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The diet and feeding ecology of *Conger conger* (L. 1758) in the deep waters of the Eastern Ionian Sea

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Abstract

The diet of the European conger eel *Conger conger* was investigated for the first time in deep waters of the Eastern Ionian Sea. Fish dominated the European conger eel diet. All other prey taxa were identified as accidental preys. However, intestine analysis showed that Natantia, Brachyura and Cephalopoda might have a more important contribution in the diet of the species. *C. conger* exhibited a benthopelagic feeding behaviour as it preyed upon both demersal and mesopelagic taxa. The high vacuity index and the low stomach and intestine fullness indicated that the feeding intensity of the species in the deep waters of the Eastern Ionian Sea was quite low. *C. conger* feeding strategy was characterised by specialisation in various resource items. A between-phenotype contribution to niche width was observed for some prey categories. European Conger eel feeding specialisation appears to be an adaptation to a food-scarce environment, as typified in deep-water habitats.

Keywords: European conger eel, stomach analysis, intestine analysis, feeding, Ionian Sea, feeding strategy.

Introduction

The European conger eel *Conger conger* L. 1758 is distributed in the northeast Atlantic, the Mediterranean Sea and the western Black Sea (Bauchot & Saldanha, 1986). It is a benthic fish found on rocky and sandy bottoms (Fischer *et al*., 1987) living down to 1171 m depth (Mytilineou *et al*., 2005). The life cycle of *C. conger* is poorly known. The leptocephalus phase has a long duration and metamorphosis varies between 205 and 324 days after hatching in a 10-16 cm size range (Correia *et al*., 2002). It is believed that the European conger eel reaches sexual maturity at the age of 5–15 years and spawns once in its lifetime in deep waters, in the summer (Lythgoe & Lythgoe, 1991). Until now the only well-known spawning area is in the Western basin of the Mediterranean (Cau & Manconi, 1983), although there are many other supposed areas (e.g. Vallisneri *et al.,* 2007). Despite being a geographically widespread species and a commercial resource, the number of studies on this species is very limited. Information on its diet has been reported from the north-eastern Atlantic Ocean (Olaso & Rodrigues-Marin, 1995; Morato *et al*., 1999; O'Sullivan *et al*., 2004; Xavier *et al.,* 2010), the Western Mediterranean (Cau & Manconi, 1984; Abi-Ayad *et al*., 2011) and the Adriatic Sea (Vallisneri *et al*., 2007). None of these works include intestine content examination.

This is the first study on *C. conger* in the Eastern Mediterranean. It aims to provide qualitative and quantitative information on the diet and feeding strategy of the species, based on the stomachs and intestines of specimens caught by experimental long line fishing in the deep waters of the Eastern Ionian Sea, off Cephalonia Island.

Materials and Methods

C. conger specimens were collected during experimental bottom long line fishing conducted by HCMR in the Eastern Ionian Sea, off Cephalonia Island, in deep waters (300 to 855 m) during summer (June) and autumn (October) 2010. The samples were frozen immediately after capture and transported back to the laboratory for standard morphometric analyses. It total, the diet of 44 European conger eels (ranging between 47.2-148 cm TL) was examined.

Stomach and intestine contents were weighted and analysed. Prey items were identified to the lowest possible taxonomic level; counted and weighted (precision 0.001 g). Diet analysis was conducted separately for the stomach and intestine of each individual because more prey taxa were identified from the intestines. Feeding intensity was described using the following indices: (i) vacuity index VI [(number of empty stomachs/number of stomachs examined) x100], (ii) stomach or intestine fullness, estimated by the percentage of empirical fullness index on a five-step scale, (0 as empty and 5 as full stomach or intestine). Four indices (Hyslop, 1980) were used to describe diet composition by prey: (i) frequency of occurrence (F%); (ii) relative abundance (N%); (iii) weight percentage (W%) and (iv) alimentary coefficient (Q%= F% x W%). The importance of various prey items was estimated using two different indices: (i) the alimentary coefficient Q; considering preys as favourite for Q>200, secondary for 20<Q<200 and accidental for Q<20 and (ii) the index of relative importance (IRI) of Pinkas *et al*. (1971) [IRI= (N% + W%) x %F].

Feeding strategy was given graphically with a two-dimensional representation of prey-specific abundance (Pi) and frequency of occurrence (F%) of the various preys (Amundsen *et al.*, 1996) Prey-specific abundance (Pi= (ΣSi/ ΣSti) x 100) is defined as the percentage of ΣSi (sum of the stomach contents comprising prey i) to ΣSti (sum of stomach contents of those predators with prey 'i' in their stomachs).

Results

Feeding intensity

The vacuity index VI of *C. conger* stomach indicated generally high values (33%). However, not one empty intestine was found (VIint=0). The fullness index analysis (Fig. 1) for the stomachs and intestines revealed mainly higher percentages for the first stages of fullness (scale 0-3) than the remaining stages, indicating a medium fullness condition. Less full stomachs were observed than intestines.

