FEEDING HABITS OF THE TWO-BANDED SEA BREAM (*DIPLODUS VULGARIS*) AND THE BLACK SEA BREAM (*SPONDYLIOSOMA CANTHARUS*) (SPARIDAE) FROM THE SOUTH-WEST COAST OF PORTUGAL

by

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ABSTRACT. - The stomach contents of *Diplodus vulgaris* and *Spondyliosoma cantharus* were analysed using three simple methods (numeric, gravimetric and frequency of occurrence) and a composite index (I.R.I - Index of Relative Importance). To compare the species, the Schoener index was used. The diet of *D. vulgaris* consisted mainly of ophiuroids, polychaetes, amphipods and echinoids, while polychaetes, amphipods and hydrozoans dominated in the case of *S. cantharus*. There were some size-related differences in *S. cantharus* feeding. Diet overlap was relatively slight, with significant differences in feeding between the two species, notably in terms of greater consumption of echinoderms by *D. vulgaris* and hydrozoans by *S. cantharus*. As is the case for the majority of sea breams, *D. vulgaris* and *S. cantharus* are characterised by a diverse diet in terms of prey reflecting available prey items in their environment.

RÉSUMÉ. - Régime alimentaire de *Diplodus vulgaris* et de *Spondyliosoma cantharus* (Sparidae) sur les côtes sud-ouest du Portugal.

L'alimentation de deux espèces de Sparidés, le sar à tête noire (*Diplodus vulgaris*) et la dorade grise (*Spondyliosoma cantharus*), a été étudiée sur la côte sud-ouest du Portugal. Les contenus stomacaux ont été analysés en utilisant trois méthodes simples (numérique, gravimétrique et fréquence d'occurrence) et un indice composé (I.R.I. - Indice d'Importance Relative). Pour comparer les habitudes alimentaires des deux espèces, l'indice de Schoener a été utilisé. Le régime alimentaire de *D. vulgaris* est composé essentiellement d'ophiurides, d'annélides polychètes, d'amphipodes et d'échinides, tandis que celui de *S. cantharus* consiste surtout en polychètes, amphipodes et hydraires. L'alimentation de *S. cantharus* varie significativement avec la taille des individus. Le recouvrement entre les deux régimes est faible et le test de corrélation de Spearman a mis en évidence des différences significatives entre eux, notamment la consommation plus élevée d'échinodermes par *D. vulgaris* et d'hydraires par *S. cantharus*. Comme c'est le cas pour la majorité des Sparidés, ces deux espèces sont caractérisées par un régime diversifié, avec une alimentation qui reflète la disponibilité en proies dans leur milieu.

Key-words. - Sparidae, *Diplodus vulgaris*, *Spondyliosoma cantharus*, ANE, Portugal, Feeding habits, Diet.

Knowledge of the feeding habits and diet of a fish species provides a key to the understanding of many aspects of fish biology, physiology and behaviour. From the ecological point of view such studies allow investigation of trophic interactions between and within species, namely predator-prey relationships and competition. Studies of the distribution and relative abundance of prey, together with information on environmental

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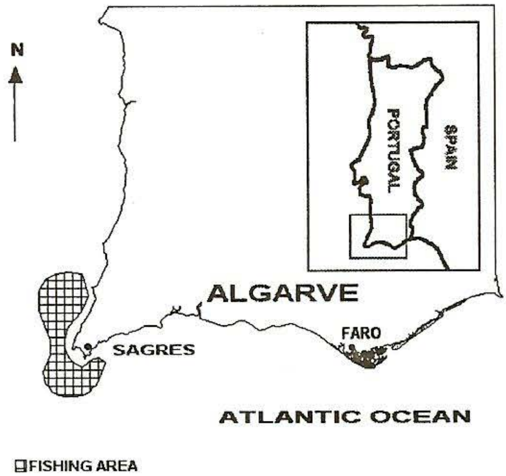

Fig. 1. - Fishing grounds for the *Diplodus vulgaris* and *Spondyliosoma cantharus* small hook longline *métier* for the fleet based in Sagres (Cape Saint Vincent, Portugal).

parameters and feeding habits aid the identification of migratory patterns and of feeding grounds both locally and regionally. Feeding habits studies also have direct implications for fishing gears such as longlines and fish traps which use bait. Knowledge of daily feeding activity cycles, feeding grounds and prey preferences can be used to select baits and to optimise fishing strategy.

