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Diet of Atlantic lizardfish, *Synodus saurus* (Linnaeus, 1758) (Pisces: Synodontidae) in the central Mediterranean Sea

VALENTINA ESPOSITO [1], PIETRO BATTAGLIA [1], LUCA CASTRIOTA [2], MARIA GRAZIA FINOIA [3], GIANFRANCO SCOTTI [1] and FRANCO ANDALORO [2]

[1] ISPRA-ex ICRAM (High Institute for Environment Protection and Research), Laboratory of Milazzo, Via dei Mille 44, 98057 Milazzo (ME), Italy. E-mail: espositovalentina@hotmail.com
[2] ISPRA-ex ICRAM, STS Palermo, c/o Marbela Residence, Via Salvatore Puglisi 9, 90143 Palermo, Italy.
[3] ISPRA-ex ICRAM, via di Casalotti 300, 00166 Roma, Italy.

SUMMARY: The diet composition of the Atlantic lizardfish *Synodus saurus*, caught on sandy bottoms of the north-western coast of Sicily (southern Tyrrhenian Sea) is described. The stomachs of 224 specimens (from 73 to 280 mm TL) were collected between June 2005 and May 2006. The analysis of stomach contents showed that this species is almost exclusively piscivorous. Unlike other benthic predators of the study area, it mainly feeds on pelagic school-forming fish, such as Clupeidae, Engraulidae and Myctophidae and juveniles of Sparidae and Centracanthidae, and benthic prey play a secondary role. The diet of *S. saurus* is related to the seasonal availability of resources, depending on the occurrence of juveniles of several species and on the migration of pelagic fishes in the study area. There were no significant changes in prey items between predator length groups, but a positive, significant linear relationship between prey size and predator size was recorded.

Keywords: diet, feeding habits, Synodontidae, *Synodus saurus*, ontogeny, central Mediterranean Sea, Sicily.

RESUMEN: Dieta del pez de San Francisco *Synodus saurus* (Linnaeus, 1758) (Pisces: Synodontidae) en el Mediterráneo central. – El presente trabajo ha estudiado la composición de la dieta del pez de San Francisco *Synodus saurus*, pescado sobre fondos arenosos en la costa nor-occidental de Sicilia (Tirreno meridional). El análisis del contenido estomacal de 224 individuos (entre 73 y 280 mm LT), pescados entre junio 2005 y mayo 2006, evidenció que *S. saurus* es una especie casi exclusivamente ictiófaga. A diferencia de otros depredadores bentónicos, *S. saurus* se alimenta fundamentalmente de peces que forman bancos pelágicos como Clupeidae, Engraulidae y Myctophidae y de los juveniles de las familias Sparidae y Centracanthidae, mientras las presas bentónicas resultaron secundarias. *S. saurus* exhibió una estrategia alimentaria relacionada con la disponibilidad estacional de recursos, dependiendo de la ocurrencia de juveniles de varias especies y de la migración de peces pelágicos en el área de estudio. No hubo cambio significativo de presas entre grupos de tallas pero se evidenció una relacción positiva, lineal y estadísticamente significativa entre el tamaño de la presa y del depredador.

Palabras clave: dieta, ecología trófica, Mediterráneo central, ontogenia, Synodontidae, *Synodus saurus*, Sicilia.

INTRODUCTION

The Atlantic lizardfish, *Synodus saurus* (Linnaeus, 1758), is an epibenthic subtropical fish belonging to the Synodontidae family, distributed in the Mediterranean Sea, the eastern Atlantic from Morocco to Cape Verde, including the Azores, and the western Atlantic from Bermuda and the Bahamas to the Lesser Antilles (Leeward Islands) (Sulak, 1986; Bauchot, 1987). In the Mediterranean, this species can reach a total length of 43 cm (Bauchot, 1987) and is commonly found on sandy bottoms, primarily at depths less than 50 m with occasional records of 400 m (Sulak, 1986; Bauchot, 1987). It is a dioecious species and its spawning period falls within the spring and summer months, with a reproductive peak in July, both in the Atlantic Ocean (Sousa *et al.*, 2003) and the Mediterranean Sea (Golani, 1993).

