving (Van Tets 1967) and later on regurgitated; 2) stones increase the specific mass of the cast, making it more maneuverable in the digestive tract (Schlatter & Moreno 1976). In the present study, the mean weight of stones per cast (0.386 g) represented less than 1% of the shag's mass. This, and the fact that non-diving birds (e.g. skuas) are also reported to regurgitate stones (Lazo *et al.* 1990), contradicts the first hypothesis. In our samples stones only represented 3% of the wet weight of the casts, which does not support the second hypothesis. Stones may be taken accidentally, while shags are feeding on benthic prey, or the smaller stones could have been originally ingested by fish.

Barrett (1991) emphasized the use of shags as biological samplers potentially capable of supplementing surveys of littoral fish species. Although the data presented in this study are spatially and seasonally limited and the methodology used needs improvement, it seems possible that an appropriate long term project monitoring diet and breeding performance of shags could provide very useful data on changes in littoral fish populations.

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References

Barrera-Oro, E. & Casaux, R. 1990. Feeding selectivity in *Notothenia neglecta*, Nybelin, from Potter Cove, South Shetland Islands, Antarctica. *Antarctic Science*, **2**, 207-213.

Barrera-Oro, E. & Marschoff, E. 1991. A declining trend in the abundance of *Notothenia rossii marmorata* and *Notothenia gibberifrons* observed in fjords in two sites in the South Shetland Islands. *CCAMLR, Selected Scientific Papers 1990*, 263- 274.

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

Bernstein, N. & Maxson, S. 1982. Behaviour of the Antarctic blue- eyed Shag (*Phalacrocorax atriceps bransfieldensis*). *Notornis*, **29**, 197-207.

Bernstein, N. & Maxson, S. 1985. Reproductive energetics of blue- eyed Shags in Antarctica. *Wilson Bulletin*, **97**, 450-462.

Blankley, W. 1981. Marine food of kelp gulls, lesser sheathbills and imperial cormorants at Marion Islands (Subantarctic). *Cormorant*, **9**, 77-84.

Brothers, N. 1985. Breeding biology, diet and morphometrics of the King Shag, *Phalacrocorax albiventer purpurascens*, at Macquarie Island. *Australian Wildlife Research*, **12**, 81-94.

Casaux, R., Mazzotta, A. & Barrera-Oro, E. 1990. Seasonal aspects of the biology and diet of nearshore nototheniid fish at Potter Cove, South Shetland Islands, Antarctica. *Polar Biology*, **11**, 63- 72.

Conroy, W., & Twelves, E. 1972. Diving depths of the Gentoo Penguin (*Pygoscelis papua*) and blue-eyed Shag (*Phalacrocorax atriceps*) from the South Orkney Islands. *British Antarctic Survey Bulletin*, No. 30, 106-108.

Cooper, J. 1986. Diving patterns of cormorants (Phalacrocoracidae). *Ibis*, **128**, 562-569.

Croxall, J., North, A. & Prince, P. 1988. Fish prey of the Wandering Albatross (*Diomedea exulans*) at South Georgia. *Polar Biology*, **9**, 9-16.

Croxall, J., Naito, Y., Kato, A., Rothery, P. & Briggs, D. 1991. Diving patterns and performance in the Antarctic blue-eyed Shag *Phalacrocorax atriceps*. *Journal of Zoology, London*, **225**, 177-199.

Espitalier-Noel, G., Adams, N. & Klages, N. 1988. Diet of the Imperial Cormorant *Phalacrocorax atriceps* at sub-Antarctic Marion Island. *Emu*, **88**, 43-46.

Everson, I. 1970. The population dynamics and energy budget of *Notothenia neglecta* Nybelin at Signy Island, South Orkney Islands. *British Antarctic Survey Bulletin*, No. 23, 25-50.

Green, K., Williams, R. & Slip, D. 1990 a. Diet of the Macquarie Island Cormorant *Phalacrocorax atriceps purpurascens*. *Corella*, **14**, 53-55.

Green, K., Williams, R., Woehler, E., Burton, H., Gales, N. & Jones, R. 1990 b. Diet of the Heard Island cormorant *Phalacrocorax atriceps nivalis*. *Antarctic Science*, **2**, 139-141.

Hecht, T. 1987. A guide to the otoliths of Southern Ocean fishes. *South African Journal of Antarctic Research*, **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.; Harris, M.; Wanless, S. & Graves, J. 1990. The usefulness of pellets for assessing the diet of adult Shags *Phalacrocorax aristotelis*. *Bird Study*, **37**, 5-11.

Kellermann, A. 1991. Egg and larval drift of the Antarctic fish *Notothenia coriiceps*. *Cybium*, **15**, 199-210.

Lazo, I., Cattan, P., Núñez, H. & Yáñez, J. 1990. Hábitos alimentarios del Salteador Pardo (*Catharacta lonnbergi*) en ausencia de colonias de pingüinos, Isla Livingston, Shetland del Sur. *Serie Científica del Instituto Antártico Chileno*, **40**, 71-77.

Maxson, S. & Bernstein, N. 1982. Kleptoparasitism by South Polar Skuas on blue-eyed Shags in Antarctica. *Wilson Bulletin*, **94**, 269-281.

North, A., Burchett, M., Gilbert, C. & White, M. 1984. Identification of fish from the Southern Ocean by means of otoliths. *British Antarctic Survey Bulletin*, No. 62, 83-94.

Radtke, R., Targett, T., Kellermann, A., Bell, J. & Hill, K. 1989. Antarctic fish growth: profile of *Trematomus newnesi*. *Marine Ecology Progress Series*, **57**, 103-117.

Radtke, R. & Hourigan, T. 1990. Age and growth of the Antarctic fish *Nototheniops nudifrons*. *Fishery Bulletin*, **88**, 557-571.

Schlatter, R. & Moreno, C. 1976. Hábitos alimentarios del cormorán antártico, *Phalacrocorax atriceps bransfieldensis* (Murphy) en Isla Green, Antártida. *Serie Científica del Instituto Antártico 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 [Unpublished].

Tomo, A. & Cordero Funes, J. 1972. Edad y crecimiento en largo del *Harpagifer bispinis antarcticus*. *Contribución del Instituto Antártico Argentino*, No. 96, 19pp.

Van Tets, G. 1967. White-breasted Cormorant swallows pebbles on land. *Emu*, **67**, 224.

Wanless, S., Harris, M. & Morris, J. 1992. Diving behaviour and diet of the blue-eyed shag at South Georgia. *Polar Biology*, **12**, 713-719.

Watson, G. 1975. *Birds of the Antarctic and sub-Antarctic*. Washington D.C.: American Geophysical Union, 350 pp.

Williams, R. & McEldowney, A. 1990. A guide to the fish otoliths from waters off the Australian Antarctic Territory, Heard and Macquarie Islands. *ANARE Research Notes*, No. 75, 1-173.