The two-banded sea bream (*Diplodus vulgaris* L.) and the black sea bream (*Spondyliosoma cantharus* L.) (Sparidae) are two of the most important species of the south-west coast of Portugal (Canário *et al.*, 1994). Within this region, they are targeted by gill nets, fish traps, and longlines using small hooks, and account for 31.2% of the catches of the latter gear (Erzini *et al.*, 1997). Information on the biology of these species in Portuguese waters is scarce and few dietary studies exist. Ara (1937), Rosecchi (1987) and Rosecchi and Nouaze (1987) studied the feeding habits of *D. vulgaris* in the Mediterranean Sea, and Quéro (1984) gives some information on *S. cantharus* from the Atlantic Ocean.

Within the framework of a baseline study on the fisheries biology and management of the living resources of the south-west coast of Portugal, and with the development of multi-species approaches to management of the resources as a goal for the future (Canário *et al.*, 1994), the objective of this study was to obtain information on the diets and feeding habits of *D. vulgaris* and *S. cantharus*. Feeding strategies were also compared with other species of the Sparidae family.

MATERIAL AND METHODS

Sampling of fish caught by commercial longliners took place between December 1992 and March 1994. The artisanal fishing fleet is based in the port of Sagres (Fig. 1), and fishing takes place around sunrise (5-7:30 A.M.) on predominantly rocky or patchy bottom at depths between 30 and 80 m, using squid (*Loligo* sp.) as bait.

The fish were selected randomly and processed in the laboratory within 3 to 4 hours after capture. A total of 132 *D. vulgaris* and 128 *S. cantharus* stomach contents were analysed. The sample size frequency distributions based on total lengths (TL) measured to the 5 mm below are shown in figure 2.

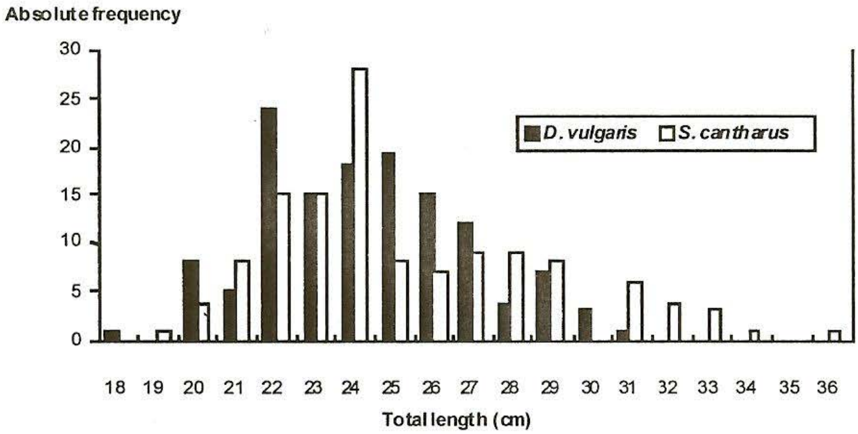

Fig. 2. - Length frequency distributions for *Diplodus vulgaris* and *Spondyliosoma cantharus*.

Prior to stomach removal, the fish were examined for signs of regurgitated prey in the mouth or oesophagus, as well as for distended empty stomachs (Bowman, 1986). The stomach contents of fish showing evidence of regurgitation were not analysed. Stomachs with contents were removed and preserved in 4% buffered formaldehyde. After drying with filter paper, the stomachs were weighed (wet weight), the contents removed, and the stomach walls re-weighed to the nearest 0.01g. The number of empty stomachs was recorded. The prey were separated into major taxonomic groups and preserved in 70% ethanol. For the quantitative analysis of the diets, the wet weight (mg), after removal of excess preservative with filter paper, was recorded for all prey items by taxonomic group, along with the number of each item per stomach.

