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Diet composition and food habits of *Diplodus puntazzo* (Sparidae) from the Gulf of Gabès (Central Mediterranean)

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The diet and feeding habits of the sharpsnout seabream, Diplodus puntazzo, *from the Gulf of Gabès were investigated using stomach contents of 490 specimens ranging from 12.6 cm to 26.1 cm total length in size and from 29.95 g to 230.83 g in weight collected from commercial catches between April 2008 and March 2009. Of the total number of examined stomachs, 279 were empty (%VI = 56.94). This percentage varied significantly with months, attaining a maximum in spring (74.88%) and a minimum in autumn (37.38%). Eight major taxa were identified (Plantae, Spongia, Tunicata, Echinodermata, Crustacea, Annelida, Mollusca and Teleostei) in stomach contents of* D. puntazzo. *Plants were the most important food source, constituting 89.88% of the total Index of relative importance. The other groups, such as teleosts, molluscs, crustaceans and annelids represented accessory food. Significant differences in diet were observed in relation to season. Plants were the most important food source item in all seasons, especially during the autumn. The estimation of trophic level gave an average of 2.57 ± 0.2 for the whole population of* D. puntazzo *in the Gulf of Gabès. Based on the composition of its diet, this species may be considered as an omnivorous fish with a preference for vegetable material, and showing specialist feeding strategy.*

Keywords: feeding habits, *Diplodus puntazzo*, Gulf of Gabès, Central Mediterranean

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INTRODUCTION

The Sparidae family consists of 106 species worldwide, with a peak of diversity in the north-east Atlantic and the Mediterranean, where 24 species have been described. The sharpsnout seabream, *Diplodus puntazzo* (Cetti, 1777), is a valuable Sparidae species inhabiting rocky bottoms and sea grass beds and is seldom found at depths greater than 50 m (Macpherson, 1998). As far as its geographical distribution is concerned, *D. puntazzo* is a common species throughout the Mediterranean Sea and the eastern coasts of the Atlantic Ocean from Gibraltar to Sierra Leone, rare in the Black Sea and in the North Atlantic (Bay of Biscay), and present in the Canaries and the Cape Verde Islands (Bauchot & Hureau, 1986). The majority of published studies deal with investigation of its potential for introduction into intensive mariculture (Divanach *et al.*, 1993; Abellan & Garcia-Alcazar, 1995; Gatland, 1995), and being reared in aquaculture for more than ten years (Abellan & Basurco, 1999; Divanach & Kentouri, 2000). Other data on biological aspects of this species that have been reported concern feeding (Hernandez *et al.*, 2001a; Atienza *et al.*, 2004), morphology and shape variation (Sara *et al.*, 1999; Loy *et al.*, 2000; Palma & Andrade, 2002; Favaloro & Mazzola, 2003a, b), settlement and recruitment process (Garcia-Rubies & Macpherson, 1995; Vigliola *et al.*, 1998; Vigliola & Harmelin-Vivien, 2001), reproductive biology (Faranda *et al.*, 1985; Micale *et al.*, 1996; Pajuelo *et al.*, 2008; Papadaki *et al.*, 2008), age and growth (Domínguez-Seoane *et al.*, 2006; Kraljević *et al.*, 2007), diseases (Athanassopoulou *et al.*, 1999), nutritional quality and sensory evaluation (Orban *et al.*, 2000; Hernandez *et al.*, 2001b), as well as the development of skeletal deformities (Boglione *et al.*, 2003). On Tunisian coasts some research on aspects of the biology of *D. puntazzo* has been studied (Bradai *et al.*, 1998a; Bradai, 2000; Guerbej *et al.*, 2002; Chaouch, 2006; Mouin *et al.*, 2006). With the exception of some data on feeding habits of *D. puntazzo* in the Gulf of Gabès (Bradai *et al.*, 1998b), little is known about the trophic ecology of this species in Tunisia.

The objectives of this study were to: (1) quantify the diet composition; (2) examine potential diet differences by predator size, sex and season; and (3) qualitatively assess feeding strategy. This study will strengthen our knowledge on the feeding biology of *D. puntazzo* in Tunisia and in the Mediterranean Sea.