Synodus saurus, like others of the Synodontidae family, is characterised by immobile and camouflage behaviour (Keenleyside, 1979; Sulak, 1986; Golani, 1993; Kagiwara and Abilhôa, 2000). Despite spending most of its time buried in the sand, the lizardfish is a highly mobile predator that can also capture pelagic fishes in midwater (Soares *et al.*, 2003). Soares *et al.* (2002) made underwater observations of the predatory behaviour of *S. saurus* in Azorean waters and found that lizardfish compete for territory through intraspecific agonistic interactions and occasionally through non-agonistic interspecific relations (e.g. with *Bothus podas maderensis*).

The diet and feeding behaviour of *Synodus saurus* in the Atlantic Ocean have been exhaustively described (Soares *et al.*, 2002, 2003); however, very little is known about these in the Mediterranean Sea. Currently Golani (1993) has made the only study, but it was based on a very low number of individuals from the Israeli coast.

The purpose of this study is to analyse the diet and feeding habits of *Synodus saurus* in the southern Tyrrhenian Sea (central Mediterranean) in different periods of the year, at different depths and in different size classes.

MATERIALS AND METHODS

Synodus saurus were collected by bottom trawl in the southern Tyrrhenian Sea, along the northern Sicilian coast, on the sandy bottoms located in an area between Capo d'Orlando and Capo Calavà (Fig. 1).

From June 2005 to May 2006, four trawl surveys were carried out during daylight hours (from 8 a.m. to 4 p.m.), using a net with a codend mesh-size of 20 mm. In each survey, 2 hauls of 20 min at an average speed of 2.8 knots were conducted at three depths (10, 20 and 30 m) for a total of 24 hauls during the entire study period.

A total of 224 individuals of *Synodus saurus* was measured (total length TL) to the nearest millimetre, weighed to the nearest 0.1 g and their stomachs removed and preserved in 70% ethanol.

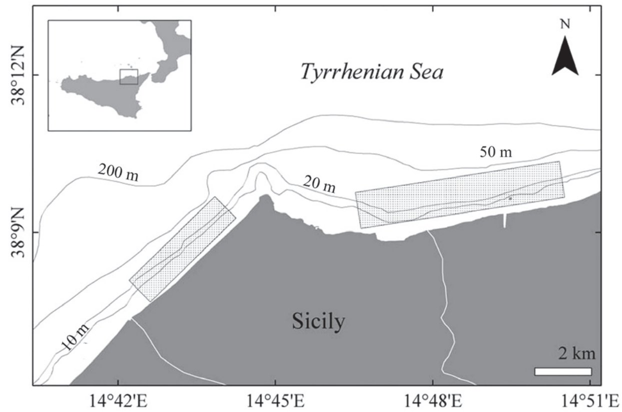

FIG. 1. – Study area, showing sampling stations.

Sorting was carried out under a binocular microscope and prey items were identified to the lowest possible taxon and counted and weighed to the nearest 0.1 mg, after removing excess water with blotting paper. The vacuity coefficient (V% = percent of empty stomachs) was calculated. Fish prey were classified according to their life stage. When found entire, prey items were measured to the nearest 0.1 mm TL with a caliper.

The cumulative number of new prey types was plotted against the cumulative number of non-empty stomachs analysed in order to measure sample size sufficiency (Ferry and Caillet, 1996). The PRIMER software was used to compute a prey species accumulation plot as an average of 999 curves based on different random orders of the stomachs. The standard deviation was calculated and represented in a graph for every five stomachs. The logistic and the linear regressions were calculated and the goodness of fit coefficient R^2 compared: the sample size was considered sufficient when R^2 for the logistic curve was higher than R^2 for the linear relation (Castriota *et al.*, 2005a).

The contribution of different prey items to the diet of *Synodus saurus* was estimated by calculating the abundance percentage (%N = number of prey *i* / total number of prey * 100) and weight percentage (%W = weight of prey *i* / total weight of all prey * 100) (Pinkas *et al.*, 1971; Hyslop, 1980; Hacunda, 1981).

