# A study of stomach contents of Cory's Shearwater, *Calonectris diomedea borealis* (Cory, 1881) (Aves: Procellariidae), from the Macaronesian Islands

CANCAP-project contribution nr 114

**J.C. den Hartog & M.R. Clarke**

Hartog, J.C. den & M.R. Clarke. A study of stomach contents of Cory's Shearwater, Calonectris diomedea borealis (Cory, 1881) (Aves: Procellariidae), from the Macaronesian Islands.
Zool. Med., Leiden 70 (7), 31.vii.1996: 117-133, figs 1-10, tabs 1-4.— ISSN 0024-0672.
J.C. den Hartog, Nationaal Natuurhistorisch Museum, Postbus 9517, 2300 RA Leiden, The Netherlands.
M.R. Clarke, "Ancarva", Southdown, Millbrook, Cornwall PL10 1EZ, U.K.

Key words: Procellariidae; *Calonectris diomedea borealis* (Cory, 1881); diet; stomach contents; Cephalopoda; SE North Atlantic; Macaronesia.
Data are presented on the diet of Cory's Shearwater *Calonectris diomedea borealis* (Cory, 1881) resulting from stomach investigations based on 18 birds from Hierro (Canary Islands), 5 from Selvagem Grande (Selvagens or Salvage Islands), 2 from São Miguel and 1 from São Jorge (Azores), collected between 1977 and 1981. These data confirm the general idea that this shearwater feeds principally on fish and squid. The glandular stomachs of 9 birds from Hierro contained significant quantities of food, varying in wet weight from ca. 4-40 gm; in four cases more or less complete squids were present, all *Ommastrephes bartrami* (Le Sueur, 1821). In addition, the gizzards of all 26 birds, except one, contained fragments of squid beaks belonging to 12 species. Several of these are generally thought to live at considerable depth and their origin is speculated upon. Estimated lengths and weights of squids that were eaten are presented. Fish remains, too, represented by bones, vertebrae, eye-lenses, and in one case by otoliths of a species of Flying Fish (Exocoetidae), were regularly found in both glandular stomachs and gizzards.
The initial aim of the present study, viz. to verify whether the diet of Cory's Shearwater includes pelagic coelenterates, could not be substantiated; not a trace of coelenterate matter was found in any of the alimentary tracts investigated.

## Introduction

It is well-known that representatives of several groups of marine animals prey upon oceanic squid. Among these are the vast majority of toothed whales (for a summary, see e.g. Evans, 1987: table 6.2; Clarke, 1996), including the largest of them all, the Sperm Whale (*Physeter macrocephalus* Linnaeus, 1758), which almost exclusively feeds on these cephalopods (Clarke, 1980), and predatory fish such as tunny and other members of the mackerel family (Scombridae) (Smale, 1996). Squid remains have even been found occasionally in the stomachs of sea turtles (Den Hartog, 1980: 602; Van Nierop & den Hartog, 1984: 43, 51).

Cephalopods figure also in the diet of many species of oceanic birds (Croxall & Prince, 1996). One of these, and the largest of its kind breeding in the Macaronesian Islands, is Cory's Shearwater, *Calonectris diomedea borealis* (Cory, 1881), locally known as Cagarra (Madeira, Selvagens Islands), Cagarro (Azores) or Pardelo (Canary Islands). Although it is known to prey on squid (cf. e.g. Cramp et al., 1977: 138), there is little

detailed information on species involved. A recent paper by Lipinski & Jackson (1989: 557) provides data on two specimens collected in the southern Benguela region that contained remains of *Sepia* spec. and *Taonius* spec., respectively.

The present paper deals with a study of the stomach contents of a series of Cory's Shearwaters collected in the framework of the CANCAP project of the former Rijksmuseum van Natuurlijke Historie (RMNH) (now Nationaal Natuurhistorisch Museum, NNM) (for a general introduction on this project, see Den Hartog, 1984). Initially, the present study was not undertaken because the species preys upon squid, but rather as a follow-up of studies on marine turtles (den Hartog, 1980; den Hartog & van Nierop, 1984; van Nierop & den Hartog, 1984), whose diet includes a considerable percentage of Coelenterata (mainly Scyphozoa and Hydrozoa), up to about 100% in the case of the Leathery Turtle (*Dermochelys coriacea* Linnaeus, 1766). If marine turtles can partly or entirely subsist on a diet of jellyfish, there seems no reason to reject this idea for oceanic birds, notably for species of Procellariidae, and it was thought possible that the oily character of both groups of animals might to some extent have a similar dietary basis.

In two previous publications (Nørrevang & den Hartog, 1984: 113-114; den Hartog, 1990: 162) some data were presented on the stomach contents of the Cape Verde Shearwater, *Calonectris edwardsii* (Oustalet, 1883), a very close relative of Cory's Shearwater and often regarded as just another subspecies of *Calonectris diomedea*, indicating two types of prey, viz. squid and fish. Not a trace of coelenterates was found during that study, in spite of painstaking microscopical search for nematocysts.

Meanwhile, the intake of coelenterates by sea-birds has been ascertained irrefutably. Harrison (1984, 1990) reported remains of medusae from the stomachs of 11 species of arctic seabirds including four species of Procellariidae, viz., *Fulmarus glacialis* (Linnaeus, 1761) (Fulmar), *Puffinus griseus* (Gmelin, 1789) (Sooty Shearwater), *P. tenuirostris* (Temminck, 1835) (Short-tailed Shearwater), and *Oceanodroma furcata* (Gmelin, 1789) (Fork-tailed Storm-petrel). Furthermore, Ates (1990), in a preliminary review of the few instances of birds feeding on jellyfish obscured in the literature, mentioned that the Fulmar preys occasionally on *Velella velella* (Linnaeus, 1758). In view of these recent discoveries it is interesting to note that the Arctic explorer Kane (1856: 304), referring to that species as Arctic Petrel (*Procellaria glacialis*), casually stated: " ...Its food is essentially marine, the acalephae, &c. &c.;...", Acalephae being an obsolete collective name for jellyfish of any kind. It is somewhat surprising that Kane's statement is presented as if common knowledge.

## Material

The material available for the present study consisted of the alimentary tracts of 26 specimens of Cory's Shearwater collected in the Canary Islands (Hierro, 1977: 18 birds), Selvagens (1978: 5 birds) and the Azores (São Miguel, 1981: 2 birds; São Jorge, 1981: 1 bird). A detailed survey of the food items found in the stomachs of these birds is presented in tables 1-4.

