Journal of the Marine Biological Association of the United Kingdom, 2016, 96(6), 1229–1234.
doi:10.1017/S0025315415001770

Feeding behaviour of greater amberjack *Seriola dumerili* (Risso, 1810) from Central Mediterranean (Gulf of Gabes, Tunisia)

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The diet of greater amberjack Seriola dumerili *(Carangidae) in the Gulf of Gabes (Tunisia, Mediterranean) was described from analysis of stomach contents of 290 specimens fished between June 2004 and May 2006. The index of vacuity (%VI) was relatively low (37.9%) and differed significantly across size classes.* Seriola dumerili *is an opportunistic predator that consumes mostly pelagic organisms; benthic prey were also examined in small proportion. The diet was quantified using the frequency of occurrence (%O), numerical abundance (%N), weight (%W) and the index of relative importance (IRI and %IRI) for each prey taxa. The most important prey were teleosts (%IRI = 99.61); molluscs and crustaceans were found occasionally (%IRI, 0.38 and 0.01%, respectively). Among teleosts, Clupeidae were also the dominant food items in number (%N = 36.06%) and then in frequency of occurrence (%O = 36.7%). In term of weight, Sparidae were the most abundant prey (%W = 36.5%). There is no significant difference between male and female diets. Seasonal differences in the diet components were observed.*

Keywords: Feeding behaviour, *Seriola dumerili*, Central Mediterranean, Gulf of Gabes, Tunisia

Submitted 3 October 2014; accepted 5 October 2015; first published online 21 January 2016

INTRODUCTION

The greater amberjack *Seriola dumerili* is a mainly coastal pelagic species occurring in the Atlantic, Pacific and Indian Oceans. It is common in the Mediterranean and Adriatic Seas, where it is targeted by important local gill net fisheries.

Commonly greater amberjack specimens measure 110 cm and weigh 25–40 kg, the maximum reported size was 180 cm in total length and the maximum recorded body weight was 80.6 kg (Smith-Vaniz, 1986; Fredj & Maurin, 1987; Fischer *et al*., 1987b).

Greater amberjack *Seriola dumerili* is a common species in Tunisian coasts especially in the Gulf of Gabes (Postel, 1956; Ktari-Chakroun & Azouz, 1971; Bradai & Bouain, 1994; Bradai *et al*., 2004; Sley, 2010). It is taken by many fishing methods including purse seines, gill nets, and by longline. However, its commercial abundance has decreased relatively in recent years in the Gulf of Gabes (Sley, 2010).

Some aspects of the biology of greater amberjack have been described throughout its geographic range: age and growth of this species were studied in the Gulf of Mexico (Manooch & Potts, 1997; Thompson *et al*., 1999). Embryonic and morphological development of larvae and juveniles were studied in Japanese coasts (Masuma *et al*., 1990; Tachihara *et al*., 1993).

Reproductive biology of Mediterranean amberjack was investigated by Lazzari & Barbera (1989), Marino *et al*. (1995a, b) and Micale *et al*. (1993). Food and feeding activity has been documented in the Central Mediterranean Sea especially in the Sicilian Canal (Badalamenti *et al*., 1995; Pipitone & Andaloro, 1995; Andalaro & Pipitone, 1997).

The purpose of the present study was to investigate the feeding habits of *S. dumerili* in the Gulf of Gabes (Tunisia), and examine the effects of sex, predator size and season.

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MATERIALS AND METHODS

Sample collection

The Gulf of Gabes spreads along 750 km, from 35.8°N to the Libyan border. This region is characterized by a broad continental shelf (Ben Othman, 1973). Stomach contents of 290 specimens were examined from June 2004 to May 2006. Throughout its ranges, specimens of *S. dumerili* were commercially taken by purse seines, gill nets and longline. Fishes were collected from different points in the Gulf of Gabes in south-eastern Tunisia: i.e. Chebba, Mehdia, Sfax, Sidi Mansour, Islands of Kerkennah, Gabes, Gannouch, Djerba and Zarzis (Figure 1). Samples were treated altogether, without any distinction between regions. Samples were examined on a monthly basis and were random subsamples of a larger catch landed by fishermen. Total length (TL), fork length (FL) and standard length (SL) were measured in mm. Total mass (TM) and mass of eviscerated fish (EM) were weighed with a digital balance to the nearest 0.1 g. Specimens examined ranged from 155 mm TL to 1660 mm TL, and 134 to 1550 mm FL. Most fish were