MATERIALS AND METHODS

In the Gulf of Gabès, from the parallel 35°N to the Tunisian–Libyan border (33°10′N), *Diplodus puntazzo* is caught by different types of artisanal fishing gear (gill-nets and trammel nets). A total of 490 specimens were collected, all year round during 2008 and 2009, ranging in size from 12.6 cm to 26.1 cm total length (TL). In the laboratory the TL of

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each fish was measured to the nearest 0.1 cm and the fish were weighed to the nearest 0.1 g. Thus fish were dissected, the number of empty stomachs recorded and prey identification carried out to the lowest possible taxonomy level using the manuals of Riedel (1963) and Fisher *et al.* (1987a, b). In order to perform a qualitative and quantitative description of the diet, the following indices were used:

- Percentage frequency of occurrence (%F): number of stomachs in which a food item was found, expressed as a percentage of the total number of full stomachs.
- Percentage numerical abundance (%Cn): number of each food item expressed as a percentage of the total number of food items in all stomachs.
- Percentage gravimetric composition (%Cw): total weight of each food item, expressed as a percentage of the total weight of stomach contents.
- Index of relative importance (IRI) (Pinkas *et al.*, 1971) as modified by Hacunda (1981), to estimate the contribution of food items in the fish diet:

$$\mathrm{IRI} = \%\mathrm{F} \times (\%\mathrm{Cn} + \%\mathrm{Cw})$$

The index was expressed in percentage as follows: $\%\mathrm{IRI} = (\mathrm{IRI}/\sum \mathrm{IRI}) \times 100$.
- In order to evaluate periods of feeding activity, the vacuity index (VI) was calculated as follows: number of empty stomachs divided by total number of stomachs multiplied by 100.

Prey species were sorted in decreasing order according to the IRI. The cumulative %IRI was calculated from the main food categories and compared among different groups according to sex, size and season. To assess for possible changes in diet with respect to size, fish were divided into two size-classes: small ($\leq$16 cm, N = 134) and large (>16 cm, N = 356). Statistical differences ($P < 0.05$) in the diet composition with respect to size, season and sex were assessed by a χ^2 test (Sokal & Rohlf, 1981) of the frequencies of a given prey. The variation of vacuity index was also tested by χ^2 test over a contingency table of the number of empty stomachs.

The trophic level (TROPH) was estimated as follows (Pauly *et al.*, 2000):

$$TROPH_i = 1 + \sum_{j=1}^{G} DC_{ij}^{*} TROPH_j$$

where $TROPH_j$ is the fractional trophic level of prey (j), DC_{ij} is the fraction of j in the diet of i and G is the total number of prey species. The trophic level permits to express the different positions of the organism in the food spectra that define a large portion in the aquatic ecosystems (Stergiou & Polunin, 2000). The determination of different prey trophic level has been made from the list established by Froese & Pauly (2000) and presented among the Trophlab database. We took account into works achieved by Konstantinos & Karpouzi (2002) and on FishBase data to estimate their trophic level.

Relative importance of prey items, for interpretation of the feeding strategy, was constructed graphically using a variation of the Costello method (Costello, 1990) proposed by Amundsen *et al.* (1996). This analysis is based on a graphical representation (Figure 1), making it possible to explore ingested food types and data in relation to feeding strategies, as well as intra- and inter-individual shifts in niche utilization. On this graphic, the first diagonal represents abundance increase along with prey/food importance. The vertical axis represents predator strategy going from generalist to specialist. The second diagonal axis represents resource use changing from BPC (between phenotype component, among individuals of population) to WPC (within phenotype component—tending towards the same resource use). Graph interpretation of fish feeding strategies based on our data follows the Amundsen *et al.* (1996) procedure illustrated in Figure 1, where coordinates x and y represent occurrence and abundance of items, respectively.

RESULTS

Feeding intensity and trophic level

Of the 490 stomachs examined, 279 were empty (VI% = 56.94). This percentage varied significantly by season (χ^2 = 34.67, $P < 0.05$), with a maximum of 74.88% during the spring and a minimum of 37.38% during the autumn (Table 1). The VI analysis did not show any significant differences between the sexes ($\chi^2 = 0.08$, $P > 0.05$) (Table 2), and among size-classes ($\chi^2 = 0.73$, $P > 0.05$) (Table 3).

