GREAT CORMORANTS *PHALACROCORAX CARBO* AND POLYCHAETES: CAN WORMS SOMETIMES BE A MAJOR PREY OF A PISCIVOROUS SEABIRD?

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SUMMARY

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Cormorants mainly eat fish, but remains of other prey are often found in their regurgitated pellets. Such remains are usually considered to stem from prey that were present in the stomachs of fish, eaten by the bird, i.e. from secondary prey. We present several cases were Great Cormorants *Phalacrocorax carbo* along the eastern North Sea actively took the polychaete *Nereis virens*. This worm can grow to a considerable size (100 gram and almost 1 meter long) and swims freely in the water column during its spawning season in spring. We found large numbers of *N. virens* jaws in cormorant pellets in the breeding colony of Vlieland (Dutch Wadden Sea) and provide equations to back-calculate worm size and mass from jaw size. Other cases of cormorants eating *N. virens* were gleaned from the local white and grey literature. Some birds may have temporarily specialised on eating these worms, when they were available.

Key words: Cormorant, *Phalacrocorax carbo*, polychaete, *Nereis virens*, Vlieland, diet

INTRODUCTION

Cormorants are, under most circumstances, piscivorous predators, both in marine and freshwater environments (Schreiber & Clapp 1987, del Hoyo *et al.* 1992, Johnsgard 1993). Although some species of cormorant may be food specialists, most are highly versatile foragers that may switch from benthic to pelagic foraging, from solitary hunting to group-feeding, from very small to very large prey, from one fish species to another and even from fish to invertebrate prey. In stomachs and pellets of cormorants that exploit marine waters, many invertebrate prey species have been found, including crustaceans, molluscs and polychaetes. It is often unclear whether such prey were in fact taken directly by the cormorant, or taken as secondary prey, i.e. taken by a fish first. Often, invertebrates are found together with remains of fish that commonly eat such prey, making the latter explanation a likely one. Casaux *et al.* (1996) presented experimental evidence that nereid jaws from worms eaten by prey fish may indeed be found in pellets of cormorants feeding on that fish and caution that this may often be the case in field studies.

In some cases, however, there is strong evidence that the birds themselves must have been the actual predator, e.g. when invertebrate prey are very abundantly present in their pellets (Green *et al.* 1990); or when invertebrates are found lying free in a bird's stomach or regurgitate, rather than packed, after digestion, in a pellet (Punta *et al.* 1993, Coria *et al.* 1995); or when these prey are too large to be prey of the accompanying fish (Nehls & Gienapp 1997). In other cases, there may be circumstantial evidence, e.g. when nereid worms are found in pellets specifically during the pelagic swarming phase of the worms when they are most available to the birds (Barrett *et al.* 1990). Here, we report on several cases, where Great Cormorants *Phalacrocorax carbo*, actively took large nereid worms. One new case is presented, with several other examples from the local, German and Dutch literature.

METHODS

Seven freshly regurgitated pellets were collected in a colony at the island of Vlieland during the pre-egg phase on 5 April 1999 and mailed to us for analysis. This colony was formed in 1994 and increased rapidly in size to 780 nests in 1999 (the study year), and continued to grow thereafter (Fig. 1). Birds from the Vlieland colony can be seen feeding both in the secluded Wadden Sea and in the open North Sea.

As the pellets could not be treated individually, the pooled material was soaked in 1M NaOH to remove any soft material, in particular the slimy casings of the pellets. After washing with water, all jaws, fish otoliths and other hard remains were recovered, dried, identified and measured. The polychaete jaws showed no signs of wear, as opposed to the fish otoliths. Wear of each otolith was assessed as: 1 (no sign of wear), 2 (some wear, sulcus and perimeter still well intact), 3 (considerable wear, but sulcus still visible) and 4 (too worn to be used for estimating fish size). Mean size per wear class and fish species was calculated (cf Leopold *et al.* 1998) and sizes of otoliths of classes 2 and 3 were accordingly corrected. Otoliths of wear class 4 were given the average size (after correction) for the species involved. Otoliths, as well as polychaete jaws were paired on the basis of species, size, shape and wear. All pairs were considered to represent one prey, as were all remaining left and right otoliths and jaws.