Following Hureau (1970) the methods used to quantitatively and qualitatively describe the diet were a) numeric (%N = (n/N) x 100), where n is the number of prey items of a particular taxon and N is the total number of prey items found in all the stomachs; b) gravimetric (%W = (w/W) x 100), where w is the total wet weight of a particular prey group or taxon and W is the total weight of all the prey in all the stomachs and c) frequency of occurrence %F, which is the proportion of all stomachs examined which contain a particular taxon or prey group.

A composite index: the Index of Relative Importance, I.R.I. = (%N+%W)x%F (Pinkas *et al.,* 1971), using wet weight instead of volume, was used to evaluate prey preferences.

In order to evaluate periods of feeding activity and inactivity, the coefficient of emptiness: CV = (total number of empty stomachs / total number of stomachs analysed) x 100) was calculated (Hureau, 1970). Stomachs containing only bait were classed as empty.

The Spearman correlation coefficient was used to compare diets (Snedecor and Cochran, 1989). T tests were used to evaluate the significance of the results (Windell and Bowen, 1978).

The Schoener Index (Schoener, 1970) was used to evaluate diet overlap:

$$C = 1 - 0.5 \times \left(\sum_{i=1}^{n} |Pxi - Pyi| \right)$$

where Pxi and Pyi are the proportions of prey i in the diets of species x and y. Of the various diet overlap indices available, this index is the most suitable within the range of possible overlap values (Linton *et al.*, 1981). Values range from 0 (no overlap) to 1 (all food items in equal proportions), with values greater than 0.6 generally considered significant (Zaret and Rand, 1971). This index was calculated using the three basic measures of stomach contents (%N, %F and %W) as well as the combined index of prey preference (I.R.I.). For standardisation purposes, %F and I.R.I. were transformed into percentage values of their total.

RESULTS

Diet composition and classification of prey

The coefficient of emptiness for *Diplodus vulgaris* was 55.3% of the 132 stomachs analysed. The mean number of prey items per stomach was 5.5, and the average weight of the stomach contents was 0.11 g. For *Spondyliosoma cantharus* 39.8% of the stomachs were empty; the mean number and weight of prey per stomach was 11.6 and 0.33 g respectively.

Table I. - Percentage composition by frequency of occurrence (%F), by number (%N) and by weight (%W) and composite index (I.R.I.) for the total sample, by size for *Diplodus vulgaris*. Ph.: Phylum; C.: Class; sC.: sub-Class; O.: Order; N.I.: Not Identified.