## Structure of the stomach of Cory's Shearwater

The stomach of Cory's Shearwater, as in most birds, consists of two distinct

chambers, an anterior glandular stomach, the proventriculus (fig. 1), and a small, posterior muscular stomach, the ventriculus or gizzard (figs 1, 6-10), which, among others, has a chewing and grinding function. There is no crop. The smooth oesophagus abruptly passes into the proventriculus (fig. 2), a distensible sac-like organ lined with glandular epithelium dotted with numerous minute depressions representing the openings of epithelial digestive gland tubes (fig. 3). In the empty, contracted state the proventriculus is marked by deep longitudinal furrows (fig. 2). The gizzard is lined by a hard, semi-transparent, keratinous, protective lining of koilin, a polysaccharide-protein substance (cf. e.g. Campbell & Lack, 1985: 10) secreted by glands of the underlying epithelium.

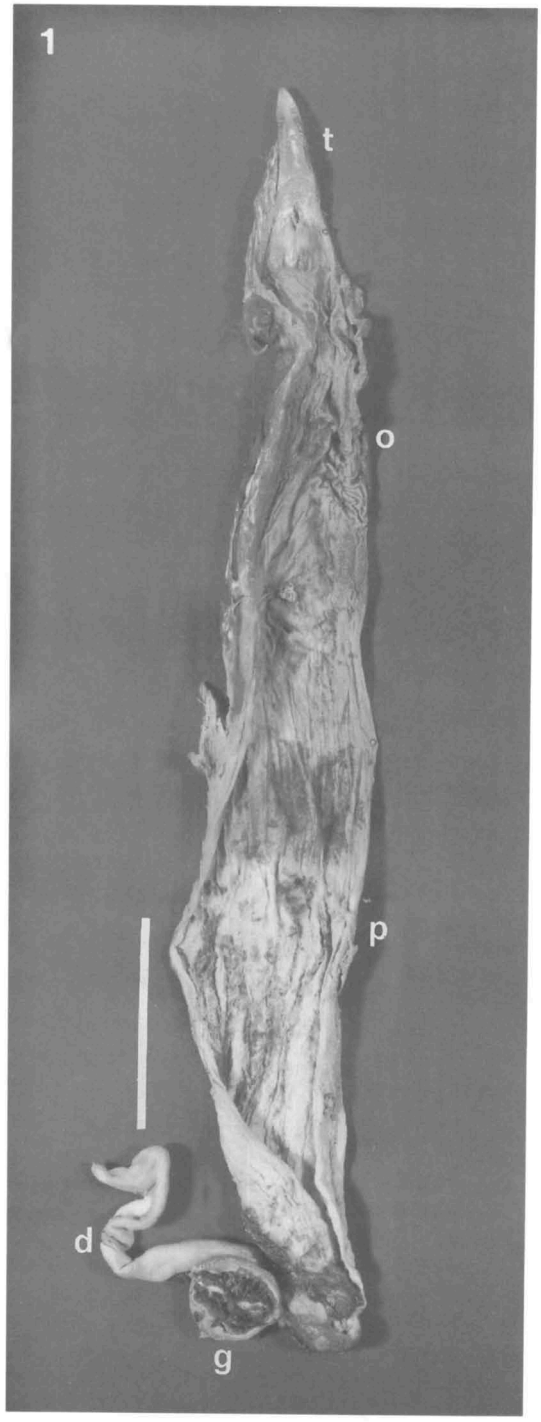
## Results of the analysis of the stomach contents

A survey of the results of analysis of the stomach contents of the birds from the three collecting locations is presented in tables 1-3.

Table 1. Data obtained from the stomachs of 18 specimens of Cory's Shearwater procured off Punta Orchilla, Hierro, Canary Islands (5.ix.1977, 18.15-19.15h).

| RMNH number/ sex, weight | Description of stomach contents |
|---|---|
| Aves 81217, male, 720 gm | Glandular stomach contracted and empty except for 2 small Nematoda. Gizzard with some crushed squid beaks (2 *Octopus* spec., 4 *Ommastrephes bartrami*) and membranous filaments. Koilin lining medium brown and knobby. |
| Aves 81218/ female, 790 gm (fig. 5b) | Glandular stomach distended, containing 2 almost complete squids (*Ommastrephes bartrami*) with mantle 8 and 8.8 cm long, and one fragment 5.2 cm long (fig. 5b). In addition some beaks (2 *Ommastrephes bartrami*, 1 *Brachioteuthis riisei*, 1 ?*Chiroteuthis* spec.). Total weight of stomach contents 28 gm.<br>Gizzard with dark, crushed squid beaks (2 *Histioteuthis* A[*1)], 1 *Megalocranchia* spec., 3 other unidentified types). Koilin lining dark brown and knobby. |
| Aves 81219/ female, 820gm (fig. 8) | Glandular stomach full and distended, containing oily fish remains and fragments of fish fins (presumably Exocoetidae), some fibrous spongy mass (muscle fibres?) interwoven with partly digested squid arms (*Histioteuthis* A), each arm with one row of well-spaced suckers. Total weight of stomach contents 40 gm.<br>Gizzard (fig. 8) crammed with crushed squid beaks (2 *Histioteuthis* A, 2 other types + many unidentifiable tips), minute brown globular bodies (eye lenses of fish fry?) and small fish vertebrae and fish bones. Koilin lining pale brown and knobby. |
| Aves 81232/ male, 825 gm | Glandular stomach contracted and empty except for a small feather and a whitish unidentified more or less discoid structure ca 3 mm across. |