The calculation of trophic level gave an average of 2.57 $\pm$ 0.2 for the whole population of *Diplodus puntazzo* of the Gulf of Gabès. We notice, according to the classification of Konstantinos & Karpouzi (2002), that this is an omnivore species with a preference for vegetable material (2.1 < TROPH < 2.9).

The TROPH of this species was 2.45, 2.65, 2.55 and 2.7 in autumn, winter, spring and summer, respectively. This level was 2.62 for females and 2.46 for males, and acrues the same value (2.57) for small size-classes (TL $\leq$ 16 cm) and for large size-classes (TL > 16 cm).

Diet composition

The stomach contents of the sharpsnout seabream consisted of eight major systematic groups: Plantae, Spongia, Tunicata, Echinodermata, Crustacea, Annelida, Mollusca and Teleostei (Table 4). Plantae were the most frequently and important observed food source, constituting 89.88% of the total IRI. Among these plantae, *Posidonia oceanica* was the most important food source (%IRI = 10.22), followed by *Caulerpa prolifera* (%IRI = 2.77). Many plants were unidentified (%IRI = 4.92). Comparatively, smaller amounts of sponges were consumed as secondary food source (%IRI = 4.81). The rest of the food items were of minor importance.

Diet composition in relation to sex

Overall, Plantae were the main food source in both sexes, reaching 96.1% and 84.55% IRI in males and females, respectively. Sponges were the secondary food source, constituted 7.6% and 1.6% in females and males, respectively. There were no dietary differences between sexes ($\chi^2 = 12.75$, $P > 0.05$) (Figure 2A).

Diet composition in relation to fish size

Plantae were the most important food source in the diet of both size-classes (90.25% and 89.32% IRI in smaller and

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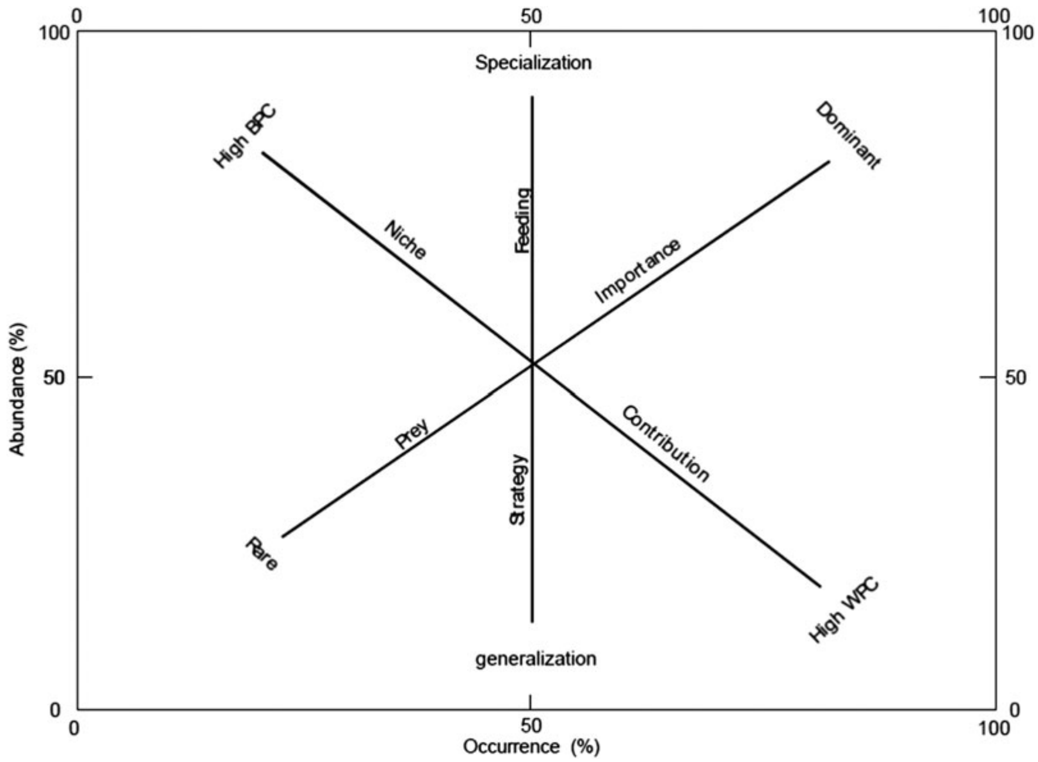