Taxa	General				TL < 23.5 cm				TL > 23.5 cm			
	%F	%N	%W	IRI	%F	%N	%W	IRI	%F	%N	%W	IRI
C. Ophiuroidea	39.2	14.5	19.7	1340.7	64.0	42.1	27.6	4458.0	36.4	6.7	18.2	907.6
C. Polychaeta	18.9	10.5	32.0	803.8	24.0	14.0	62.4	1834.1	24.2	39.9	10.0	1208.4
O. Amphipoda	17.6	24.9	2.8	487.9	8.0	5.3	0.4	44.9	27.3	8.0	2.6	287.3
C. Echinoidea	14.9	21.2	7.6	429.1	12.0	3.5	0.0	42.1	27.3	16.0	16.7	890.6
O. Isopoda	18.9	4.9	0.7	106.4	8.0	5.3	0.1	43.2	27.3	6.7	3.0	267.2
O. Decapoda	13.5	3.1	2.2	71.8	4.0	7.0	4.1	44.4	21.2	3.7	1.5	110.8
C. Cephalopoda	2.7	0.6	17.3	48.4	4.0	1.8	1.7	13.9	3.0	0.6	41.7	128.2
N.I. Prey	9.5	3.1	1.7	45.3	4.0	1.8	1.3	12.4	3.0	0.0	1.1	3.4
C. Bivalvia	5.4	1.2	6.2	40.4	4.0	1.8	< 0.1	7.0	3.0	0.6	< 0.1	1.9
C. Gastropoda	8.1	2.5	1.3	30.7	4.0	3.5	< 0.1	14.0	15.2	3.7	1.1	72.9
C. Osteichthyes	6.8	1.8	0.2	13.9	8.0	3.5	0.5	32.3	9.1	1.8	0.5	21.5
C. Hydrozoa	2.7	3.1	1.6	12.8					3.0	0.6	3.0	11.0
O. Mysidacea	5.4	1.2	0.9	11.7	8.0	3.5	0.7	33.7	6.1	1.2	0.2	8.6
O. Holothurioidea	1.4	0.3	5.1	7.3	4.0	1.8	1.2	11.8				
C. Bryozoa	2.7	1.5	< 0.1	4.2	4.0	3.5	< 0.1	14.0	3.0	1.8	< 0.1	5.6
C. Anthozoa	1.4	3.1	< 0.1	4.2					3.0	6.1	< 0.1	18.6
sC. Ostracoda	4.1	0.9	< 0.1	3.8	4.0	1.8	< 0.1	7.0	3.0	0.6	< 0.1	1.9
Ph. Porifera	1.4	0.9	0.1	1.4					3.0	1.2	< 0.1	3.7
C. Scaphopoda	1.4	0.3	0.1	0.6					3.0	0.6	0.3	2.8
C. Crustacea N.I	1.4	0.3	0.1	0.5					3.0	0.0	< 0.1	0.0

Concerning the basic diet composition, 441 individual prey items (6.7 g) were identified in the stomachs of the two-banded sea breams. The diet was found to be diverse; with ophiuroids occurring most frequently, polychaetes giving the highest weight contribution, and amphipods particularly important in numbers (Table I).

Of a total of 891 individual prey items (25.4 g) found in the stomachs of *S. cantharus*, polychaetes were the most frequent and important in terms of weight, and amphipods were numerically the dominant group, with a great variety of other marine organisms contributing to the diet (Table II).

Analysis based on the feeding index (I.R.I.) showed that the principal prey groups for *D. vulgaris* were the classes Ophiuroidea, Polychaeta, and the order Amphipoda, followed by the class Echinoidea (Table I). According to the prey classification method of Rosecchi and Nouaze (1987) applied to the I.R.I., ophiuroids and polychaetes are principal prey, while amphipods and echinoids are secondary prey, and isopods are accessory.

For *S. cantharus*, the I.R.I. index indicated that the main prey groups were polychaetes, followed by amphipods, hydrozoans, and gastropods (Table II). According to the classification system of Rosecchi and Nouaze (1987), polychaetes and amphipods are classified in the principal prey category, and hydrozoans as secondary prey, with gastropods as accessory prey.

Table II. - Percentage composition by frequency of occurrence (%F), by number (%N) and weight (%W) and composite index (I.R.I.) for the total sample, by size for *Spondyliosoma cantharus*. Ph.: Phylum; C.: Class; sC.: sub-Class; O.: Order; N.I.: Not Identified.