Allometric relationships, relating (corrected) otolith size to fish length and fish mass were taken from Leopold *et al.* (2001). If two otoliths (a pair) were available for a fish, fish size and mass were estimated from both, and the average value used. Jaw size to worm size relations were derived for this study, using fresh *Nereis virens* of various sizes supplied by a colleague and by a local bait company (Fig. 2). Worm length was measured by grasping the worm's head with a pair of pincers, holding it vertically and waiting

until the worm stopped wriggling, following Zwarts & Esselink (1989). After taking their lengths, the worms were weighed and then decapitated. The jaws could be easily removed after the heads were cooked in a microwave oven for a few seconds, after which the jaws were cleaned and measured. Jaw size was taken as the distance from the tip to the inner end of the toothed section (cf. Zwarts & Esselink 1989, Boudewijn *et al.* 1994: see Figs. 2 & 3). Worm length proved to be difficult to measure accurately (Fig. 2, R^2 = 0.43) and presented lengths should be considered approximate. Worm mass correlated better with jaw size (R^2 = 0.74). As in fish, worm size and mass were calculated from each retrieved jaw, and average values for paired jaws were further used.

Published data on *Nereis virens* in the diet of Great Cormorants pellets at two other locations along the eastern seaboard of the North Sea (Fig. 1) were re-analysed, partly via correspondence with the original authors. *N. virens* has been recorded at Sylt, German Wadden Sea by Nehls & Gienapp (1997) and in Lake Grevelingen, a dammed-off estuary in the Dutch Delta, SW Netherlands by Buckens & Raeijmaekers (1992) and again by Boudewijn *et al.* (1994). In all three studies, the recovered polychaete jaws were assigned to *Nereis virens*. In our own material (Vlieland) this was straightforward, as the jaws were so large, that they could not belong to any of the other *Nereis* species that live in this region (i.e. *N. diversicolor* or *N. pelagicus*), as these species are much smaller (generally less than 15 cm and 1 gram) and their jaws do not reach the sizes found in the Vlieland pellets. The same was true for part of the jaws from the Dutch Delta. Worm or jaw sizes for Sylt were not given, it was just stated that they were *N. virens* and 'too large to be prey of juvenile flatfish'.

RESULTS

Allometric relationships

A total of 58 fresh *N. virens*, ranging from 12-67 cm and from 4.1-52.2 gram, were available as reference material. Left and right mandibles did not differ significantly in size (Paired t-test) and one jaw per worm was randomly selected for regressing jaw size to worm size. Worm length as a function of jaw size is best described by the linear function: Length(cm) = 8.673*Jaw(mm)+5.00. Worm mass is best estimated by a power function: Mass(gram) = 0.542*Jaw(mm)$^{2.737}$ (Fig. 2).

The Vlieland pellets

In the pooled material from seven Great Cormorant pellets from Vlieland, otoliths (pairs and singles) of 159 fish and jaws (pairs and singles) of 80 *N. virens* (33.5% of all prey items) were found (Table 1). Estimated lengths of the *Nereis* ranged from 18.3 to 45.1 cm and their summed mass was 940 gram, or 17.2% of total ingested prey mass. On average, each pellet contained remnants of 34.1 prey items, including 11.4 worms (134 gram, compared to 648 grams of fish). On the basis of species composition, it is likely that one of the seven cormorants had foraged at the freshwater lake IJsselmeer, or near the large sluices that discharge water from this lake into the western Wadden Sea, some 20 km south of the colony. Two fish species, Perch *Perca fluviatilis* and Ruffe *Gymnocephalus cernuus*, can only be found there, and their summed masses (698 gram) make up about the average daily intake per bird (see: Feltham & Davies 1996, Keller & Visser 1999). Hence, the 80 worms were probably taken by the remaining six birds, or by one or two specialists. The sizes of the worms found, compared to those of the fishes in this pooled sample, strongly suggest that the worms were primary prey, as even the largest flatfishes found (Table 1) are unlikely to take such large worms.

Review of previous findings

The Dutch Delta

Buckens & Raeijmaekers (1992) were the first to find 'large' nereid jaws in cormorant pellets in the region. In 24 pellets, collected 8 October 1992 at a roost in central Lake Grevelingen (the 'Slikken van Flakkee') they found jaws and chaetae of a minimum of 28 *Nereis*. At least 18 of these were 'large', i.e. had jaws with total lengths (base including) of 'about 1 cm'. This would correspond with worms of circa 50 gram (75 cm), a size only reached by *N. virens* in the area. Seven other *Nereis* were 'small' and could have been of any species; the size of the remaining three was not given and the material has not been kept (P.L. Meininger, pers. comm.). In one pellet with 'large' jaws only otoliths of very small fish were