Fig. 1. Schematic representation of species feeding strategies proposed by Costello (1990) and modified by Amundsen *et al.* (1996).

larger specimens, respectively). Between smaller individuals, echinoderms (%IRI = 3.17) were relatively important, while sponges (%IRI = 5.42) and tunicates (%IRI = 3.50) were frequently in the diet of larger fish. A Chi-square test revealed no significant differences in the diet among size-classes in any prey category ($\chi^2 = 7.18$, $P > 0.05$) (Figure 2B).

Diet composition in relation to season

The analysis of stomach contents of sharpsnout seabream in the Gulf of Gabès showed that there was some seasonal variation in food habits of the species (Figure 2C). The sharpsnout seabream diet was dominated by plants in all seasons particularly in autumn (%IRI = 90.21). Sponges were present in the stomachs throughout the year, with a peak recorded in summer (%IRI = 22.41). The other taxa, represented by echinoderms, tunicates, crustaceans, annelids, molluscs and teleosts were present in stomach contents in very low quantities, whereas 'others' represented 13% of the total IRI in winter. Analysis of the stomach contents of *D. puntazzo* in the Gulf of Gabès evidenced significant differences in the diet composition of this species among seasons ($\chi^2 = 66.02$, $P < 0.05$).

Table 1. Variation in vacuity index (VI) of *Diplodus puntazzo* in the Gulf of Gabès by season.

Season	Non-empty stomachs	Empty stomachs	Total	VI	χ^2
Spring	51	152	203	74.88	13.124
Summer	36	38	74	51.35	1.273
Autumn	67	40	107	37.38	15.597
Winter	57	49	106	46.23	4.680
Total	211	279	490	56.94	34.67

Feeding strategy

The feeding strategy plots (Figure 3) revealed that *D. puntazzo* ate eight food items, predominantly plants. We regarded this species as specializing in this food item during all seasons. These plots also position prey types which indicate some individual specialization in some periods, e.g. crustaceans, echinoderms and tunicates in spring; teleosts and sponges in summer; echinoderms and sponges in autumn; tunicates, crustaceans and annelids in winter. The variability in resource breadth between individuals was high (high variation between phenotypes).

DISCUSSION

Dietary studies of *Diplodus puntazzo* in the Gulf of Gabès, show a high proportion of empty stomachs. This is consistent with results from Bradai *et al.* (1998b) who estimated annual VI to be 59.3% in the same area. In view of the lack of evidence

Table 2. Variation in vacuity index (VI) in female and male of *Diplodus puntazzo* in the Gulf of Gabès.

Sex	Non-empty stomachs	Empty stomachs	Total	VI	χ^2
Female	141	191	332	57.53	0.014
Male	70	88	158	55.7	0.063
Total	211	279	490	56.94	0.077

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Table 3. Variation in vacuity index (VI) of *Diplodus puntazzo* in the Gulf of Gabès by size-classes.

Classes	Non-empty stomachs	Empty stomachs	Total	VI	χ^2
TL ≤ 16 cm	63	71	134	52.99	0.638
TL > 16 cm	148	208	356	58.43	0.090
Total	211	279	490	56.94	0.728

of stomach reversion at capture, the high percentage of empty stomachs may reflect short periods of feeding followed by periods of rapid digestion. Rapid digestion can complicate dietary analysis, because of the possibility of a reduction in the number of prey species/food sources that may be positively identified.

The present study revealed that the diet of *D. puntazzo* was diverse, consisted mainly of plants (%F = 63.03) and sponges (%F = 14.69), with an important occurrence of ascidiacea (%F = 10.9). Other prey groups, i.e. echinoderms, crustaceans, annelids, molluscs and teleosts, were less important in the diet of sharpsnout seabream. In the Gulf of Gabès, Bradai *et al.* (1998b) found that plants and sponges were preferential food sources, while crustaceans, echinoderms and ascidiacea represented secondary food; remaining prey, such as annelids, molluscs and teleosts, were of minor importance and represented a sort of 'accessory' food. In our study, temporal variation of the diet revealed that the sharpsnout seabream diet in all seasons was dominated by plants, while in the summer there was an increase in the consumption of sponges. This species showed a high proportion of empty stomachs in spring. Decrease in feeding rate might be attributed to a lower ingestion of food during this month. According to Wassef & Eisawy (1985), temperature has a strong effect on the feeding activity of the seabream.