[*1)] *Histioteuthis* A is a type of beak possessed by several North Atlantic species of *Histioteuthis* (see Clarke, 1986). In the present collection they are all probably either *H. bonnellii* (Ferussac, 1835) or *H. hoylei* (Goodrich, 1896).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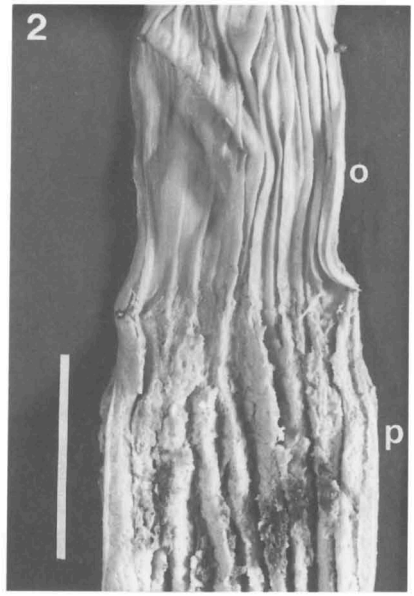
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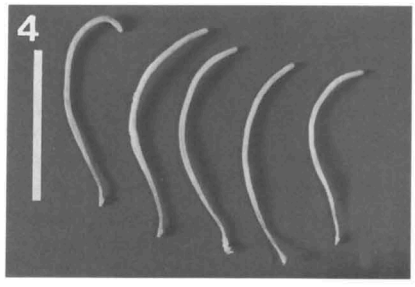
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| | Gizzard with crushed squid beaks (unidentifiable). Koilin lining medium brown. |
| Aves 81215/ female, 800 gm | Glandular stomach with two squid mantle fragments 4.2 and 4.7 cm long, the latter enveloping buccal mass with beak (*Ommastrephes bartrami*). Total weight of stomach contents 25 gm.<br>Gizzard , containing few hard fragments of crushed squid beaks (unidentifiable), some minute brown globular bodies and 1 unsclerotized pair of beaks (*Sepia* spec.). Koilin lining medium brown and knobby. |
| Aves 81233/ male, 785 gm | Glandular stomach contracted and empty.<br>Gizzard crammed with crushed squid beaks (incl. 3 lower beaks of *Ommastrephes bartrami*), fibrous material (remains of squid pens), one small piece of pumice, minute brown globular bodies (eye lenses of fish fry). Koilin lining medium brown and knobby. |
| Aves 81211/ female 720 gm (fig. 5c) | Glandular stomach distended, containing the remains of at least 4 small squids (*Ommastrephes bartrami*) (fig. 5c): two more or less complete specimens with mantle lengths 8 and 10 cm and two mantle fragments, 4 and 7 cm long; in addition 3 eye lenses ca 3 mm across, one more or less complete beak and a separate jaw.<br>Gizzard containing numerous crushed squid beaks (mostly unidentifiable tips and 2 lower beaks of *Ommastrephes bartrami*), fibrous material (remains of pen). Koilin lining dark brown and knobby. At least one small fragment of hard crushed squid beak in intestines. |
| Aves 81212/ female, 830 gm (figs 3, 5a) | Glandular stomach distended, containing 2 more or less complete squids (*Ommastrephes bartrami*) with mantle ca 7 and 7.5 cm long and 4 fragments 4.6, 6.5, 5.3 and 6 cm long (partly telescoped into each other) (fig. 5a); in addition 1 small whitish globular body (see gizzard). Total weight of stomach contents 32 gm.<br>Gizzard with dark crushed squid beak fragments (including *Histioteuthis* A and *Chirotheuthis* spec.) and 8 whitish semi-globular to disc-shaped bodies ca 2-4.5 mm across. Koilin lining rather dark brown and knobby. |
| Aves 81221/ male, 830 gm | Glandular stomach with mantle fragment 2 cm long and head plus tentacles and beak 22 mm long (*Ommastrephes bartrami*) and some fibrous material (remains of pens and/or spermatophores). Total weight of stomach contents 4 gm.<br>Gizzard with 10 fragments of crushed squid beaks (unidentifiable) and a tiny fragment of pumice. Koilin lining pale brown and knobby. |
| Aves 81225/ male, 770 gm | Glandular stomach empty except for a fragment of the vertebral column of a small fish and a single nematode.<br>Gizzard with squid beak fragments (including 1 *Histioteuthis* A, 1 ?*Taonius* spec., and many unidentifiable tips) and remains of spermatophores, 2 |

Figs 1-4. Fig. 1. Total view of the anterior part of the gut of Cory's Shearwater (RMNH Aves 81222). Fig. 2. Transition of oesophagus and empty contracted stomach, with characteristic ridges with glandular tissue (RMNH Aves 81228); fig. 3. Enlarged detail of distended glandular stomach; dots indicate openings of digestive glandular tubules (RMNH Aves 81212); fig. 4. Spermatophores from glandular stomach of RMNH Aves 81243. Scale bars: fig 1 = 5 cm; fig. 2 = 3 cm; fig. 4 = 2 cm; d = duodenum; g = gizzard; o = oesophagus; p = proventriculus or glandular stomach; t = tongue.

