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The feeding habits of the Lessepsian fish *Stephanolepis diaspros* (Fraser-Brunner, 1940) in the Gulf of Gabes (eastern Mediterranean Sea)

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Abstract: The feeding habits of a Mediterranean population of the Lessepsian fish *Stephanolepis diaspros* were investigated with respect to fish size and seasons. Stomach contents of 1124 specimens, collected at monthly intervals, were analysed. 40.8% of the stomachs examined were empty, with a maximum recorded in winter and a minimum in summer and their proportion varied also among size classes. Maximum feeding intensity occurred for males of total length > 186 mm. The diet was composed of benthic organisms, mainly crustaceans, foraminifers, gastropods, ostracods, sea urchins and phytobenthos, while other animal groups were consumed occasionally. The frequencies of primary preys increased with size while those of secondary preys were reduced and even absent in the largest size classes. The varied food spectrum indicates that *S. diaspros* is an omnivorous species and could be considered an opportunistic predator.

Résumé : *Régime alimentaire du poisson lessepsien* Stephanolepis diaspros *(Fraser-Brunner, 1940) dans le golfe de Gabès (Méditerranée orientale).* Le régime alimentaire du poisson lessepsien *Stephanolepis diaspros* a été étudié en fonction de la taille et des saisons. 1124 spécimens de longueur totale comprise entre 3,7 et 23,7 cm ont été disséqués. 459 estomacs étaient vides, ce qui donne un coefficient de vacuité de 40,8%. Cette valeur varie au cours de l'année avec un maximum d'estomacs vides enregistré en hiver. Le coefficient de vacuité varie également en fonction de la taille. L'intensité d'alimentation est maximale chez les mâles de taille supérieure à 186 mm. L'analyse de la composition du bol alimentaire suggère que *S. diaspros* est une espèce omnivore et un prédateur opportuniste. Il présente un spectre alimentaire très diversifié renfermant divers groupes zoologiques benthiques. Les gastéropodes, les crustacés, les foraminifères, les ostracodes et les oursins représentent les proies les plus importantes, ainsi que des macroalgues, tandis que d'autres groupes zoologiques sont considérés comme des proies occasionnelles. La fréquence des proies principales augmente avec la taille tandis que les proies secondaires (de basse fréquence) ne sont ingérées que par les petits spécimens.

Keywords: Feeding • *Stephanolepis diaspros* • Lessepsian fish • Mediterranean Sea • Gulf of Gabes

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Introduction

The total number of fish species in the Mediterranean Sea is currently close to 700 (Golani et al., 2006), including several exotic species, like *Stephanolepis diaspros* (Fraser-Brunner, 1940) (Monacanthidae). This species originated of Red Sea immigrated via the Suez Canal into the Levant Sea (Golani et al., 2002), where it was able to adapt rapidly and spread, establishing successfully new populations.

The reticulated leatherjacket *S. diaspros* was recorded first in Palestine (Steinitz, 1927), successively in Syria, Cyprus, Rhodes (Greece), Gulf of Taranto (Italy), Crete (Greece), Gulf of Palermo (Italy) (Golani et al., 2002) and in the Adriatic Sea (Dulçic & Pallaoro, 2003). In Tunisia, it was first recorded in the Gulf of Gabes (Eastern Mediterranean Sea) since the years 1965-1966 (Chakroun, 1966) and then in the lagoon of Bizerte at 5-7 m of depth (north of Tunisia, at the border of the Western Mediterranean Sea) (Bdioui et al., 2004). Currently, this filefish is common in the Gulf of Gabes at depths between 0 and 60 m (Bradai, 2000; Zouari-Ktari et al., 2003).

Although *S. diaspros* is very common in the eastern Mediterranean and the Red Sea, no detailed data on its biology, and in particular on its feeding habits, are available. According to Golani et al. (2002), it inhabits shallow waters, on coastal rocky substratum, usually with vegetation and it feeds on small invertebrates plucked from rocks. Eggs and larvae are planktonic and young individuals form schools and feed also in open water, on sandy and muddy substrate (Golani et al., 2002).

The study of feeding ecology is useful and fundamental to understand the functional role of the fishes within the ecosystems they inhabit (Blaber, 1997; Cruz-Escalona et al., 2000). This work provides data on the food and feeding habits of the population of *S. diaspros* from the Gulf of Gabes, Tunisia, analysing qualitative variations in diet composition, with regards to factors such as seasonality and fish size. The feeding habits described contribute to understand the reasons which have permitted the successful adaptation and spreading of this Erythrean species in the Mediterranean area.