According to the classification of fish in functional groups based on their Troph (Stergiou & Karpouzi, 2002), *D.*

Table 4. Diet composition of *Diplodus puntazzo* in the Gulf of Gabès.

Food items	F(%)	Cn(%)	Cw(%)	IRI	IRI(%)
Plantae					
Posidonia oceanica	23.22	18.28	17.62	833.81	10.28
Caulerpa prolifera	11.37	8.96	18.8	224.72	2.77
Cymodocea nodosa	8.53	6.72	8.03	125.8	1.55
Hypnea sp.	6.64	5.22	5.87	73.61	0.91
Lyngbia sp.	3.32	2.61	2.5	16.97	0.21
Non-identified plants	13.74	10.82	18.24	399.42	4.92
Total plantae	**63.03**	**52.61**	**63.07**	**7291.57**	**89.88**
Spongia	**14.69**	**12.69**	**13.88**	**390.37**	**4.81**
Tunicata					
Ascidiacea	**10.9**	**15.67**	**6.2**	**238.38**	**2.94**
Echinodermata					
Paracentrotus lividus	3.32	3.73	3.51	24.01	0.30
Crinoidae	4.74	5.22	2.92	38.58	0.48
Total Echinodermata	**8.06**	**8.96**	**6.42**	**123.91**	**1.53**
Crustacea					
Metapenaeus monoceros	0.95	1.12	1.4	2.39	0.03
Non-identified crustacean	3.79	2.99	3.31	23.85	0.29
Total Crustacean	**4.74**	**4.1**	**4.71**	**41.77**	**0.51**
Annelida	**2.37**	**2.61**	**3.06**	**13.44**	**0.17**
Mollusca					
Non-identified Cephalopoda	**2.37**	**1.87**	**1.89**	**8.91**	**0.11**
Teleostei	**1.9**	**1.49**	**0.77**	**4.29**	**0.05**

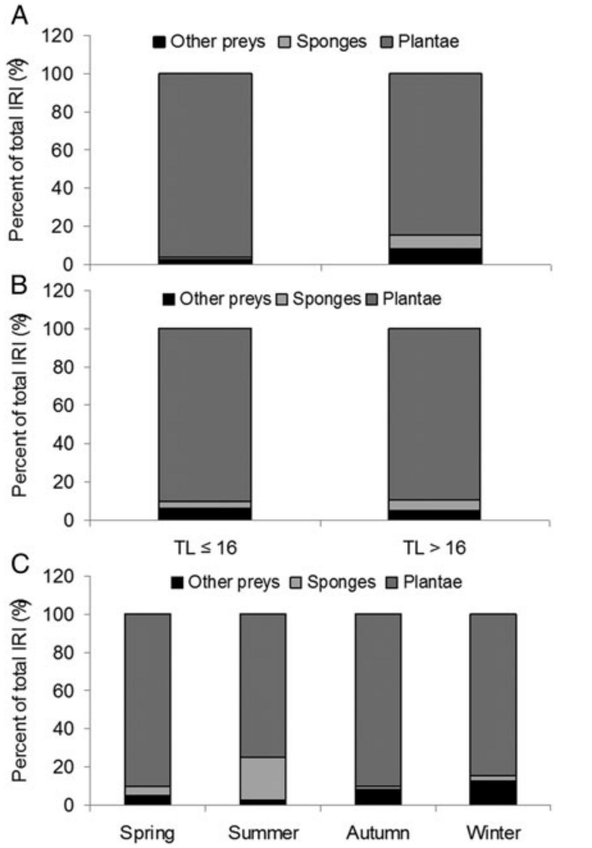

Fig. 2. Diet composition of *Diplodus puntazzo* among sex (A), size-classes (B) and season (C), based on percentage index of relative importance (IRI) values of major prey groups in the Gulf of Gabès (April 2008–March 2009).

puntazzo is an omnivorous fish with a preference for vegetable food source (2.1 < TROPH < 2.9). In addition, we compared its TROPH in other areas of its distribution based on published diet composition data (Table 5).