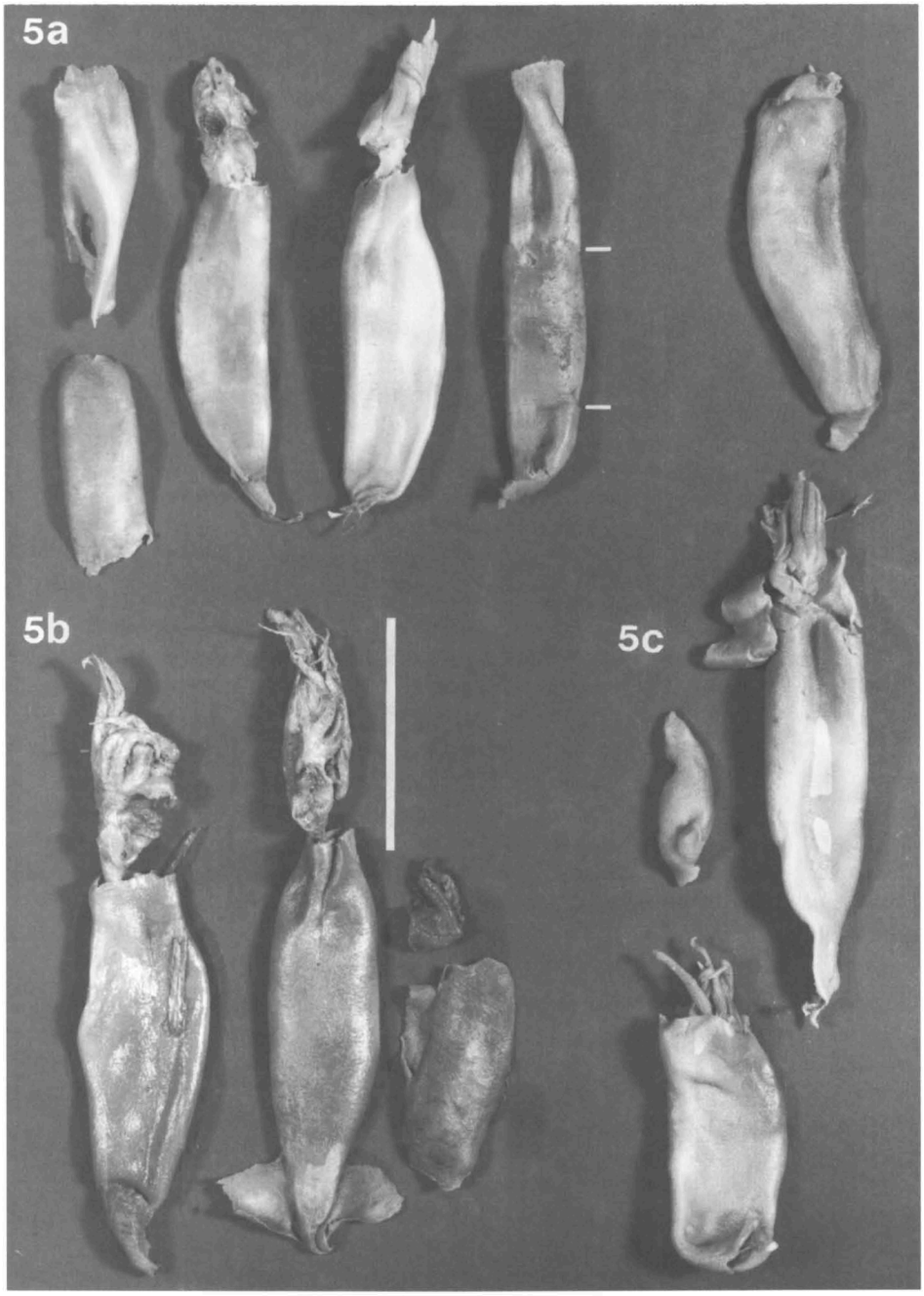


Fig. 5. Specimens and mantle fragments of the squid *Ommastrephes bartrami* from glandular stomachs of Cory's Shearwater collected off Hierro, Canary Islands. Fig. 5a. From RMNH Aves 81212; note three mantle fragments to the right telescoped into each other (limitation indicated by white bars). Fig. 5b. From RMNH Aves 81218: Fig. 5c. From RMNH Aves 81211. Scale bar = 5 cm.

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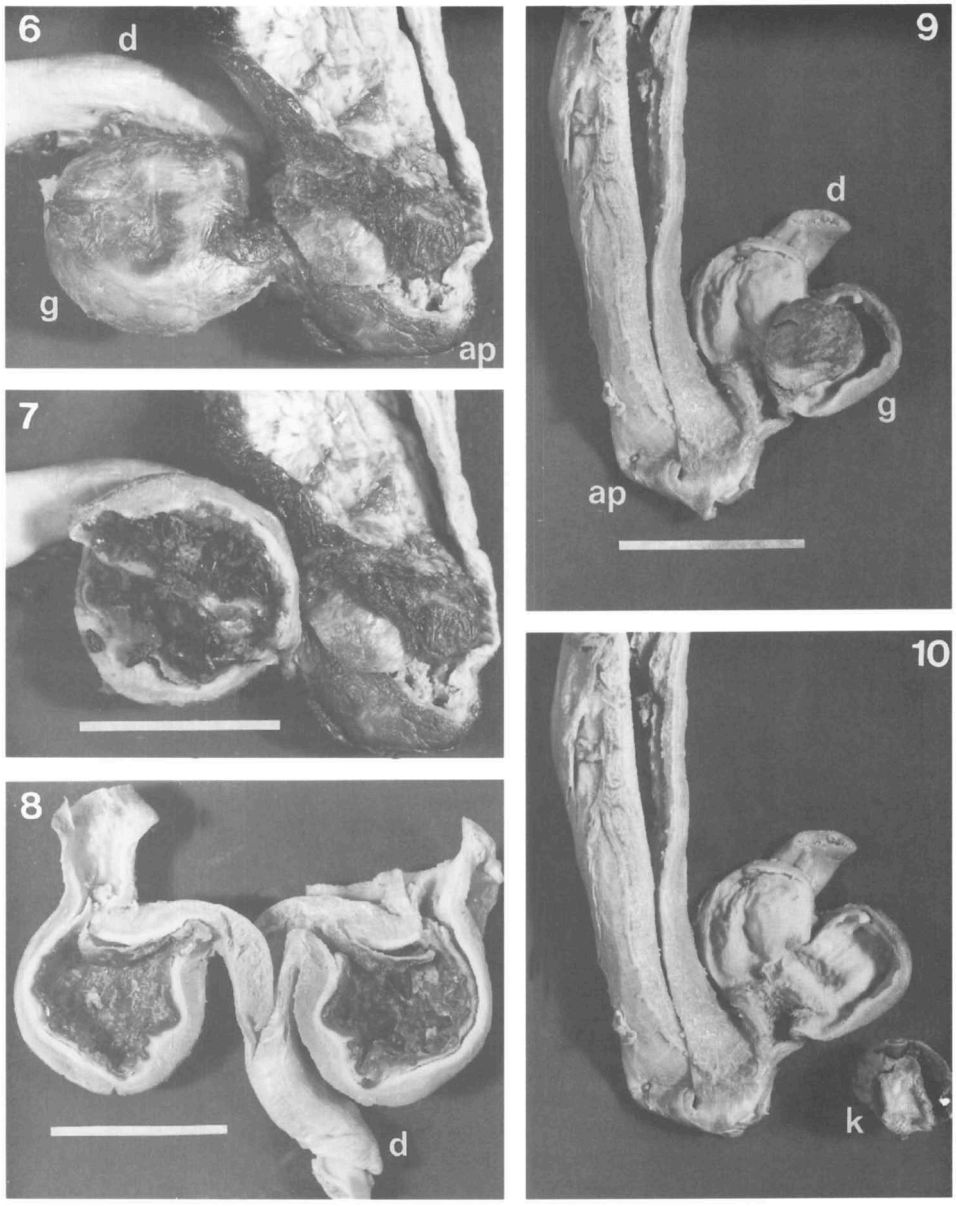
|---|---|
| | otoliths of a species of Flying fish (Exocoetidae), 1 small fragment of nylon fish line and a small bird's feather. Koilin lining medium brown and not so knobby. |
| Aves 81227/ male, 820 gm | Glandular stomach with some yellowish and reddish substance in aboral part. Gizzard almost empty, with only one or two unidentifiable squid beak fragments. Koilin lining pale brown and knobby. |
| Aves 81226/ female, 625 gm | Glandular stomach contracted and empty, except for 2 small Nematoda. Gizzard containing a whitish substance with crushed squid beaks (some tips including one *Ommastrephes bartrami*), many minute brownish globular bodies and a small bunch of membranous material (squid pens). Koilin lining pale brown and medium knobby. |
| Aves 81224/ female, 720 gm | Glandular stomach distended containing macerated fish and fish bones, squid eye lense ca 7 mm across, and 1 globular body 1.5 mm across. Total weight of stomach contents 24 gm. Gizzard with few crushed squid beaks (*Histioteuthis* A) and many small fish vertebrae. Koilin lining pale brown and not so knobby. |
| Aves 81228/ female, 750 gm (figs 2, 9-10) | Glandular stomach contracted and empty except for a few minute brownish globular bodies ca 1 mm across (eye lenses of fish fry). Gizzard with few crushed fragments of squid beaks (4 unidentifiable tips + 1 *Histioteuthis* A), minute globular bodies and 1 fragment of a small gastropod shell. Koilin lining medium brown and rather knobby. |
| Aves 81229/ female, 870 gm | Glandular stomach contracted, in its lowest part with 4 rather large squid eye lenses, 10-11 mm across. Gizzard with numerous fragments of crushed squid beaks (mostly tips including *Histioteuthis* A) and a few small globular bodies. Koilin lining medium brown and not so knobby. |
| Aves 81220/ female, 880 gm | Glandular stomach distended, full of oily fish remains (e.g. 2 partial vertebral columns and numerous fish bones, as well as squid eye lenses (12 mm across). Total weight of stomach contents 40 gm. Gizzard with few crushed squid beaks (unidentifiable), fragments of fish neurocranium and fragments of squid pen. Koilin lining medium brown and rather knobby. |
| Aves 81222/ male, 875 gm (figs 1, 6-7) | Glandular stomach with amorphous substance and partly digested squid arms. Total weight of stomach contents 24 gm. Gizzard with crushed squid beaks, including 1 *Histioteuthis* A, and some remains of spermatophores and small fish vertebrae. Koilin lining medium brown and rather knobby. |
| Aves 81230/ female, 840 gm | Glandular stomach, rather distended with some tiny fleshy squid fragments, an eye lens 3 mm across, and an upper beak (unidentifiable). Gizzard with crushed squid beaks and 1 rather fresh beak (mostly tips + 1 *Octopus* spec. and 1 *Ommastrephes bartrami*), 2 squid eye-lenses 4.5 mm across, 1 eye lens 1.5 mm across, and 1 tough threadlike flexible structure ca 15 mm long. Koilin lining pale brown, not so knobby. |