To assess potential diet changes with respect to sampling periods and depths, abundance (a) and biomass (b) data were analysed by means of a multivariate analysis of similarities (ANOSIM). This analysis was based on Gower distances and was performed on 22 prey categories after the data had been square root transformed. Pair-wise a posteriori comparisons were computed after significant differences ($p<0.05$) among factor levels were detected.

Table 1. – Abundance percentage (%N) and weight percentage (%W) for prey items of *S. saurus*. Total values are given in bold print.

	%N	%W		%N	%W
VERTEBRATA Teleostei			CLUPEIDAE	1.4	21.2
SPARIDAE	12.3	25.5	*Sardina pilchardus*	0.7	8.9
Pagellus acarne (juv)	3.6	14.4	*Sardinella aurita*	0.7	12.3
Boops boops (juv)	7.2	10.8	ENGRAULIDAE	7.2	8.0
Unid. Sparidae (juv)	1.4	0.3	*Engraulis encrasicolus*	7.2	8.0
CENTRACANTHIDAE	6.5	5.2	Unid. Clupeiformes	0.7	1.2
Spicara sp. (juv)	4.3	0.4	BOTHIDAE	1.4	0.4
Spicara smaris (juv)	0.7	2.1	*Arnoglossus thori* (juv)	1.4	0.4
Spicara maena (juv)	1.4	2.7	TRIGLIDAE	0.7	6.8
AMMODYTIDAE	1.4	0.3	*Lepidotrigla cavillone*	0.7	6.8
Gymnammodytes cicerelus (juv)	1.4	0.3			
GOBIIDAE	5.1	1.7	Unid. Teleostei	48.6	26.2
Deltentosteus quadrimaculatus	2.9	1.1	VERTEBRATA Teleostei total	94.2	99.7
Unid. Gobiidae	2.2	0.6			
CALLYONIMIDAE	2.2	1.8	ANNELIDA		
Callyonimus sp.	2.2	1.8	Polychaeta Serpulidae	0.7	<0.1
MYCTOPHIDAE	6.5	1.5	ANNELIDA total	0.7	<0.1
Ceratoscopelus maderensis	4.3	0.8			
Hygophum benoiti	1.4	0.7			
Unid. Myctophidae	0.7	<0.1	SPERMATOPHYTA *Cymodocea nodosa*	7.2	0.3

A multivariate multiple permutation test (SIMPER) was used to establish the contribution of each prey category to the average within-group similarity and dissimilarity between groups in terms of Bray-Curtis similarities. These analyses were performed using the statistical software PRIMER 6 (Plymouth Routines In Multivariate Ecological Research) (Clarke and Warwick, 2001).

A correspondence discriminant analysis (CDA) was used with prey abundance data to separate prey items in relation to study periods and depths. This analysis was developed to analyse ecological data and is appropriate for comparing individuals belonging to several groups. It is particularly useful for describing how groups differ in terms of variables (Chessel and Thioulouse, 1996). CDA was repeated to classify prey items into 4 predator size classes (<158 mm; 158-196 mm; 196-217 mm; >217 mm) obtained by dividing the length frequency distribution of *Synodus saurus* into quartiles. CDA was computed with the ADE-4 software package.

Linear regression analysis was performed using SPSS software to assess the relationship between prey size and predator size. In addition, to examine the pattern of relative prey size of *Synodus saurus*, a relative frequency histogram of prey-size/predator size ratios was generated.

RESULTS

Of the total 224 stomachs analysed, 101 contained food (V% = 45). The length-frequency distribution

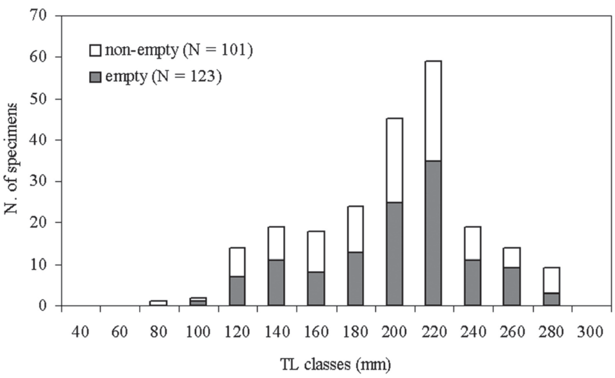

Fig. 2. – Length frequency distribution of specimens of *S. saurus* with empty and non-empty stomachs.

of samples with empty and non-empty stomachs for 20 mm total length (TL) classes is shown in Figure 2; specimens ranged from 73 to 280 mm TL and were almost equally distributed in all size classes, with a predominance of lengths between 200 and 220 mm.