In our study based on the Amundsen's method, the sharpsnout seabream is a specialist feeding strategy. Plants were the main diet of *D. puntazzo* during all seasons exhibiting a preference for this item. A dietary analysis is key to the assessment of feeding strategy (Amundsen *et al.*, 1996) and the breadth of a predator's diet (i.e. niche width; Schoener, 1971), which ultimately identify the functional role of a predator in an ecosystem. The main division of feeding strategies is that of generalist or specialist, where predators with a diverse diet or broad dietary niche are described as generalists, and specialists are predators that have low prey diversity or narrow niche width (Bridcut & Giller, 1995; Amundsen *et al.*, 1996). Feeding strategies, however, have traditionally been described for populations of predators under the assumption that the individuals within the population share identical strategies (Bolnick *et al.*, 2003).

Data on feeding of sharpsnout seabream from other areas indicate that the diet of the species includes a wide range of prey. Rossechi (1987) showed that these fish have very diverse diets throughout their lives, although there are marked changes in the types of invertebrate prey targeted (amphipods, isopods, and larvae for small fish; decapods, molluscs, echinoderms and polychaetes for larger fish). Bauchot & Hureau (1990) reported that this species feeds on seaweeds, worms, molluscs and shrimps. Sala & Ballesteros (1997)

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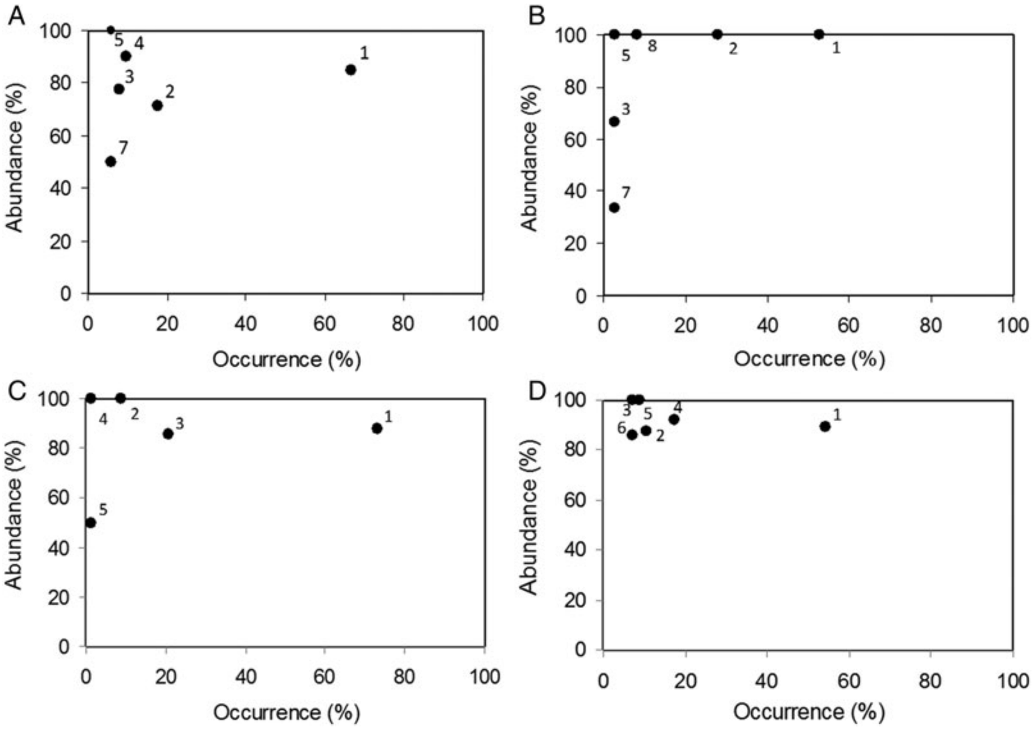

Fig. 3. Feeding strategy plots for *Diplodus puntazzo* in (A) spring, (B) summer, (C) autumn and (D) winter. Food sources and prey types are numbered as follows: 1, plants; 2, sponges; 3, tunicates; 4, echinoderms; 5, crustaceans; 6, annelids; 7, molluscs; 8, teleosts.