Diet composition

The diet composition of the examined *C. conger* specimens included 23 prey taxa (Table 1). Among the examined individuals, only one had a reverted stomach. The stomach analysis showed that Fish (Osteichthyes) were the dominant and most favorite prey (Q>200; IRIst: 95.04%). All the other prey taxa were identified as accidental. However, intestine analysis revealed that Crustaceans, Natantia (IRIint: 15.72%) and Brachyura (IRIint: 11.91%) in particular, as well as Cephalopoda played a more important role in the diet of the species. As regards Fish, remains of *Mora moro, Phycis blennoides* and Myctophidae were identified, while the identified cephalopod remains belonged to *Histiotheuthis bonnellii*, *Abralia veranyi*, *Rossia macrosoma, Neorossia caroli* and the most frequently found *Heteroteuthis dispar* (Table 1).

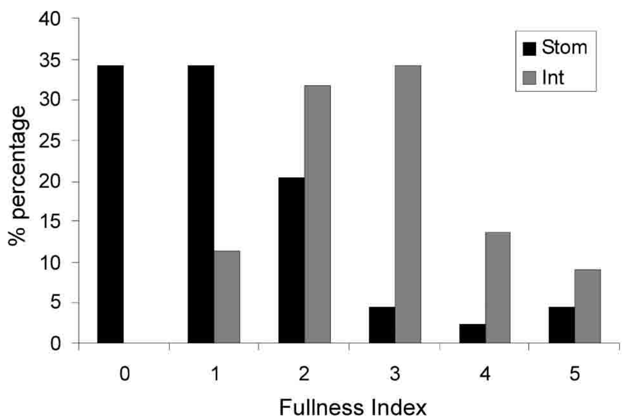

Fig. 1: Fullness Index of *Conger conger* in the Eastern Ionian Sea; (Stom: stomachs; Int: intestines).

All stomachs and intestines always contained digested food at an advanced stage, which was not identifiable. It is noteworthy that stomachs and intestines always contained a very low number (1-2) of prey items per stomach or intestine. Moreover, a number of parasites, Nematoda and Platyhelminthes in particular, were found in the stomachs and intestines of the species.

Feeding strategy

Analysis of the overall (stomach and intestine) *C. conger* feeding strategy showed Fish as the dominant prey taxon in the diet of the species. It also indicated a varied specialization on Fish, Cephalopoda, Brachyura and Natantia, as in general the preys were located at the upper half of the diagram (Fig. 2). The location of some prey categories (i.e. Histioteuthidae) in the upper left part of the diagram indicated a between-phenotype contribution to the niche width, which means that some individuals within the population had specialized on the above specific preys.

Discussion

The diet analysis of *C. conger* within the framework of this study showed that species feeding intensity (expressed by the vacuity, repletion and fullness indices) was quite low, particularly taking into account the supposed slow digestion rate in deep Mediterranean waters (Cartes & Abello, 1992). These results could be related to the following: a) longline fishing is a passive method, which might select fish that are not satiated and which show a high response to eat the bait, b) sampling time (daylight hours) may not coincide with the feeding time of the species, which has been reported as a nocturnal predator (Göthel, 1992) and c) the oligotrophic character of Eastern Mediterranean deep waters (Danovaro *et al.*, 2010).

The diet of *C. conger* in the deep waters of the Eastern Ionian Sea was based mainly on Osteichthyes. However, intestines showed that Natantia, Brachyura and Cephalopoda might play a more important role in the diet of the species in the area, evidenced by the presence of some structures resistant to digestion (e.g. beaks, mandibles, and carapace). Intestine content analysis proved to be useful, revealing prey taxa missing from the stomachs (Table 1). The results of this study generally agree with

Table 1. Stomach dietary composition and trophic indices of Conger conger. F%: frequency of occurrence; N%: relative abundance; W%: weight percentage; Q: alimentary coefficient; IRI%: index of relative importance (Number of stomachs with contents: 29)

PREY	Stomachs					Intestines				
TAXA	F%	N%	W%	Q	IRI%	F%	N%	W%	Q	IRI%
NATANTIA	6.90	10.00	1.05	10.54	1.98	11.36	18.92	22.17	276.24	15.72
BRACHYURA						6.82	8.11	24.42	198.00	11.13
Xanthidae						2.27	2.70	4.14	11.23	0.78
ISOPODA						2.27	2.70	0.02	0.05	0.31
CEPHALOPODA	6.90	10.00	0.56	5.65	1.90	6.82	10.81	2.38	25.78	4.52
Enoploteuthidae										
Abralia veranyi						2.27	2.70	0.03	0.07	0.31
Histioteuthidae	3.45	5.00	1.62	8.09	0.59					
Histioteuthis bonnellii	3.45	5.00	0.39	1.97	0.48					
Sepiolidae										
Rossia macrosoma						2.27	2.70	0.21	0.58	0.33
Neorossia caroli						2.27	2.70	0.45	1.21	0.36
Heteroteuthis dispar						9.09	10.81	0.31	3.37	5.08
OSTEICHTHYES	44.83	65.00	9.44	613.47	86.80					
Moridae										
Mora moro	3.45	5.00	86.93	434.65	8.25					
Myctophidae						2.27	2.70	0.27	0.74	0.34
Phycidae										
Phycis blennoides						2.27	2.70	7.64	20.70	1.18
SIPUNCULIDA						4.55	5.41	0.22	1.19	1.28
UNIDENTIFIED						2.27	2.70	5.88	15.89	0.98