The cumulative prey type curve (Fig. 3) for the entire data set fitted a logistic curve ($R^2 = 0.983$, $F_{(1,99)} = 2974.4$, $p<0.001$) better than a linear relation ($R^2 = 0.866$, $F_{(1,99)} = 640.3$, $p<0.001$); therefore, the sample size was considered sufficient for describing the diet of the Atlantic lizardfish.

The prey items and their respective %N and %W values are reported in Table 1. 22 prey categories were recorded. Teleosts (mostly juveniles) attained a numerical percentage of 94.2% and accounted for a weight percentage of 99.7% of the total weight. 10 families were identified among the teleosts: according to all numerical indicators, sparids were dominant, and were mainly represented by juveniles

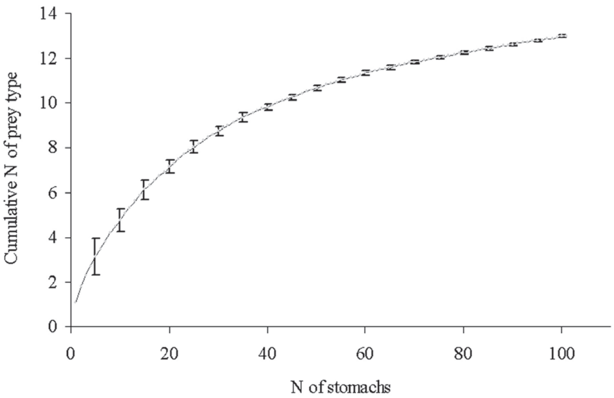

FIG. 3. – Prey species accumulation plot as an average of 999 curves based on different random orders of the stomachs extracted (n. of stomachs = 101). Vertical bars represent standard deviation.

of *Boops boops* and *Pagellus acarne*; engraulids and mictophids were also important in terms of N% while clupeids were accounted for mainly in W%. Teleosts were generally present in a highly digested state and as unidentifiable remains, and account for the highest percentage of unidentified fish among prey items. Serpulids was the sole invertebrate prey and was only found once.

The results of the ANOSIM test performed on abundance and biomass data showed that the diet of the species was not affected by depth, while there were significant differences between the sampling periods in terms of both prey abundance (global R_a = 0.068) and prey biomass (global R_b = 0.08). In particular, the diet of the specimens caught in June 05 and in October 05 differed significantly from that of the specimens caught in December 05 (R_a = 0.102 and R_a = 0.107 respectively; R_b = 0.097 and R_b = 0.068 respectively). The results of the SIMPER analysis showed that the average similarity between samples of the same period (group) in all cases was <50%, which evidences the opportunistic behaviour of this species. The highest average similarity was found within the specimens caught in June, with mainly *Pagellus acarne* juveniles contributing to their diet. The high dissimilarity found between the June and December groups (δ_a = 81.4% and δ_b = 81.2%) is imputable to the absence of *P. acarne* juveniles and the occurrence of the mictophid *Ceratoscopelus maderensis* in the December samples. The high dissimilarity between the October and December groups (δ_a = 87.1% and δ_b = 86.7%) is due to Myctophidae only occurring in December, and *Engraulis encrasicolus* and *Boops boops* only occurring in October.

CDA computed for study periods explained 83.8% of the total variance and clearly separated the individuals of *Synodus saurus* caught in June-December from those caught in October-May. Prey items that were responsible for the differences were *Engraulis encrasicolus,* which was predominantly predated in October, *Callyonimus* sp. predated mainly in May, Myctophidae, *Arnoglossus thori* juveniles, Clupeidae and Gobiidae predated in December and *Lepidotrigla cavillone*, *Gymnammodytes cicerelus* and *Pagellus acarne* juveniles in June (Fig. 4).