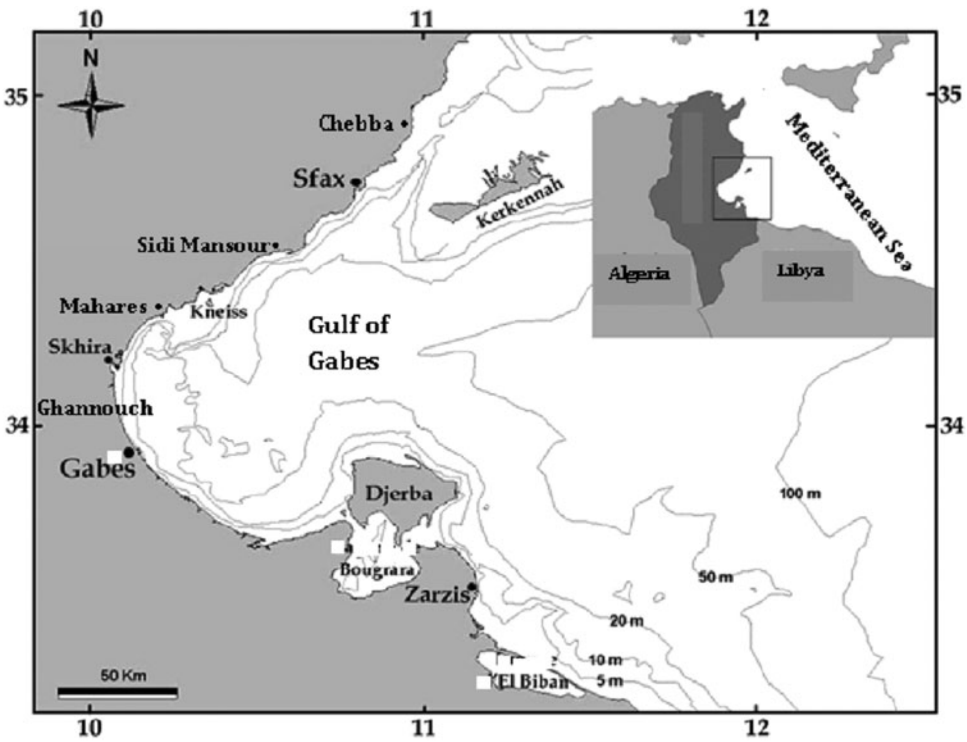

Fig. 1. Map of the Gulf of Gabes (Tunisian coast, Mediterranean Sea).

examined fresh, shortly after landing. Sex and date of capture were also recorded for each fish.

In the laboratory, the stomach contents were removed, and the prey identified to the lowest taxon (Fischer *et al.*, 1987a, b). The number of prey found in each stomach was recorded to determine the feeding pattern of *S. dumerili*. Each prey item was weighed in wet condition to the nearest 0.001 g.

No single method of analysis of stomach contents completely describes the diet of a predator (Hyslop, 1980); hence, the index of vacuity (%VI) was calculated to describe the trophic behaviour of this species. We evaluated the importance of the different prey types by calculating the frequency of occurrence (%O), abundance by both number (%N) and weight (%W). These indices were used to calculate the index of relative importance (IRI) (Pinkas *et al.*, 1971; Hacunda, 1981; Cortés, 1997) for each taxonomic category, using mass instead of volume. This index facilitates comparisons to other studies, provides a single measure of the diet, and is less biased than weight, frequency or number alone (Cortés, 1997). In the present study, the following formulae of these indices were used:

1. Vacuity index (%VI) = number of empty stomachs/total number of examined stomachs × 100;
2. Frequency of Occurrence (%O) = number of stomachs in which a food item was found/total number of full stomachs × 100;
3. Percentage of Numerical abundance (%N) = total number of each prey item/total number of all prey in all stomachs × 100;
4. Percentage of Weight (%W) = total wet weight of each prey item/ total weight of stomach contents × 100;
5. The main food items were determined using the Index of Relative Importance:

$$\mathrm{IRI} : \mathrm{IRI} = \%O \times (\%N + \%W).$$

Morato-Gomes *et al.* (1998) proposed a classification according to the following subdivision:
Main prey:

$$\mathrm{IRI} \geq 30 \times (0.15 \times \Sigma O\%)$$

Secondary prey:

$$30 \times (0.15 \times \Sigma O\%) < \mathrm{IRI} < 10 \times (0.05 \times \Sigma O\%)$$