recorded that sharpsnout seabream is markedly omnivorous, macrophyta being the most important food source, followed by sponges and cnidarians. According to them this species exploited a resource that is apparently not used by any other species of littoral fish in the western Mediterranean, and exploitation of sponges may segregate this species ecologically from other sparid species, thereby helping minimize whatever level of competition for food resources may occur between them. Some other authors also pointed that this species is omnivorous (Bauchot & Hureau, 1986; Jardas, 1996). Sala & Ballesteros (1997) have also noted that even large *Diplodus* specimens tend to eat algal material. Dulčić *et al.* (2006) used the frequency of occurrence to assess the diet composition of *D. puntazzo*, finding that the diet of this species consists mainly of macrophyta, followed by bivalves, polychaetes, sponges and ophiuroids. Sala & Ballesteros (1997) pointed out that sharpsnout seabream have sharp teeth to help it cut algae and molars to grind crustaceans, snails and molluscs. It exhibits morphological differences, having a longer intestine than either of the other species of *Diplodus*, and thus it appears to be adapted to feeding on 'low-digestible' organisms, like algae and sponges. Mena Sellés & García-García (2002) noted that sharpsnout seabream, takes advantage of a resource like sponges that apparently goes unused by other coastline fish species, in spite of the fact that these are important sources of prey in other environments, such as for certain reef-dwelling fish species. In general, these finding are similar with the present study, especially regarding plants and sponges. Many of the authors (Rosecchi & Nouaze, 1987; Caragitsou & Papaconstantinou, 1998; Pallaoro *et al.*, 2003) have observed generally analogous feedings habits in other species of Sparidae. Similar indications were also made by authors working on sparid species on the coasts of Tunisia (Ghorbel & Bouaïn, 1991; Bradai *et al.*, 1998b, c, Bradai, 2000; Chemmam-Abderkader 2004).

Sharpsnout seabream is an omnivorous sparid of potential interest for Mediterranean aquaculture (Hernandez *et al.*, 2001b) and being omnivorous, dietary flexibility makes it an interesting model for studying dietary self-selection. Sharpsnout seabream can select a complete diet from two incomplete diets (Vivas *et al.*, 2002) and show an apparent ability to compose a preferred diet when offered diets differing in fat and protein composition (Atienza *et al.*, 2004). In a study analysing locomotor activity and feeding, sharpsnout seabream displayed a diurnal, albeit quite plastic, locomotor activity pattern, as some fish spontaneously shifted from a diurnal to a nocturnal pattern. By contrast, irrespective of whether or not locomotor activity had switched to nocturnal,

Table 5. Feeding habits of *Diplodus puntazzo* in different areas. Length range (or mean length) of specimens (in cm); TROPH, trophic level; SE, standard error of TROPH.

Reference	Area	Length range	Main prey	Troph	SE
Sala & Ballesteros (1997)	Balearic Sea	28–37	Sponges, algae (*Flabellia petiolate*, *Plocamiumcartilagineum*), anthozoans, other	2.69	0.17
Mirto *et al.* (1994)	Western Sicily	Mean TL 3.2	Fish, copepods, amphipods, isopods, algae, other	3.30	0.48
Present study	Gulf of Gabès	12–26	Plantae, Spongia, other	2.57	0.2

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feeding activity remained strictly diurnal, pointing to phase independence between locomotor and feeding activity (Vera et al., 2006). Also, Vivas et al. (2006) investigated feeding behaviour; dietary self-selection and the capability of sharpsnout seabream demonstrates that this species can select from incomplete diets to compose a balanced diet, and the fish are also able to compensate for a dietary dilution to regulate both energy intake and the relative proportions of macronutrients.

In conclusion, sharpsnout seabream is mainly an omnivorous fish with a specialist feeding strategy, with a preference for vegetable food. But feeding mechanisms that lead to specialization or generalization in the diet are not yet properly defined. This question is broad and has so far barely been addressed. Furthermore, morphological and physiological specialization can also influence fish feeding behaviour, and must be considered. Further research will be focused on feeding ecology of *Diplodus puntazzo* in order to better understand inter- and intra-specific interactions in the study area and elucidate the impact of climate changes on these interactions.

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