The CDA computed for depths explained 100% of the total variance and did not show a clear separation

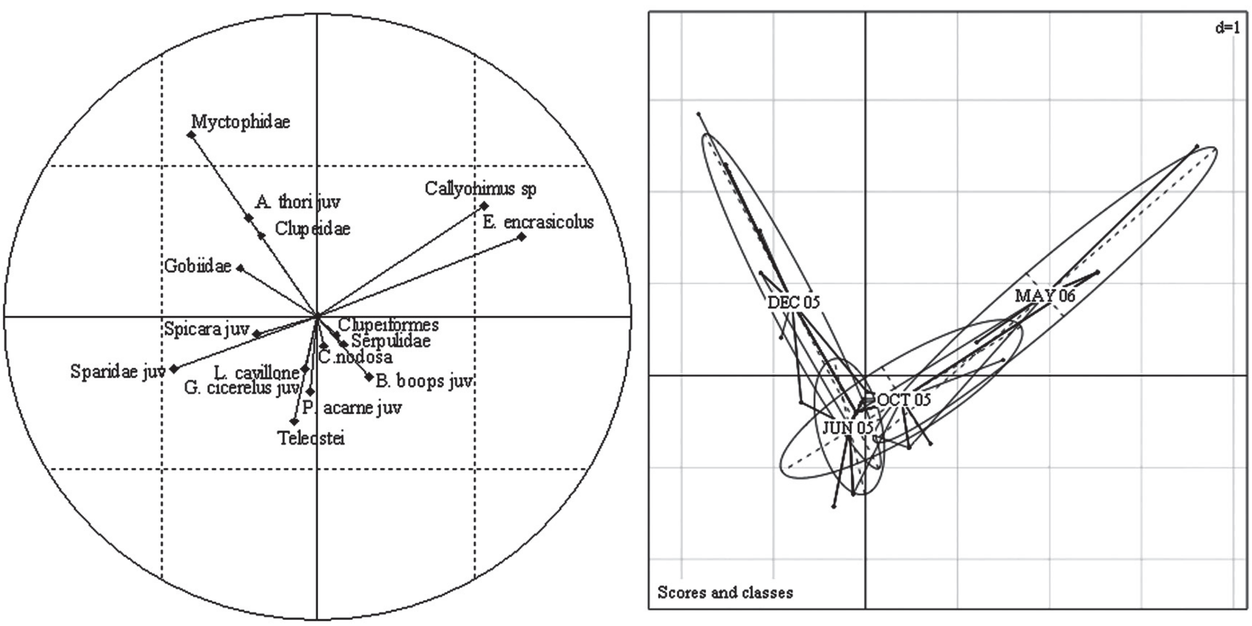

FIG. 4 – Correspondence discriminant analysis (CDA) computed for study periods explaining 83.8% of the total variance.