Occasional prey:

$$\mathrm{IRI} \leq 10 \times (0.05 \times \Sigma O\%).$$

The index was expressed in percentage as follows:

$$\%\mathrm{IRI} = (\mathrm{IRI}/\Sigma\mathrm{IRI}) \times 100$$

Prey species were sorted in decreasing order according to IRI and the cumulative %IRI was calculated and recorded for the major prey taxa (Hyslop, 1980) and compared between different size-groups, seasons and sex. This index was examined for three size groups that corresponded to juveniles ($\leq$ 280 mm FL), medium-size fish (280 mm < FL < 960 mm) and adults FL $\geq$ 960 mm.

Statistical differences ($P = 0.05$) in diet composition with respect to length-class and season were assessed by Chi-square test (χ^2) of the frequency of a given prey (Sokal & Rohlf, 1981). The variation in the index of vacuity (%VI) was also tested using the χ^2-test over a contingency table of number of empty stomachs.

RESULTS

Feeding intensity

Of the 290 specimens examined 110 had empty stomachs (VI% = 37.9%) and 180 specimens had stomachs containing food. The proportion of empty stomachs was significantly different between the sexes ($\chi^2_{ob.} = 8.5 > \chi^2_{th} = 5.99$), and the %VI of females and males and juveniles which have undifferentiated sex were 44, 50.7 and 25.2% respectively.

The highest number of empty stomachs was found in winter and spring (60%), and was lowest from autumn (32%) and summer (22%).

The proportion of empty stomachs was also significantly different among size-classes ($\chi^2_{ob.} = 19.24 > \chi^2_{th} = 5.99$, $P = 0.05$), with the %VI of juveniles (≤ 280 mm FL), medium-size fish (280 mm < FL < 960 mm) and adults FL ≥ 960 mm, 25.2, 50 and 23.8%, respectively.

Diet composition

The diet of *S. dumerili* consisted of 346 different prey items across 20 identified prey taxa with an average of two prey items per stomach for fish containing food.

The observed prey were either teleosts, crustaceans or molluscs (Table 1), with teleosts the main groups, as indicated by %IRI for these groups (99.61%), although fishes were most important in terms of weight (98.8%) and frequency of occurrence (95.2%). Molluscs and crustaceans were only found occasionally (%IRI, 0.38 and 0.01%, respectively).

At the family level, Clupeidae were the most numerous group (%N = 36.06%), due to *Sardinella aurita* and *Sardina pilchardus* occurring in large numbers, whereas Sparidae (*B. boops, S. salpa, D. pentazoo, D. annularis*) were the most important family in terms of weight (%W = 36.5%).

According to the classification of Morato-Gomes *et al.* (1998), the main prey (IRI ≥ 510) were Clupeidae (IRI = 1799.8; %IRI = 54.78), while secondary prey (56.7 < IRIi < 510) were Sparidae (IRI = 135.4; %IRI = 4.12%) and Carangidae (IRI = 94.4; %IRI = 2.9%). Mugilidae and Engraulidae (*Engraulis encrasicolus*) and other fishes were as occasional prey with IRI ≤ 56.7. Other taxa (molluscs and crustaceans) were only taken occasionally (%IRI <2%) (Table 1).

Fish were the main prey group for all size classes (%IRI > 95%). In fish, ≥ 280 mm FL, teleosts and molluscs accounted for 99.03% and 0.07% IRI, respectively. Forever, Crustaceans were only observed in the medium size class, 280–960 mm FL (%IRI = 0.04%) (Figure 2).

Ontogenetic differences in the teleosts diet of *S. dumerili* were apparent among size. In fish ≤ 280 mm FL, stomach of *S. dumerili* contained Clupeidae, Engraulidae and Gobiidae. However, many categories of fish prey appeared with increasing predator size. Other fish families were observed in the diet of medium size class of *S. dumerili* (280–960 mm FL): Sygnatidae, Belonidae, Dactylopteridae, Argentinidae, Synodontidae and Serranidae. However, for the large size class (adults; ≥ 960 mm FL), we observed new categories of fish: Sparidae, Carangidae, Mugilidae, Centracanthidae, Mullidae, Trachinidae and Balistidae. However, many fish prey were unidentified; we couldn't determine if they were pelagic or benthic species because they were

Table 1. Prey categories of *S. dumerili* from the Gulf of Gabes (Tunisia), with the proportion of the diet by frequency of Occurrence (%O), Numerical abundance (%N), Weight (%W), IRI and %IRI.