Figs 6-10. Details of gizzards of Cory's Shearwater. Figs 6-7. RMNH Aves 81222, lower part of glandular stomach with gizzard closed and opened showing numerous crushed squid beaks. Fig. 8. RMNH Aves 81219, gizzard cut in two halves showing knobby koilin lining; note separation of koilin lining from gizzard-wall. Figs 9-10. RMNH Aves 81228, lower part of glandular stomach and open gizzard with koilin lining peeled off and removed. Scale bars: figs 6-7 = 3 cm; fig 8 = 3 cm; figs 9-10 = 5 cm; ap = aboral part of glandular stomach; d = duodenum; g = gizzard; k = koilin lining of gizzard.

Table 2. Data on stomach contents of five specimens of Cory's Shearwater collected on Selvagem Grande (6 and 7.vi.1980).

| RMNH number/ sex, weight | Description of stomach contents |
|---|---|
| Aves 81243/ male, 1020 gm (fig. 4) | Glandular stomach stuffed with ca 100 squid spermatophores, ca 3-4 cm long (species not identified)<br>Gizzard with several crushed squid beaks (tips including 3 *Histioteuthis* A) and detached roundish fragments of koilin. Koilin lining dark brown and very knobby. |
| Aves 81244/ male, 940 gm | Glandular stomach empty, except for one small nematode, ca 2 cm long.<br>Gizzard with few crushed squid beak fragments (unidentifiable). Koilin lining dark brown and knobby. |
| Aves 81245/ female, 850 gm (egg included) | Glandular stomach aborally with membranous material (fragments of squid pens) and some squid jaws (1 *Argonauta* spec., 1 *Megalocranchia* spec., 1 *Gonatus steenstrupi* and 1 *Histioteuthis reversa*).<br>Gizzard crammed with crushed, sclerotized squid beaks (9 *Histioteuthis reversa*, 1 *Brachiotheuthis riisei*, 6 tips belonging to 3 other unidentifiable types) and membranous matter. Koilin lining rather dark brown and knobby. |
| Aves 81241 female, 920 gm (egg included) | Glandular stomach with remains of single *Histioteuthis* A (1 beak, some flesh and fragments of pen).<br>Gizzard containing dense cluster of crushed squid beaks including 1 *Histioteuthis* A, 1 *Chiroteuthis* spec. and 1 *Taonius* spec. and in addition membranous/fibrous material and roundish fragments of detached koilin. Koilin lining dark brown and very knobby. |
| Aves 81242/ female, 640 gm | Glandular stomach empty.<br>Gizzard with crushed squid beaks, including 1 *Histioteuthis* A, 2 *Chiroteuthis* spec. and 1 *Valbyteuthis* spec. Koilin lining dark brown and knobby. |

Table 3. Data on stomach contents of three specimens of Cory's Shearwater from the Azores: two from Ilhéu do Vila Franca, São Miguel (31.v. 1981), and one from São Jorge (4.vi.1981; Aves 80884).

| RMNH number/ sex, weight | Description of stomach contents |
|---|---|
| Aves 81008/ female, weight unknown | Glandular stomach empty except for some greenish brown fatty substance.<br>Gizzard with some crushed squid beaks including 1 *Chiroteuthis* spec., a few loose knobby koilin fragments and minute rock fragments. Koilin lining rather dark and very knobby, some of the knobby structures almost papillate. |
| Aves 81010/ small male, weight unknown | Glandular stomach empty except for a hyoid (2.4 cm long) of a fish, and a nematode worm.<br>Gizzard empty; koilin lining absent (!). |
| Aves 80884/ female, 610 gm | Glandular stomach with one small nematode but without food remains.<br>Gizzard with several crushed squid beaks including 5 *Histioteuthis* A and four whitish subglobular to disc-shaped gizzard stones some 3-4 mm across (possibly worn fish otoliths). No data on koilin lining. |