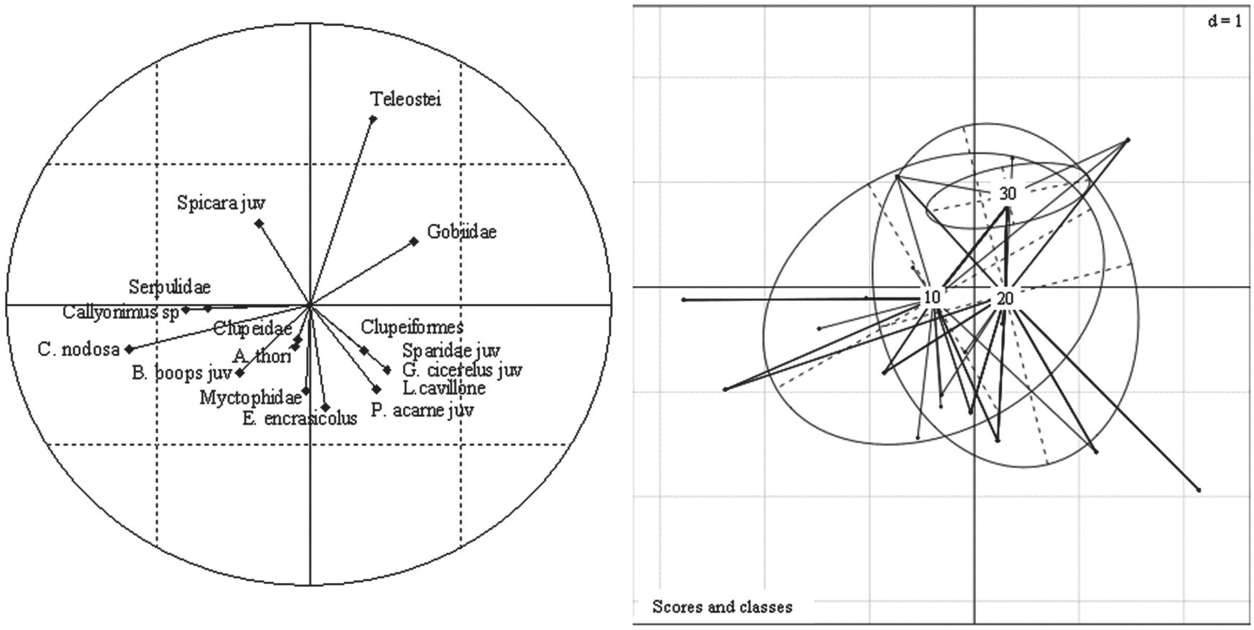

FIG. 5 – Correspondence discriminant analysis (CDA) computed for depth explaining 100% of the total variance.

of prey items. *Callyonimus* sp, *Cymodocea nodosa* and Serpulidae were distributed towards the 10 m bathymetry; Clupeiformes, *Engraulis encrasicolus*, *Pagellus acarne* juv, *Gymnammodytes cicerelus* juv, *Lepidotrigla cavillone* and Sparidae juv were found at a depth of 20 m; Gobiidae were typical at the 30 m bathymetry (Fig. 5).

The CDA computed for size classes explained 77.4% of the total variance and revealed that Myctophidae and *Arnoglossus thori* juveniles were mainly predated by the smallest specimens of lizardfish (<158 mm), *Engraulis encrasicolus, Boops boops* and *Pagellus acarne* juveniles by the intermediate predator size classes (158-217 mm) and Clupeidae and *Spicara* juveniles by the largest ones (>217 mm) (Fig. 6).

Of the 101 individuals of *Synodus saurus* with non-empty stomachs, 48 specimens, ranging from