Taxa	General				TL < 24.0 cm				TL > 24.0 cm			
	%F	%N	%W	IRI	%F	%N	%W	IRI	%F	%N	%W	IRI
C. Polychaeta	33.8	7.6	53.0	2047.6	37.5	22.6	71.1	3515.3	33.3	2.5	52.2	1824.0
O. Amphipoda	24.7	58.5	10.8	1708.5	25.0	37.2	2.1	982.3	22.2	65.6	14.9	1788.9
C. Hydrozoa	24.7	19.0	4.0	566.1	17.5	20.1	4.0	421.7	26.7	18.1	3.7	583.6
C. Gastropoda	10.4	2.1	13.2	159.5	7.5	3.0	6.9	74.0	6.7	1.6	13.6	101.4
O. Decapoda	14.3	2.0	0.8	40.5	15.0	4.3	3.5	117.0	8.9	0.7	0.5	10.7
C. Ophiuroidea	6.5	2.7	3.1	37.7	5.0	0.0	< 0.1	0.0	8.9	6.2	4.4	94.3
C. Cephalopoda	3.9	0.3	7.5	30.4	2.5	0.4	4.0	11.1	8.9	0.6	9.0	85.5
O. Isopoda	10.4	2.2	0.4	27.5	10.0	5.1	0.3	54.2	13.3	1.3	0.5	24.6
C. Osteichthyes	11.7	1.2	0.2	17.2	10.0	0.4	1.4	18.3	8.9	0.0	0.1	0.7
N.I. Prey	2.6	0.3	5.0	13.8	2.5	0.4	2.6	7.6	2.2	0.1	0.1	0.4
C. Bivalvia	5.2	1.0	1.1	10.8	7.5	1.7	3.6	40.0	4.4	0.7	0.1	3.7
N.I. Worms	6.5	0.9	0.1	6.3	5.0	0.9	< 0.1	4.3	6.7	0.9	< 0.1	5.9
O. Mysidacea	5.2	0.4	0.1	3.0					8.9	0.6	< 0.1	5.5
C. Echinoidea	2.6	0.2	0.6	2.2					4.4	0.3	0.9	5.2
C. Anthozoa	2.6	0.4	0.1	1.5	2.5	0.9	0.4	3.2	2.2	0.1	< 0.1	0.3
sC. Copepoda	3.9	0.3	< 0.1	1.3	7.5	1.7	< 0.1	12.8	2.2	0.1	< 0.1	0.3
Ph. Cnidaria	2.6	0.3	< 0.1	0.9	5.0	1.3	< 0.1	6.4				
sC. Ostracoda	1.3	0.1	< 0.1	0.2					2.2	0.1	< 0.1	0.4
C. Bryozoa	1.3	0.1	< 0.1	0.2					2.2	0.1	< 0.1	0.4

The relationship between body size and diet

The two-banded sea breams analysed in the study ranged in size from 19.5 to 31.0 cm TL, with mean values of 21.9 ± 1.2 (SD) cm for individuals less than 23.5 cm TL and 26.3 ± 1.9 (SD) cm for those greater than 23.5 cm TL. Diets of these two groups were significantly correlated according to the Spearman test ($p < 0.1$; rs(obs.) = 0.642 and rs(tab.) = 0.564) (Table I). However in the group of smaller individuals, small crustaceans were relatively more important, while bivalve and gastropod molluscs together with echinoderms were more dominant in the diet of larger fish.

A similar size range of black sea breams was used in the study: 19.0 to 35.5 cm TL, with mean lengths of 22.2 ± 1.1 (SD) cm for fish less than 24 cm TL and 27.4 ± 2.7 (SD) cm for fish greater than 24 cm TL. The two size groups differed significantly in terms of diet ($p > 0.05$; rs(obs.) = 0.714 and rs(tab.) = 0.886) with gastropods and ophiuroids relatively more important for the largest fish (Table II).

Comparison of diets between species

According to the Spearman rank correlation coefficient the diets of these two species are significantly different: $p > 0.05$; rs(obs) = -0.122 and rs(tab) = 0.576, with differential consumption especially of echinoderms, but also of hydrozoans and gastropods, contributing to this result. In terms of diet overlap, Schoener coefficient values were all below or close to the 0.60 limit (%N = 0.49, %F = 0.61, %W = 0.53 and I.R.I. = 0.43), indicating some overlapping.

D. vulgaris and *S. cantharus* are caught on patchy bottoms of sand, gravel and rock, in an area of convergence of different substrates. Based on the qualitative study of Monteiro Marques (1987) of the benthic and epibenthic communities, it can be concluded that the diets of the two-banded and the black sea breams generally reflect the principal available prey groups in this area, especially with regards to polychaetes and crustaceans.