## Discussion on the stomach contents

For plausible reasons, the best preserved and hence best identifiable materials were found in the glandular stomachs. The gizzards nearly always mainly contained crushed cephalopod beaks, usually rather sclerotized and more brittle than the ones found in the glandular stomachs. To check whether these hard and often rather sharp fragments do enter the posterior part of the alimentary tract beyond the gizzard, the intestines were checked by touch; in addition the intestines of a few specimens were fully dissected and inspected microscopically. In all, only one little beak fragment was found (RMNH Aves 81211), indicating that such fragments do not normally enter beyond the gizzard, unless completely pulverized.

Nine out of the 18 birds collected off Hierro (cf. table 1) had significant amounts of food in the glandular stomach, varying in total weight from 4 to 40 gm, and mostly consisting of squid and squid fragments (fig. 5). The proventriculi of the other 9 birds were empty or practically so, possibly as a result of regurgitation after being shot.

The stomachs of the eight birds from Selvagem Grande and the Azores (table 2, 3) were all but empty. These birds were all taken from their nests between 31 May and 7 June, i.e. during the egg-laying season (two birds, RMNH Aves 81241 and 81245, still contained an egg) and the initial phase of the breeding season (cf. Zino, 1971; Cramp et al., 1977: 139; Zino et al., 1987); hence, before being collected, they may not have taken any food for days.

In birds, it is usually easy to peel the koilin lining off the gizzard wall and this also holds true for Cory's Shearwater (see figs 8-10). For this reason, it is generally assumed, and actually confirmed for a number of species, that this lining can be moulted in many, perhaps most bird species, and disposed of either via the mouth or by passing through the intestinal tract (cf. Farner, 1960: 430; Ziswiler & Farner, 1972: 375). In the case of Cory's Shearwater and other species of Procellariidae shedding of this lining might be a useful mechanism to get rid of its contents of accumulated crushed sclerotized squid beaks and other indigestible matters. Periodical shedding of this lining might further explain the variation in its colour intensity (caused by bile products; cf. e.g. Ziswiler & Farner l.c.: 374), thickness and relief: a pale brown colour and weak relief would suggest it to be relatively young, whereas a dark brown colour and a more conspicuous, knobby, sometimes almost papillate relief might indicate relatively old age. In the gizzards of three birds from Selvagem Grande and the Azores (RMNH Aves 81234, 81241 and 81008) loose, roundish fragments of koilin were present, presumably representing papilla-like projections having become detached from the dark and very knobby koilin lining in these specimens.

In the present context it is noticeable that the gizzard of one of the specimens from the Azores (table 3, RMNH Aves 81010) happened indeed to lack a lining of koilin. The gizzard of this bird was aberrant in being somewhat distended and not distinctly separated from the proventriculus, a condition suggesting that the lining (plus its contents) had been regurgitated.

Not a single stomach or alimentary tract examined was found to contain a trace of macroscopically identifiable coelenterate matter, and microscopical investigation

did not yield a single coelenterate nematocyst. As nematocysts are extremely resistent structures we are confident that none of the birds investigated had eaten coelenterates.

## Squid species found in the stomachs of the birds examined

An overall survey of the cephalopod species found in the stomachs of the birds examined (cf. tables 1-3) is summarized in table 4.

Table 4. Number of Cory's Shearwaters from Hierro, Selvagem Grande and the Azores containing identifiable cephalopod remains (21 out of 26 birds examined), analysed for each species of cephalopod. Classification of Cephalopoda after Nesis (1987).
In each column the number of birds (+ percentage, where relevant) is followed by the minimum total number of cephalopod specimens involved.
Abbreviations in first column: S = sinkers, i.e. animals that tend to sink in dead condition (after Clarke et al., 1979) (S* = S at size of animals represented); F = floaters, i.e. animals that normally float in dead condition; P = photophores present; A = photophores absent.

| Geographical origin of birds examined | | Hierro | Selvagem Grande | Azores | Areas combined |
|---|---|---|---|---|---|
| Number of birds/minimum total number of cephalopod specimens | | 15 /52 | 4 /35 | 2 /6 | 21 /93 |
| Cephalopod taxa | | | | | |
| **Order Teuthida** | | | | | |
| **Ommastrephidae** | (S) | | | | |
| 1. *Ommastrephes bartrami* | (S, P) | 9 (60%)/22 | 0 | 0 | 9 (42.9%)/22 |
| **Gonatidae** | (F) | | | | |
| 2. *Gonatus steenstrupi* | (S*, A) | 0 | 1 /1 | 0 | 1 (4.8%)/1 |
| **Brachioteuthidae** | (S, A) | | | | |
| 3. *Brachioteuthis* spec. | (S, A) | 1 (6.7%)/1 | 1 /1 | 0 | 2 (9.6%)/2 |
| **Histioteuthidae** | (F) | | | | |
| 4. *Histioteuthis* A | (F, P) | 8 (53.3%)/21 | 4 (100%)/15 | 1 /5 | 13 (61.9%)/41 |
| 5. *Histioteuthis reversa* | (F, P) | 0 | 1 /1 | 0 | 1 (4.8%)/1 |
| **Chiroteuthidae** | (F) | | | | |
| 6. *Chiroteuthis* spec. | (F, P) | 2 (13.3%)/2 | 2 /3 | 1 /1 | 5 (23.8%)/6 |
| 7. *Valbyteuthis* spec. | (F, A) | 0 | 1 /10 | 0 | 1 (4.8%)/10 |
| **Cranchiidae** | (F) | | | | |
| 8. *Megalocranchia* spec. | (F, P) | 1 (6.7%)/1 | 1 /1 | 0 | 2 (9.6%)/2 |
| 9. *Taonius* spec. | (F, P) | 1 (6.7%)/1 | 1 /1 | 0 | 2 (9.6%)/2 |
| **Order Sepiida** | | | | | |
| Sepiidae | (F) | | | | |
| 10. *Sepia* spec. | (F, A) | 1 (6.7%)/1 | 0 | 0 | 1 (4.8%)/1 |
| **Order Octopoda** | | | | | |
| **Octopodidae** | (S, A) | | | | |
| 11. Octopus spec. | (S, A) | 2 (13.3%)/3 | 1 /1 | 0 | 3 (14.3%)/4 |
| **Argonautidae** | (S, A) | | | | |
| 12. *Argonauta* spec. | (S, A) | 0 | 1 /1 | 0 | 1 (4.8%)/1 |