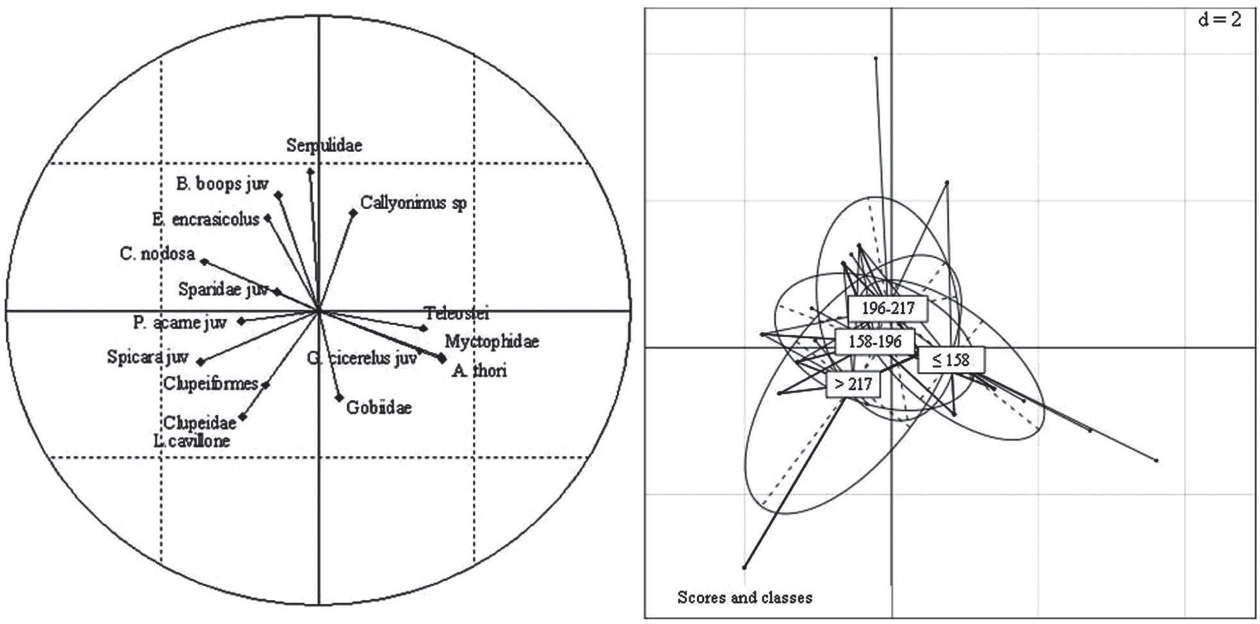

FIG. 6 – Correspondence discriminant analysis (CDA) computed for predator size classes explaining 77.4% of the total variance

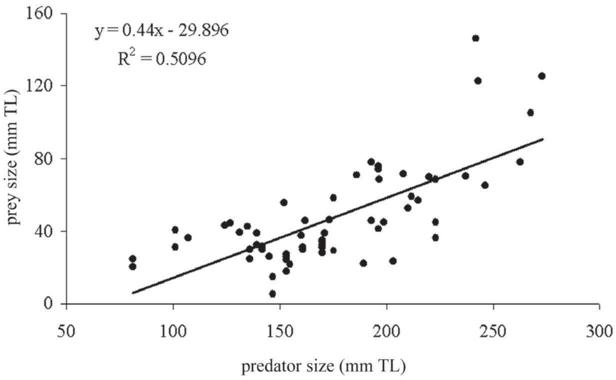

FIG. 7 – Prey size-predator size relationship.

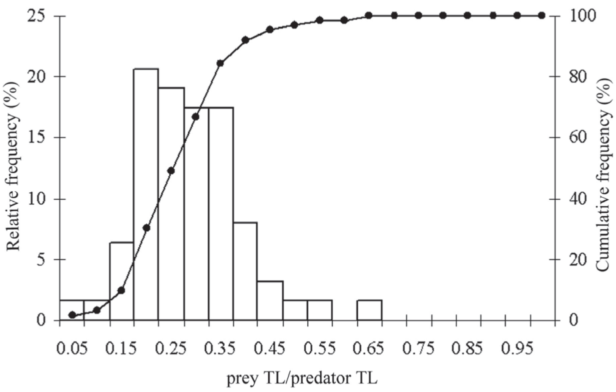

FIG. 8 – Relative frequency distribution of prey size/predator size ratios consumed by *S. saurus.* Cumulative frequency is indicated by a continuous line with filled circles at 5% intervals of prey size/ predator size ratios.

81 to 273 mm TL, had 63 entire prey items, among which clupeids were the largest prey. The results of the linear regression analysis (Fig. 7) showed a positive and significant linear relationship ($r = 0.7$, $F_{(1,61)} = 63.38$, $p<0.05$) between prey size and predator size. The relative frequency histogram of prey-size/ predator size ratios (Fig. 8) showed that nearly 84% of the diet of *S. saurus* was made up of prey with a body size <35% of the predator body size.

DISCUSSION

Atlantic lizardfish is considered to be an epibenthic cryptic predator that feeds primarily on small gregarious pelagic fish but also on crustaceans and cephalopods (Golani, 1993; Soares *et al.*, 2002, 2003). In our study area, this species was found to be almost exclusively piscivorous with the ability of exploring different habitats and capturing different prey types. *Synodus saurus* feeds on benthic fishes of the families Callionymidae, Gobiidae, Bothidae and Triglidae that occupy the same habitat as it, and also on gregarious pelagic fishes of the Clupeidae and Engraulidae families, on juveniles of Sparidae and Centracanthidae which occur periodically in coastal waters and on mesopelagic fishes (Myctophidae) which migrate to shallow layers at night (Scotto di Carlo *et al.*, 1982). According to Soares *et al.* (2003) and Golani (1993), benthic fishes have a secondary role in the diet of *Synodus saurus* in comparison to other fishes, as demonstrated by the %N indexes. Conversely, *Engraulis encrasicolus* and juveniles of Sparidae were the major components of the diet of *S. saurus* in the southern Tyrrhenian sea; among the Sparidae, *Pagellus acarne* and *Boops boops*, which are commonly recorded in the study area (Andaloro, 2008), dominated. Golani (1993) also pointed out the importance of *B. boops* in the diet of the Atlantic lizardfish in eastern Mediterranean waters, while Soares *et al.* (2003) found that the main food resources were *Sardina pilchardus* and *Sphyraena viridensis* in Azorean waters.