DISCUSSION

General considerations

Feeding studies based on stomach contents are conditioned and influenced by a number of factors. The poor state of preservation / advanced stage of digestion of many of the prey items did not allow identification to the species level for a wide range of taxonomic groups. The prey found in the stomachs of the two species differed greatly in terms of size, weight, relative abundance and digestibility. Thus, the results in terms of relative importance of different prey groups should be treated with caution since some prey items which are small, soft, and rapidly digested may be under-estimated while large prey with durable hard parts may be given undue importance (Windell and Bowen, 1978).

The size selectivity associated with longlines used to catch the fish in this study, resulting in the capture of few small individuals, was a limitation in terms of evaluating changes in the diet with growth. Another limitation associated with this type of gear is that the samples may have been unrepresentative in the sense that fish which are hungry and have empty stomachs may be more attracted to the bait, thereby contributing to a significant number of empty stomachs in the sample (Brulé and Canché, 1993). Hureau (1970) and Brulé and Canché (1993) found significant numbers of empty stomachs or stomachs containing only bait in samples collected by hook and line gear.

On the other hand, the high values of the coefficient of emptiness could be related to the daily feeding cycle, since the fish were always caught at approximately the same time of day. Availability of prey and reproductive activity may also be other factors of feeding activity.

Considering that each simple method of evaluating feeding (%N, %W and %F) has some associated error and limitations (Hyslop, 1980; Herrán, 1988), the incorporation of the three in the composite I.R.I. may compensate for the individual inadequacies.

Diet composition and comparison with other studies

Diplodus vulgaris

Analysis of the gut contents and of the feeding indices indicates that the diet of the two-banded sea bream consists mainly of a wide range of small prey which are often very frequent (polychaetes, ophiuroids, amphipods), with large prey being rare (cephalopods). These results are similar to those of Rosecchi (1987) for *D. vulgaris* of 3 to 40 cm TL from the Gulf of Lion (Western Mediterranean), although in our study, echinoderms were relatively more important in numbers as well as weight, while decapod crustaceans were less abundant. Rosecchi (1987) reported that although fish were an important part of the diet by weight, they were relatively rare, as was the case for cephalopods in this study. Differences between these two studies may be partly due to the greater size range of the *D. vulgaris* collected on the French coast and to samples originating from different environments, lagoons as well as the sea in the Rosecchi (1987) study. Otherwise, the generally similar diets from the two regions suggests selective feeding and/or similar benthic faunal communities in the two areas.

Ara (1937) in Naples (Italy) and Quéro (1984) in France reported that the two-banded sea bream was a generalist feeder, with crustaceans and molluscs forming the basis of the diet. Bauchot and Hureau (1986) considered this a carnivorous species, feeding mainly on crustaceans, molluscs, and worms. These authors did not attribute much importance to echinoderms and polychaetes, which may be due to regional differences in faunal composition, given the lack of information on feeding selectivity in these studies.

Pieces of undigested algae which were probably ingested together with other attached prey items were found in the intestines of some of the fish. Despite the occurrence of algae, the two-banded sea bream is essentially an opportunistic carnivore. The versatile feeding behaviour of the two-banded sea bream is often noted by divers who are followed by these fish, which ingest any prey uncovered by the diving activity (pers. obs.). Typically, mouthfuls of sediment and prey are ingested, followed by the expelling of the non-consumable particles.

While neither chemical nor mechanical decomposition was studied in the stomach, the fact that significant quantities of similarly sized, low-energy value echinoderms (Molander, 1928 *in* Mattson, 1992) were consumed, together with the absence of completely full stomachs, suggests that *D. vulgaris* may use this prey in part to help break down its food. This 'grinding' action would increase digestion rates, allowing greater feeding rates (Mattson, 1992). On the other hand, the habit of continuously searching for food, combined with the consumption of generally small, easily digested, prey items, together with polychaetes and crustaceans, may compensate for the large amounts of nutritionally poor echinoderms.