Item	N. est./it.	O%	N. pr./it.	N%	W. pr./it (g)	W%	IRI	IRI%
Clupeidae	66	36.67	119	36.06	913.80	13.03	1799.84	54.78
Sparidae *B. boops*	8	4.44	27	8.18	1412.32	20.13	125.84	3.83
S. salpa	1	0.56	1	0.30	840.00	11.97	6.82	0.21
D. pentazoo	1	0.56	1	0.30	262.11	3.74	2.24	0.07
D. annularis	1	0.56	1	0.30	46.03	0.66	0.53	0.02
Total Sparidae	11	6.11	30	9.09	2560.46	36.50	135.44	4.12
Carangidae (*Caranx crysos, C. rhonchus*)	7	3.89	17	5.15	1340.83	19.11	94.36	2.87
Engraulidae (*Engraulis encrasicolus*)	11	6.11	23	6.97	94.67	1.35	50.84	1.55
Mugilidae	5	2.78	6	1.82	738.69	10.53	34.30	1.04
Centracanthidae	3	1.67	4	1.21	253.78	3.62	8.05	0.24
Sygnatidae (genus *Hippocampus*)	2	1.11	2	0.61	172.00	2.45	3.40	0.10
Mullidae	2	1.11	10	3.03	46.43	0.66	4.10	0.12
Belonidae (*Belone belone*)	1	0.56	2	0.61	162.40	2.31	1.62	0.05
Trachinidae (*Trachinus draco*)	1	0.56	1	0.30	115.14	1.64	1.08	0.03
Dactylopteridae (*Dactylopterus volitans*)	1	0.56	1	0.30	84.32	1.20	0.84	0.03
Argentinidae (genus *Argentina*)	1	0.56	4	1.21	28.73	0.41	0.90	0.03
Synodontidae (*Synodus saurus*)	1	0.56	1	0.30	68.73	0.98	0.71	0.02
Serranidae	1	0.56	1	0.30	52.45	0.75	0.58	0.02
Balistidae (Balistes *capriscus*)	1	0.56	1	0.30	46.43	0.66	0.54	0.02
Labridae (*Coris julis*)	1	0.56	1	0.30	11.51	0.16	0.26	0.01
Gobiidae	1	0.56	1	0.30	10.15	0.14	0.25	0.01
Poissons ind.	67	37.22	90	27.27	227.79	3.25	1136.02	34.57
Total teleosts	183	101.67	314	95.15	6928.32	98.76	3273.13	99.61
Molluscs	4	2.22	15	4.55	74.11	1.06	12.45	0.38
Crustaceans	1	0.56	1	0.30	12.79	0.18	0.27	0.01
Total	188	104.44	330	100	7015.22	100	3285.85	100

N. est./it, number of stomachs containing prey i; N. pr./it, number of prey item i; W. pr./it (g), wet weight of prey item i.

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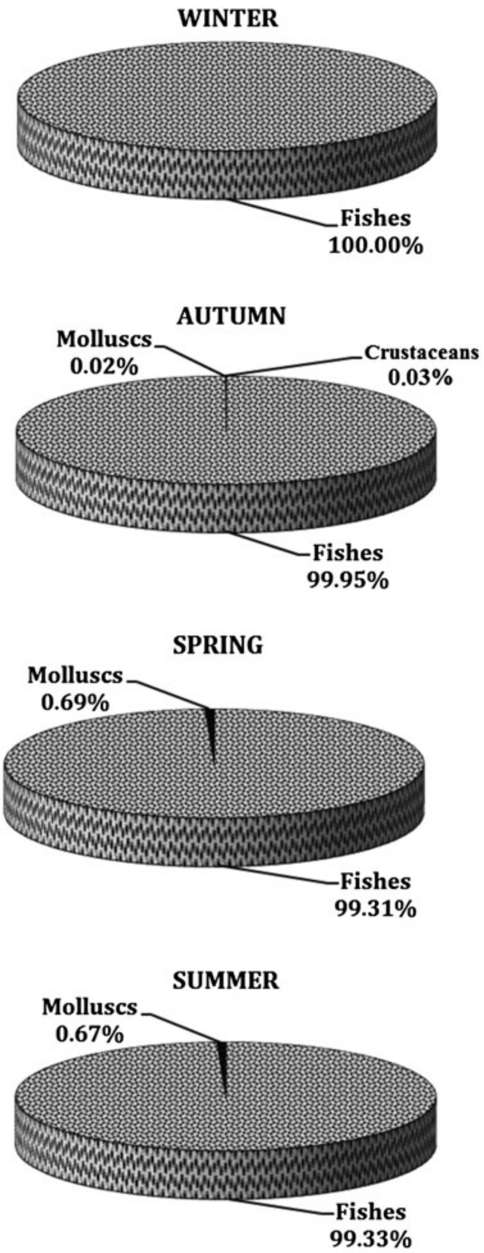