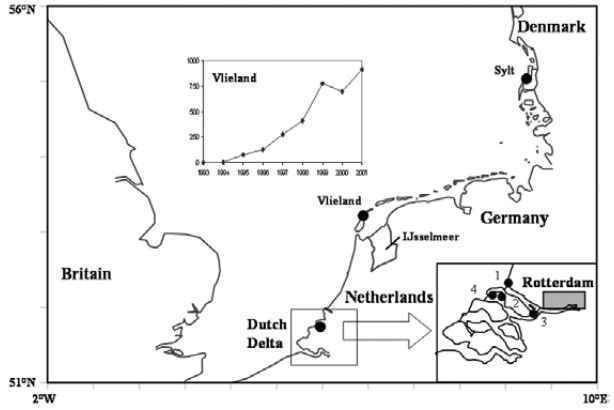

Fig. 1. Locations of Great Cormorant *Phalacrocorax carbo* colonies and roosts, mentioned in the text. Inset centre: numbers of nests in the Vlieland colony from the establishment in 1994 (6 nests) to 2001 (919 nests). Source: SOVON-database on Dutch seabird colonies). Inset right: Dutch Delta, with the colonies Brede Water (1) and Ventjagersplaten (3) and the roosts Slikken van Flakkee (2) and Archipel (4).

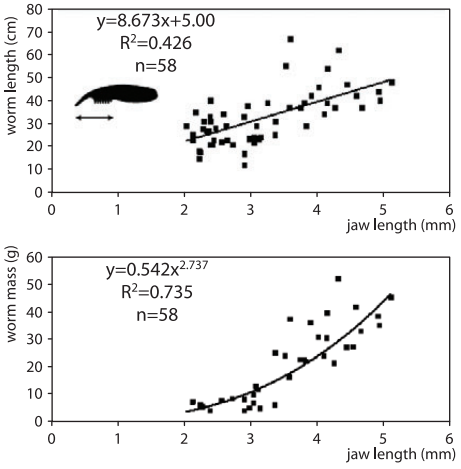

Fig. 2. Jaw-length to worm length and jaw-length to worm-mass relationships for *Nereis virens*.

found, indicating that the bird had taken *N. virens* as prey. The total contribution of *Nereis* by numbers to the diet was small, with only 8% of all prey items, but in terms of prey mass the worms were important, with some 50-100 gram of *Nereis* ingested per bird if the jaws were indeed 1 cm long.

Boudewijn *et al.* (1994) confirmed that Great Cormorants take *Nereis* in Lake Grevelingen. They sampled the same roost from July to September 1993 and from March to June 1994 and found nereid jaws in all months. Remains of a total of 35 worms were found in 79 pellets. Higher numbers of *Nereis* were found at a more seaward roost ('*Archipel*') in Lake Grevelingen in the same study period: a total of 327 worms in 146 pellets. Average worm mass was relatively small, at 4.7 and 5.1 gram respectively, and although the authors assigned all jaws to *N. virens*, at least some might have been *N. diversicolor*. In terms of prey numbers, nereid worms were more important in this than in the previous study, reaching on average 5% and 17.5% of all prey items on the two roosts. In percentage of ingested mass, *Nereis* was only marginally important in central Lake Grevelingen (2.3 gram per pellet on average) but contributing significantly to the intake at the more seaward roost. Here an average of 10.6 gram *Nereis* per pellet was found, with a peak intake of 31.6 gram per pellet in September 1993. As in the first Grevelingen study, Boudewijn *et al.* (1994) found evidence that some birds specialised on eating *Nereis*, as some pellets contained only small fish and *Nereis*, while others held only nereid jaws.

In two follow-up studies Boudewijn & Dirksen (1995, 1998) found *Nereis virens* jaws in pellets in two breeding colonies in the region. At the seaward colony of Brede Water (Fig. 1), they found 260 jaws of *N. virens* in one pellet collected in May 1994 (and none in 26 further May or 3 March pellets). At the colony Ventjagersplaten (Fig. 1), they found 640 *N. virens* jaws in a single pellet collected in April 1998 (none in 13 further pellets and none in 22 pellets collected in May). The relative importance of *Nereis*, i.e. compared to the importance of fish, cannot be calculated from the data presented in these studies, as fish otoliths were not corrected for wear, resulting in a considerable underestimate of fish masses. However, using uncorrected fish masses, the average contribution of *Nereis* would have been between 1 and 20% at roost Archipel, September 1993 to July 1994; 0-4% at roost Slikken van Flakkee in that same period; 39% for colony Brede Water, May 1994; and circa 25% at Ventjager in April 1998. In other words, *Nereis* was of greatest importance in April/May, when some birds specialised in feeding on this prey.

Sylt

Nehls & Gienapp (1997) studied the foraging behaviour and diet of Great Cormorants around Sylt, Germany's northernmost Wadden isle, in summer (June through September). *N. virens* jaws were found in pellets collected in September 1992 (circa 5% of 59 prey remains) and in June 1993 (circa 1% of 873 prey remains; figures estimated from Fig. 3 in original publication). The authors stated that the worms must have been taken directly by the cormorants, as they were too large to be prey of the accompanying fish. Specific identification of the jaws was not explained in the original paper, but Nehls (pers. comm.) later stated that the jaws were much larger than those of *N. diversicolor*, often found in Bar-tailed Godwit *Limosa lapponica* droppings, that were studied at Sylt at the time (see Scheiffarth 2001).