In all study periods, about half the sampled specimens of *Synodus saurus* had empty stomachs; as sampling was carried out in the daytime, we can suppose that this species feeds at different times during the 24 hours of the day. Nocturnal feeding is also suggested by the occurrence of myctophids in some stomachs. However, the high vacuity index found may be biased because of the method employed to catch the specimens (i.e. trawling) that would cause regurgitation in some individuals, thus leading to underestimations of diurnal feeding.

The diversity of prey of Tyrrhenian *Synodus saurus* caught in the different periods of the year seems to reflect the periodical occurrence of certain species in the study area. Such a correspondence would confirm the opportunistic behaviour of this predator, whose diet depends on the different resource availability in the area, which has also been observed for other *Synodus* species elsewhere (Cruz-Escalona *et al.*, 2005).

In particular, the contribution of *Pagellus acarne* and *Spicara* spp. juveniles to the diet of *Synodus saurus* was important during spring, while *Boops boops* juveniles and *Engraulis encrasicolus* were mainly predated in autumn then replaced by myctophids in late autumn-early winter. This pattern is consistent with the seasonal succession of species abundance recorded in the study area (our trawl surveys and commercial landings), and is also confirmed by data from the literature from nearby areas (Montalenti, 1937; Scotto di Carlo *et al.,* 1982; Matarrese *et al*, 1996).

The occurrence of lanternfish in autumn-winter, is probably related to the major mixing of water layers in the absence of a thermocline; the presence of this transition layer seems to influences the vertical distribution of some mesopelagic fishes (Paxton, 1967). The particular bottom morphology in the study area, together with the presence of submarine valleys and canyons, a narrow continental shelf and a very steep slope (Andaloro, 1994; Brambati *et al.*, 1995; Tramontana *et al.*, 1995), also facilitate the upward migration of mesopelagic organisms making them available to coastal predators. The predation of Atlantic lizardfish on mesopelagic species therefore plays an important role in the energy transfer and recycling from deep to coastal waters.

Soares *et al.* (2003) found that *Synodus saurus* exhibited a size-based feeding strategy, as its diet, regardless of the length of the predator, was concentrated on juveniles or prey species with a body size <35% of the predator body size.

However, whereas these authors did not find any positive relation between prey size and predator size, in our study we found that as the predator grew prey sizes significantly increased. According to Soares *et al.* (2003) a significant change of prey items did not correspond to such a size-related ontogenetic shift. We observed that small prey, such as Myctophidae and the flatfish *Arnoglossus thori* juveniles, were more frequent in the stomach contents of smaller predators than in those of larger predators, where, conversely, bigger prey, such as Clupeidae, were more commonly found. Therefore, in addition to resource availability, prey size seems to strongly influence the feeding behaviour of this predator; however, according to the low discrimination of prey items across depths, this factor does not affect its food choices.

The specialised sit-and-wait predatory behaviour of the Atlantic lizardfish also allows it to hunt pelagic school-forming fish, which are not usually preyed upon by other benthic predators. Studies on the feeding habits of predators (*Xyrichtys novacula, Mullus barbatus, Bothus podas*) living in the same area, have clearly shown their preferences for benthic invertebrates (Castriota *et al.*, 2005a, 2005b, 2006; Andaloro, 2008), which therefore indicates trophic niche segregation in *Synodus saurus*.

In conclusion, the Atlantic lizardfish in the southern Tyrrhenian Sea is piscivorous: it feeds mainly on juveniles of others predators, so it can be considered an apex predator of the sandy bottoms of the continental shelf, exploring different habitats during its feeding activity and hunting various prey types, depending on resource availability and the size of prey.

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