Material and Methods

Study site

The Gulf of Gabes is located in southern Tunisia and in southern Mediterranean Sea. It extends along 150 km from La Chebba 35°N to the Libyan border (Fig. 1). Surface temperature ranges between 16.7°C in winter and 26°C in summer, while mean surface salinity is 38.5 (Ktari-Chakroun & Azouz, 1971). Both wide and shallow continental shelves are topographically regular. The bottom slightly declines towards the sea and 60 m depth occurs at 110 km far from the coast (Ben Othmen, 1973). The Gulf of Gabes is locally the most important fishing area and comprises more than 50% of the Tunisian fishing fleet.

Sampling

Monthly samples of *S. diaspros* were collected from May 2003 to December 2005 caught by pelagic trawlers, along the continental shelf of the Gulf of Gabes, mainly at depths between 0 and 40 m.

Fishes were taken from the net, identified to species and frozen for laboratory analyses. In the laboratory, a random sample was measured and weighed, the total length (TL) to the nearest 1 mm and the wet weight to the nearest 0.01 g. A total of 1124 specimens ranging from 37 to 237 mm in TL was examined.

The fish stomachs were immediately removed and preserved in a 7% buffered formalin solution. Later, stomachs were washed, dissected and contents transferred to a Petri dish for observation under a stereomicroscope. Preys were identified to the lowest possible taxonomic level on the basis of their digestion state.

Two indices have been used to analyse the diet of *S. diaspros*:

Vacuity index (VI) = number of empty stomachs (ES) divided by total number of examined stomachs (TS) multiplied by 100 (VI = ES/TS x 100),

Index of frequency (IF) = number of stomachs in which a food item was found (SF), divided by the total number of non-empty stomachs NES), multiplied by 100 (SF/NES x 100). This index was used to evaluate variation in food habits as a function of size and season.

In the aim to evaluate the effects of size, specimens were separated into three classes: total length TL < 100 mm (class 1, juvenile specimens: males and females), 100 mm < TL < 186 mm (class 2, mature specimens: males and females), TL > 186 mm (class 3, all males).

The variation of vacuity index (VI) was tested by a chi-square test. Statistical differences in diet composition with respect to size and season were also tested by a chi-square test.

Results

Vacuity index

Among the 1124 stomachs examined, 459 were empty (VI = 40.8%). The proportion of empty stomachs varied significantly over the year ($P < 0.05$). The maximum number of empty stomachs was found in March (75%), while the minimum was observed in October (22.5%) (Fig. 2).

This proportion also varied significantly among seasons, showing a minimum in summer (33.5%) and a maximum in