DISCUSSION

Nereis virens is a potentially valuable food species, as these worms attain lengths of up to 90 cm (Hartmann-Schröder 1996; pers. obs.), and masses exceeding 100 gram. *N. virens* normally lives buried in the sediment, i.e. is unlikely to be available to cormorants.

TABLE 1

Total numbers and mass (g) of all prey species found in seven Great Cormorant pellets, collected at Vlieland, 5 April 1999. Mean length (cm) and range (Min-L and Max-L) of all species found are also given. Unidentified Pleuronectidae were given the mean length and mass of all Plaice, Flounder and Dab.

Common name	Latin name	No.	Mass	Mean-L	Min-L	Max-L
Ragworm	***Nereis virens***	**80**	**940**	**35.9**	**18.3**	**45.1**
Plaice	*Pleuronectes platessa*	14	483	22.8	10.6	18.2
Flounder	*Platichthys flesus*	10	697	23.6	12.2	24.3
Dab	*Limanda limanda*	12	467	15.4	9.4	19.3
Flatfish undet.	*Pleuronectidae*	9	822	20.6	-	-
Sole	*Solea solea*	1	104	22.8	-	-
Sandeel undet.	*Ammodytidae*	69	1124	17.2	14.2	22.4
Goby undet.	*Gobiidae*	11	14	5.0	2.6	6.2
Bull-rout	*Myoxocephalus scorpius*	2	96	14.3	11.8	16.7
Smelt	*Osmerus eperlanus*	1	29	16.4	-	-
Perch	*Perca fluviatilus*	4	158	15.0	14.1	15.7
Ruffe	*Gymnocephalus cernuus*	26	540	10.7	3.7	17.0
Total		**239**	**5474**			

However, in their mating season, which extends from March to July, the males become pelagic and swim around in the sea, often near the surface (De Kraker 1993, Hartmann-Schröder 1996). This makes them highly vulnerable to avian predators, including Great Cormorants (Barrett *et al.* 1990). In Lake Grevelingen, large numbers of Black-headed Gulls *Larus ridibundus* have been observed taking these worms (De Kraker 1993). Likewise, in nearshore, North Sea off Vlieland, Common Gulls *Larus canus*, Black-headed Gulls and Sandwich Terns *Sterna sandvicensis* have been seen taking *N. virens* by surface plunging in spring (M.F. Leopold & C.J. Camphuysen, unpublished data).

Great Cormorants apparently take nereid worms if these are encountered. The short period of abundant swarming of these worms in spring temporarily presents good feeding conditions for Great Cormorants, and some birds apparently seize the opportunity. In other months of the year, *N. virens* is only occasionally taken, suggesting that the worms are hardly available for birds outside their swarming season. Another problem for diurnal birds like the Great Cormorants is, that the worms swarm mainly around dusk (de Kraker 1993). This may explain why only relatively few Great Cormorants take these worms, as many birds have already returned to their roosts before dusk.

Cormorants have been seen diving amidst swarming worms (K. de Kraker, pers. comm.), but direct, visual observations of a cormorant surfacing with a nereid worm in its bill are still lacking. However, the sizes of the jaws found in the pellets, as well as the fact that some pellets contained nereid jaws only (cf. Green *et al.* 1990), and the fact that large numbers of *Nereis* were only found in the worms' swarming season (cf. Barrett *et al.* 1990) all provide strong, albeit circumstantial, evidence that the birds took these worms directly (*contra* Casaux *et al.* 1996).

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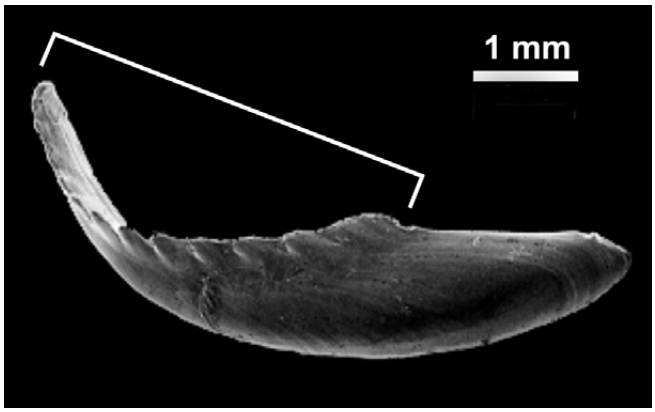

Fig. 3. Electron-microscopic image of a *Nereis virens* jaw, with the part that is measured for estimating worm length and worm mass indicated.

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