Squid was present as flesh (sometimes represented by more or less complete individuals) in the glandular stomachs of eight birds collected off Hierro (cf. fig. 5). In all but one case (remains of tentacles of *Histioteuthis* A) it concerned a single species, viz. *Ommastrephes bartrami* (Le Sueur, 1821). Considering the good condition of these squids (cf. fig. 5) it seems plausible that they were fresh when taken by the Cagarras, and not the result of scavenging activities. This idea is supported by the fact that *Ommastrephes bartrami* normally tends to sink when dead (for information on "sinkers" and "floaters", see table 4). It is interesting that all more or less complete squids or squid mantles were oriented in the bird's stomachs with the tail down, indicating, or at least suggesting that living squids are normally swallowed tail first. In one stomach three squid mantles were found neatly telescoped into each other (fig. 5a).

Although the total number of birds examined does not allow far reaching conclusions, the present study seems to indicate that *Ommastrephes bartrami* and *Histioteuthis* spp. [including *H. reversa* (Verrill, 1880)] are among the most important prey species of Cory's Shearwater in Macaronesia (cf. table 4).

*Ommastrephes bartrami* is a species which may be seen close to the surface between dawn and dusk (Clarke, 1966; as *O. caroli* Furtado, 1887), and the presence of rather fresh specimens of this species in the glandular stomachs of Cagarras collected off Hierro is not, therefore, surprising. The condition of the squids as well as the fact that this species tends to sink when dead indicate that these specimens were taken alive. Taking also into account the remains found in the gizzards, this squid species was present in 9 (60%) of the Hierro birds containing identifiable cephalopod remains. Other cephalopods that may be seen near-surface of which remains were found in the gizzards are members of the inshore genera *Sepia* and *Octopus* and the oceanic genus *Argonauta*. These were present in 3 (20%) of the birds from Hierro and in 5 (23.8%) of the total number of birds containing cephalopod remains. A considerable percentage of Sepiida and Octopoda was also recorded in the diet of seabirds in the south Benguela region (Lipinski & Jackson, 1989).

If the presence of *Ommastrephes bartrami* in the diet of Cory's Shearwater is easily accounted for, the presence of several other species and genera that are not normally observed near the surface is less understandable. These include *Histioteuthis reversa*, *Histioteuthis* A [probably *H. bonnellii* (Férussac, 1835) and/or *H. hoylei* (Goodrich, 1896)], *Brachioteuthis riisei* (Steenstrup, 1882), *Megalocranchia* spec., *Chiroteuthis* spec., *Valbyteuthis* spec. and *Taonius* spec. The number of Hierro birds containing remains of these deep water squids (8 out of 15; cf. table 1) amounts to no less than 53.3%, and all these birds contained remains of at least *Histioteuthis* A (likewise 53.3%), the presence of this last-named species thus approaching the percentage found for *Ommastrephes bartrami* (60%). Taking into account the birds from Selvagem Grande and the Azores this percentage even amounts to 61.9% for *Histioteuthis* A (13 out of 21 birds) against 42.8% for *Ommastrephes bartrami* (9 out of 21 birds).

## Speculations on the origin of remains of deeper living squid species in stomachs of Cory's Shearwater

Deep water squids have been reported from the stomachs of many other species of Procellariidae. Quite recently, this issue has been reviewed by Croxall & Prince

(1994: 160-161) with reference to albatrosses, but the explanations given, although still to a large extent unconfirmed, would seem to have general validity for the larger species of Procellariidae, Cory's Shearwater included. However, a certain explanation for the presence of remains of deeper living squid species in the stomachs of Macaronesian Cagarras cannot be given here. There are several possibilities, which could be complementary and which, from one situation to another, might all play their part:

1. These squids come closer to the surface than is generally assumed on the basis of net catches etc., either in zones of local upwelling, so far unnoticed by biologists, or in the course of normal but little known nocturnal vertical upward movements. The presence of photophores in most oceanic squid species (see table 4) would explain why nocturnal or semi-nocturnal conditions do not prevent their capture by the mainly night feeding Cagarras (Cramp et al., 1977: 138).

This possibility seems the most plausible for the Macaronesian region, because it accounts for the regular ingestion of squids by a large population of birds.

2. These squid remains derive from regurgitations of Cetacea at the surface. Periodical regurgitations to get rid of cephalopod beaks and other hard materials being a common phenomenon in these marine mammals, this possibility has previously been suggested for other Procellariidae by e.g. Clarke et al. (1981) and Croxall & Prince (1994).

There is no doubt that regurgitated remains of cephalopods will be scavenged at least occasionally by Cagarras, but it is doubtful whether such cetacean regurgitations form the only or the most significant food source for the tens of thousands of Cagarras in the Macaronesian region. Certainly the largest deep living cephalopod represented here, *Megalocranchia* spec., is likely to have been from this source or from offal from fishing boats (see 3; below). There is some indication that the olfactory sense of Cory's Shearwater is considerable (e.g. Benvenuti et al., 1993), so that the presence of cetacean regurgitations at the sea surface, even at night, might not generally go undetected. In this connection it is interesting to note that Vasallo (1984: 20) observed in the Mediterranean how birds of nominate subspecies *Calonectris diomedea diomedea* (Scopoli, 1769) were readily attracted by a liver of a dogfish, *Scyliorhinus stellaris* (Linnaeus, 1758), thrown overboard from a fishing boat. Although no birds were to be seen when the liver was entrusted to the sea, they very soon came flying from all directions to feast on it. Similar observations were made on the south coast of Selvagem Grande in 1970 and 1987 (P.A. Zino, in litt.), although in this case shark and trigger fish livers were used to attract Cagarras that were within sight (On 3.xi.1970 cut up sharks livers that were thrown off the stern of RV "Atlantis 2" some three miles off Selvagem Grande formed a pronounced oil slick which attracted hundreds of birds, and the same was observed on 30.vii.1987 in Cagarra Bay, south-west coast of Selvagem Grande, when finely chopped triggerfish livers were thrown in the water).