Fig. 2. Diet composition of *S. dumerili* throughout the year, based in the percentage index of relative importance values of the major prey groups.

in advanced stages of digestion; this may reflect short periods of feeding followed by periods of rapid digestion.

Clupeidae were the main prey for smaller (≥ 280 mm FL, %IRI = 56.7%) and medium sizes (280–960 mm FL, %IRI = 76.4%), but were absent for the large size class (≥ 960 mm FL). Other categories of fish prey were of lesser importance. Sparidae (%IRI = 49), Carangidae (%IRI = 31) were observed in the diet of adults, however, molluscs were present occasionally (%IRI = 4.48).

No significant differences between items among seasons was observed, for all taxa ($\chi^2_{ob} = 54.5 > \chi^2_{th} = 7.81$, $P < 0.05$). Fish were the main prey group throughout the year, (%IRI > 95%), especially in winter (%IRI = 100%), and crustaceans were found in the stomachs only in autumn. Molluscs were absent in winter. Many prey groups of fish were observed specially in the summer (Figure 3).

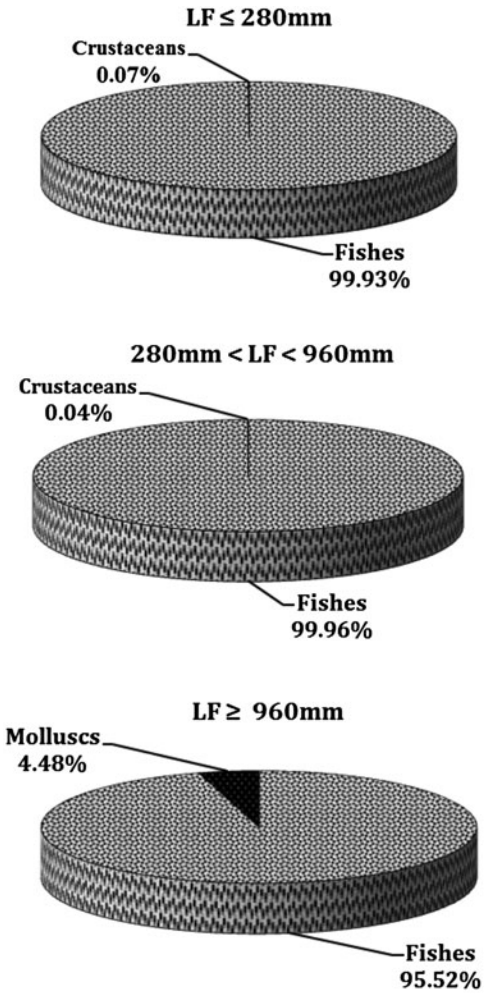

Fig. 3. Diet composition of *S. dumerili* among size classes, based in the percentage index of relative importance values of the major prey groups.

DISCUSSION

Feeding intensity of *S. dumerili* was important. In fact, the vacuity index was relatively low (VI% = 37.9%).