Spondyliosoma cantharus

The diet of the black sea bream from the south-west coast of Portugal was characterised by polychaetes, small crustaceans (amphipods), and hydrozoans, along with gastropods and decapods. Quéro (1984) reported that the diet of *S. cantharus* in the Gulf of Biscay was based on algae (enteromorpha), crustaceans (copepods and amphipods), and hydrozoans. This species was found also to feed on fishes, crustaceans (mysids, crabs, and ostracods), as well as polychaetes and marine plants (Zosteracea). In general, these findings have much in common with the present study, especially regarding small crustaceans, hydrozoans and polychaetes. In the Santo André lagoon in Portugal, black sea breams were found to feed primarily on insects (chironomids, Diptera) (Bernardo, 1990), revealing the adaptability of this species in terms of feeding. As with other sparids, the black sea bream is an opportunistic feeder, including a wide range of organisms from rocky, mud and sand substrates in its diet. The presence of algae in approximately 25% of the stomachs analysed confirms the classification of this species as an omnivore (Quéro, 1984; Bauchot and Hureau, 1986).

Size and diet

The absence of individuals smaller than 19.0 and 19.5 cm TL for *D. vulgaris* and *S. cantharus* respectively due to size selectivity of the hook and line gear used in this fishery, meant that the sampled fish were fairly homogenous in terms of diet, particularly in the case of *D. vulgaris*. The small differences observed between the different size classes may be due to factors such as time of capture, seasonality, and fishing ground, rather than behavioural or morphological differences between small and large fish. According to Rosecchi (1987), there is a clear change in feeding preferences with size, with echinoderms and larger crustaceans replacing molluscs and small crustaceans, in the diet of large *D. vulgaris*. These changes may be simply due to an evolution in feeding preferences with increasing size, as determined by the relationship between prey size and mouth dimension (Rosecchi, 1983), or to changes in habitat (e.g., depth).

Comparison with other sea breams

The other species of the genus *Diplodus* found in this area, namely *D. sargus* and *D. annularis*, which are potential competitors, have similar diets to *D. vulgaris*, with a wide range of prey species and with more than one principal prey group. Rosecchi (1987) showed that these three species had three groups of preferred prey each, with all sharing two groups in common: crustacean decapods and polychaetes for *D. vulgaris* and *D. annularis*, decapod crustaceans and echinoderms for *D. vulgaris* and *D. sargus*, and decapod crustaceans and bivalves for *D. annularis* and *D. sargus*.

As shown by the catches of various gears used by the artisanal fishing fleet, *S. cantharus* is the species which is most commonly associated with *D. vulgaris* in this area, and is therefore most likely to compete with it. Based on the high species diversity both in the natural environment and the diet, these species can be considered euryphagic (Berg, 1979). Both species appear to feed on a variety of bottoms on the most available prey groups. In fact, for both species polychaetes and amphipods were two of the principal prey groups. However, the calculated diet overlap was relatively low, and statistically significant differences between diets were found. This could be explained in part by reduced consumption by the black sea bream of echinoderms in general and echinoids in particular, together with a preference for hydrozoans. The two species feed on a wide range of prey, taking different proportions from the same invertebrate communities.

These two species differ markedly in terms of mouth shape and dentition, with the teeth of the two-banded sea bream enabling the crushing and consumption of species with a hard shell or carapace (e.g. echinoderms). *S. cantharus* has a relatively larger, more round mouth. Alexander (1967 *in* Caillet, 1977) postulated that fish with larger mouths would be better at biting or pulling, while those with smaller mouths would be more successful in engulfing small particles or prey.

The wide geographic range of *D. vulgaris* and *S. cantharus*, as well as their capacity of feeding on prey from all types of bottom as well as the water column, together with ready adaptation to different food items, lead these species to consume a variety of baits; even those such as *Upogebia* sp., *Ensis siliqua* and *Loligo opalescens* (Erzini *et al.*, 1995) which are not found in their normal environment.

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