Although Vasallo left the possibility open that the liver was detected by sight, this seems less likely, as he also mentioned that other offal thrown overboard, e.g. dead fish, did not produce this same striking effect. Bent (1922: 58) (see also Cramp et al., 1977: 138) already

mentioned that Cory's Shearwaters scavenge offal thrown overboard of fishing vessels, and explicitly mentioned their preference for oily substances: "They are particularly fond of cod livers and other oily portions, with which they can be readily tolled up to the boat or caught on baited hooks".*2)

Apart from feeding on regurgitations of odontocetes, Cagarras and other seabirds have been observed to feed on cetacean faeces (e.g. Evans, 1982), but as such materials do not normally contain edible squid remains and beaks, this way of feeding has no relevance to the present discussion

3. These squids or their remains derive from offal from fishing boats.

Scavenging of fish offal, particularly viscera including full stomachs, swept off the deck of fishing boats or thrown overboard, may occur on a more or less regular basis, and many of the larger commercial fish species such as swordfish, tunny and sharks eat deep living cephalopods (e.g. Clarke et al., 1995; Smale, 1996).

4. These squids derive from post-spawning near-surface die-offs.

This is not possible for most cephalopods represented here because they are mainly of an immature size. Males mature at a smaller size than females and do not immediately die after delivering spermatophores which they probably do over a period of several months.

5. Schools of these squids are chased to the surface by hunting cetaceans or large predatory fish, where they may also be taken by seabirds.

Seabirds often associate with schools of cetaceans and large predatory fish. This is also true for Cory's Shearwater; there are many records in the literature confirming this (e.g. Zino, 1971; Pierotti, 1988). Zino (l.c.: 113) mentions that "during the breeding season, concentrations of Cory's Shearwaters act as a very good indication of the presence of tunny *Thunnus* spp. and bonito *Katsuwonus pelamis* around the Salvage Islands, and are used as such by Madeiran fisherman". In our view these birds are first of all attracted, either instinctively or by learning, by the conspicuous hunting activities of the large predators by which squid and fish are hunted to the surface and even emerge to escape, a technique perfected in flying fish

*2) An interesting observation, also worth mentioning here, although not bearing on Cory's Shearwater, was made by the whaling captain Joseph Fuller (1839-1920), who spent many years sealing on Kerguelen. Describing the feeding behaviour of the Giant-Petrel [presumably *Macronectes halli* (Matthews, 1912), which is much more common on Kerguelen than *Macronectes giganteus* (Gmelin, 1789) (Marchant & Higgins, 1990)], he stated (Fuller, 1980: 22): "I noticed one thing curious: that is, when we commenced to kill [sea]elephants, there was no nellie to be seen. We had not finished killing our first elephant before they commenced to swarm around us. The smell of the gore must have been wafted by the wind to their haunts". Such an observation, and especially the suggestion by this experienced sea elephant hunter about smelling blood (implicitly emphasizing the unlikelihood that vision was involved), although again not providing actual proof of olfaction, should be taken seriously.
The olfactory bulbs of the brain in Procellariiformes are among the largest in birds (Campbell & Lack, 1985) so that olfaction in Procellariidae in general might not be unimportant, not only in homing behaviour, but also in locating specific food sources, including carrion, offal, and possibly partly digested squid. Experiments to test this seem quite feasible.

and also used by *Ommastrephes bartrami* (Clarke, 1966). Several species of dolphin are known for their joint hunting techniques whereby fish schools are surrounded and herded. This has been observed in surface waters (see e.g. Evans, 1987: 149-152), but presumably also involves the chase of prey (fish as well as squid) from deeper water towards the surface. However, this is not likely for *Histioteuthis*, *Chiroteuthis* and the two cranchiids found here, which are all thought to live deeper than 500 m during the day.

## Size of squids found in the stomachs of Cory's Shearwater

The rostral lengths of some of the lower beaks could be measured because their jaw angles were intact and estimates of mantle lengths and weights of the cephalopods from which the beaks came could be made (Clarke, 1986). The *Ommastrephes bartrami* (22 lower beaks) had mantle lengths of 86-127 mm and a mean weight of 24 gm; for other species these estimates were: *Histioteuthis* A (probably *H. bonnellii* and/or *H. hoylei*) (37 lower beaks) 33-78 mm and 46 gm, *H. reversa* (1 lower beak) 55 mm and 58 gm, *Gonatus steenstrupi* (1 lower beak) 240 mm and 270 gm, *Brachioteuthis riisei* (2 lower beaks) 79-89 mm and 10 gm, *?Chirotheuthis* spec. (1 lower beak) 141 mm and 71 gm, *Megalocranchia* spec. (2 lower beaks) 256-440 mm and 65-220 gm, *Octopus* spec. (3 lower beaks) 115 mm and 550 gm.

It is interesting to note that some of the cephalopods eaten by the Cagarras were of considerable size.

The largest squid that was eaten was a specimen of *Megalocranchia* spec. with an estimated total length of 600 mm (mantle length 440 mm) and an estimated weight of some 220 gm. The heaviest cephalopod probably was a species of *Octopus* with a weight over 500 gm. These maximum lengths and weights are similar to the maxima recorded for albatrosses (cf. Croxall & Prince, 1994). However, as has been discussed above, the birds may not have caught the living animals (an achievement which would seem especially unlikely in the case of the one-pounder *Octopus*), and may only have eaten part of them.

## Acknowledgements

We thank Mr P.A. Zino, Funchal, Madeira, for information on the feeding of Cory's Shearwaters on livers of sharks and triggerfish at Selvagem Grande. Dr P.A.M. Gaemers, NNM, identified fish otoliths found in the gizzard of one of the birds studied and Mr E.L.M. van Esch (deceased) made the photographs.

Various kinds of practical help were provided by Drs R.W.R.J. Dekker, M.J.P. van Oijen and C. Smeenk, and Messrs M.W.P. van Dam and J.C.G. van der Voorn (all Department of Vertebrates, NNM), Mr M. Koppenberg and Ms M.E. van de Wal (Library), and by Mr M. Slierings (assistent of the first author).

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Received: 17.iii.1996
Accepted: 9.v.1996
Edited: R.W.R.J. Dekker