The IRI method is a convenient way to combine both of the above measures, plus counts of individuals eaten. The diet of *S. dumerili* from the Gulf of Gabes consisted almost exclusively of fish, indicating that this species is piscivorous and predates a wide range of teleots (Sparidae, Mugilidae, Engraulidae: Sygnatidae, Belonidae, Dactylopteridae, Argentinidae, Synodontidae and Serranidae) mostly on pelagic fish (Clupeidae). Some crustaceans (e.g. Penaeidae) and molluscs are also consumed. *Seriola dumerili* from the Gulf of Gabes is mainly a carnivorous and voracious fish as are all species of the Carangids (Overko, 1979; Maigret & Ly, 1986; Chavance *et al.*, 1991; Marchal, 1991). The most important major category were Clupeidae (*Sardinella aurita, Sardina pilchardus*), which accounted for the greatest proportion of the diet by number of prey, while Sparidae and Carangidae, while more important by biomass, were of secondary importance. Other taxa (e.g. crustaceans, molluscs) were of minor importance and may be considered occasional prey. Nearly all the fish prey observed were pelagic (*S. aurita, S. pilchardus* and *Belone belone*). These prey items, which were only found in the stomachs of fish caught at shallow depths,

https://doi.org/10.1017/S0025315415001770 Published online by Cambridge University Press

are common in Tunisian waters (Gaamour, 1999), especially in the Gulf of Gabes. Demersal fish (Gobiidae, Sparidae and Serranidae) were only observed occasionally in the stomachs of *S. dumerili*. The present study, as with many others (e.g. McCormick, 1998; Piet, 1998; Jennings *et al*., 2001; Hanson & Chouinard, 2002; Nakamura *et al*., 2003) indicates important ontogenetic changes in the diet, with the role of fish in the diet increasing with predator size.

In this study, the diet composition of greater amberjack *S. dumerili* in the Gulf of Gabes was found to be broadly similar to those of related species in the family (Sudekum *et al*., 1991; Jobling, 1995) indicating that this species is piscivorous.

Similar results for feeding were recorded in the Mediterranean Sea. Lazzari & Barbera (1989), Andalaro & Pipitone (1997) reported that *S. dumerili* from the central Mediterranean Sea was primarily a piscivorous species (*Trachurus trachurus, Scomber scombrus, Engraulis encrasicolis, Sardina pilchardus* and *Merluccicus merluccicus*). Cephalopoda (*Loligo vulgaris* and *Sepiola* sp.) and crustaceans (*Squilla mantis*) were observed occasionally in the stomachs of greater amberjack.

Stomachs of small-sized fish contained mainly smaller prey than the stomachs of larger-size fish. The smallest fish fed on small clupeids. As the fish grew (medium size-class and the large size-class (adults); there was an increased preference for fish, mainly *E. encrasicolus* and a declining proportion of crustaceans. The prey items occurring most frequently in the stomach contents of adult *S. dumerili* from the central Mediterranean Sea were *Boops boops, Loligo* ssp., *Sardinella aurita, Sardina pilchardus* and *Sepia officinalis* (Andalaro & Pipitone, 1997).

Wooton (1990) and Badalamenti *et al.* (1995) reported that *S. dumerili* is zooplanktivorous (copepoda, larval decapods), and larval and juvenile fish are common components of its diet. In the West Indies, adult blue runner is considered to be primarily piscivorous (Randall, 1967; Christmas *et al*., 1974). Mazzola *et al.* (1993), Badalamenti *et al.* (1995), Pipitone & Andaloro (1995) reported that holoplanktonic and meroplanktonic crustaceans are the main food items of juveniles of *S. dumerili* from the central Mediterranean Sea (Sicilian waters). Study of juveniles of *S. dumerili* reported that small specimens (90–185 mm SL) had a planktonic diet, based on decapod larvae, pelagic amphipods and gastropods, while larger ones (200–330 mm SL) are essentially piscivorous.

In our study, the food content of *S. dumerili* showed little seasonal variation, as teleosts were the main prey in all seasons. Therefore, feeding intensity decreased during winter months, as can be deduced from the high number of empty stomachs (60%). This can be explained either by the unavailability of the prey or by a temperature-dependent physiological process. In our study, Vacuity Index (%VI) values are decreased in summer (Sley, 2010). This period coincides with the spawning season. The greater feeding intensity of *S. dumerili* coincides with the same time period, which may reflect that the fish require more energy during spawning than in other periods.

CONCLUSION

This research provides new and essential knowledge about feeding behaviour of *Seriola dumerili* of Tunisian waters especially from the Gulf of Gabes and supports the importance of its farming. Results of these surveys confirm that *S. dumerili* is a common component of Carangidae fisheries in the Gulf of Gabes.

FINANCIAL SUPPORT

This work was supported by National Institute of Marine Science and Technologies of Tunisia and Faculty of Sciences of Sfax (Tunisia).

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