the findings of other authors concerning the importance of Fish as the favourite prey in the diet of *C. conger* (Cau & Manconi, 1984, Morato *et al*., 1999, O'Sullivan *et al.,* 2004 and Xavier *et al*., 2010). These authors classified Crustacea as accidental prey, whereas Abi-Ayad *et al*. (2011) classified it as a favourite prey indicating that these differences may be attributed to geographical differences in prey availability.

According to our results, the diet of *C. conger* includes demersal fish (*M. moro* and *P. blennoides*)*,* supra-benthic and bathy-benthic cephalopods (*A. veranyi*, *R. macrosoma* and *N. caroli*)*,* benthic Brachyura, meso-pelagic Myctophids, meso-pelagic squids (*H. bonnelii*) and meso-pelagic *sepiolids* (*H. dispar*). Thus, it could be suggested that *C. conger* forages both in the near bottom layer and the water column. This is in accordance with the published information on European conger eels from different geographic areas (Morato *et al.*, 1999: Azorean waters, O' Sullivan *et al*., 2004: Irish waters, Xavier *et al.*, 2010: Portuguese waters).

The feeding strategy study on the European conger eel in the deep waters of the Eastern Ionian Sea showed

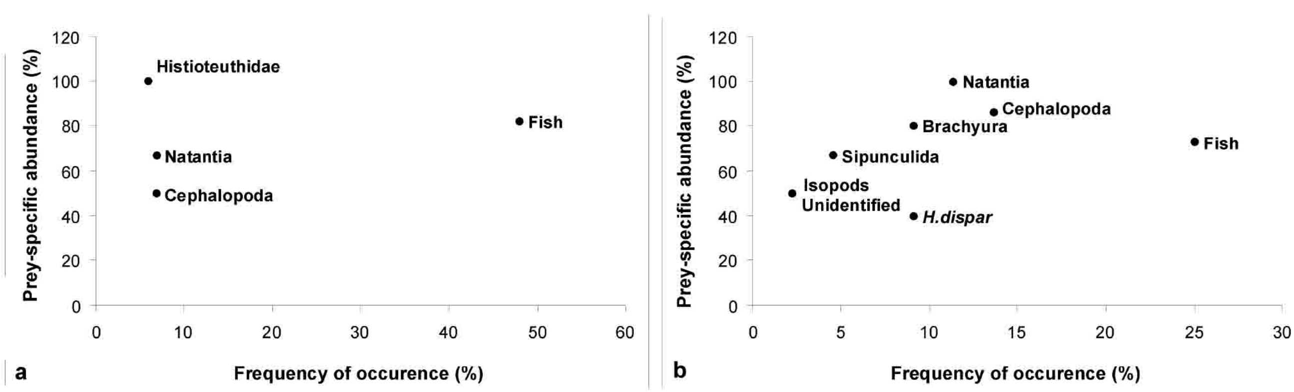

Fig. 2: Feeding strategy diagram of *Conger conger* caught in the E. Ionian Sea [according to Amundsen *et al*. (1996) method] for stomachs (a) and intestines (b).

that, the species is a specialist, at the individual and population level, for most of the prey categories, although sometimes it may feed on accidental preys. A specialisation at the population level was found for Fish in all analyses. Some studies have suggested dietary specialization (Fish: Morato *et al*., 1999 and O'Sullivan *et al*., 2004), while Xavier *et al*. (2010) suggested a more opportunistic behaviour. These contrasting diets indicate the adaptability of this species, which may partially explain its wide distribution. By specializing in a particular resource/prey type (such as Histioteuthidae cephalopods), an individual is likely to become more effective at foraging in that particular niche. With respect to the oligotrophic E. Mediterranean (Danovaro *et al.*, 2010), it appears that the specialization of *C. conger* in our study area yields greater benefits than a generalist approach, so it is likely to be selected.

This is the first study on *C. conger* in the Eastern Mediterranean Sea, focusing on its diet. Thus, it highlights our knowledge of a basic aspect of the species whose life history in this area is poorly understood. Additionally, the use of the entire gastro-intestinal tract for first time in this study was very successful, as more prey taxa not found in the stomachs, were identified, thus providing a more complete description of the species' diet.

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