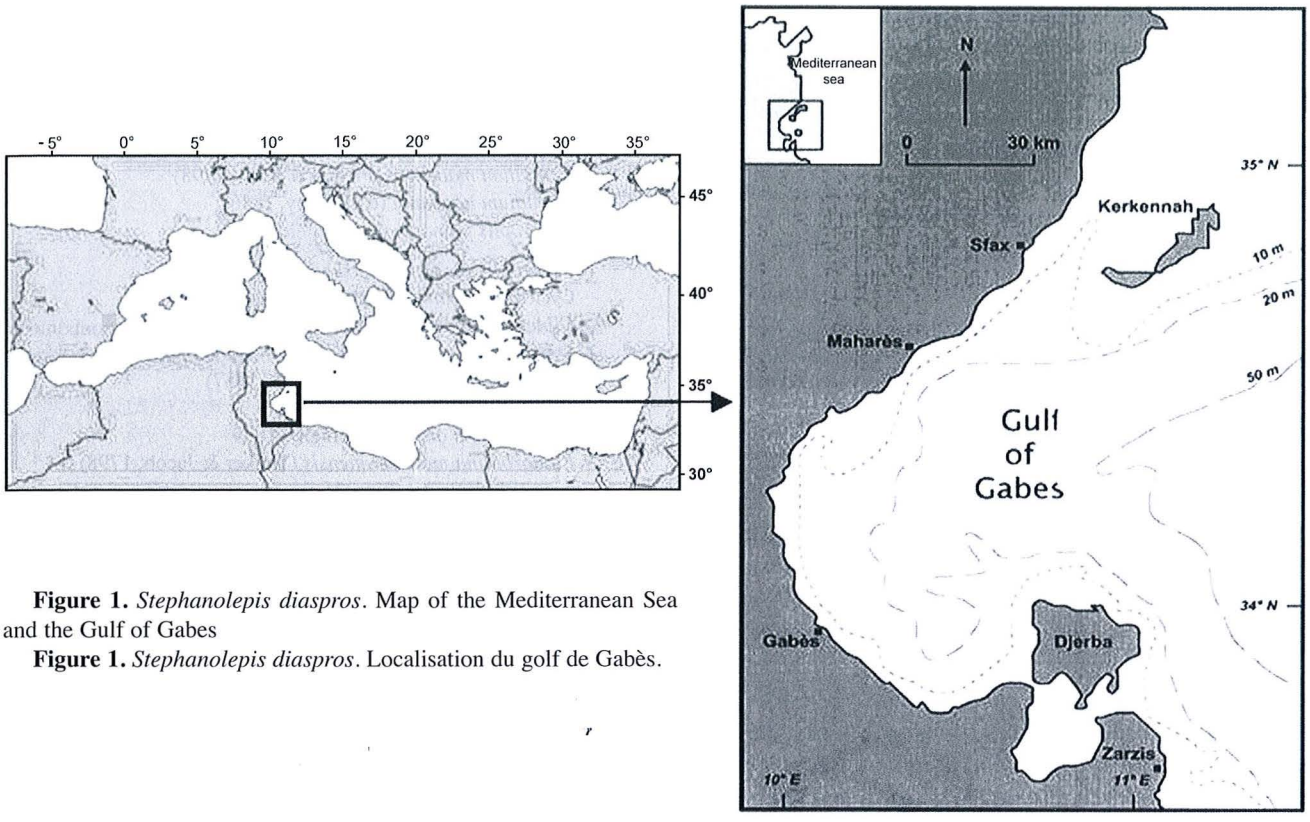

Figure 1. *Stephanolepis diaspros*. Map of the Mediterranean Sea and the Gulf of Gabes

Figure 1. *Stephanolepis diaspros*. Localisation du golf de Gabès.

winter (59.0%) (Fig. 2). The analysis of the variations of VI according to the size showed a value of 65.9% for class 1, 37.8% for class 2 and 34.9% for largest specimens (TL > 186 mm). The difference between these three values was significant ($\chi^2_{cal} = 22.59$, $p < 0.05$).

The VI was 33.8% for males and 50.4% for females and the difference was significant ($\chi^2_{cal} = 32.32$, $p < 0.05$).

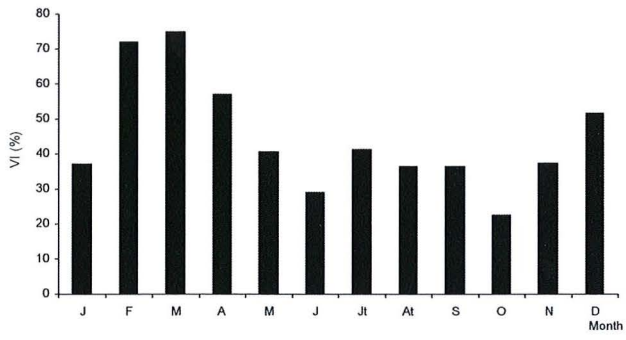

Figure 2. *Stephanolepis diaspros*. Variation in percentage of empty stomachs throughout year (VI: Vacuity index).

Figure 2. *Stephanolepis diaspros*. Evolution annuelle de l'indice de vacuité VI.

Diet composition

A large range of benthic organisms was identified in the stomachs of *S. diaspros*. The principal groups were crustaceans (isopods, decapods, amphipods and copepods), foraminifers, bivalves, gastropods, sea urchins, represented only by the spines, and also phytobenthos (Table 1).

Food in relation to fish size

The distribution of frequencies IF of the various prey categories, varied significantly among the three size classes (χ^2 cal = 41.9, $p < 0.05$). Crustaceans, foraminifers, phytobenthos, gastropods, spines of sea urchins and bivalves were the most important groups of preys present in the diet of all size classes, but their frequencies increased with the size (Fig. 3). Furthermore, ostracods were important prey items for small and medium size classes, while their occurrence decreased in the largest fishes. Siphonophores, larvae of Veneridae and hydrozoans occurred only in the diet of small and medium size classes, while they were not ingested by the largest specimens.

Seasonal variation in the diet composition

The same food categories were present during the four seasons, but the occurrence of the various preys varied significantly according to the season ($p < 0.05$) (Fig. 4).

Table 1. *Stephanolepis diaspros*. List of the preys found within the stomachs contents.
Tableau 1. *Stephanolepis diaspros*. Liste des proies trouvées dans les contenus stomacaux.

Phylum/ Class/ Order	Family	Genus and species
Protozoa/ Rhizopoda/ Foraminiferida		*Elphidium crispum* (Linnaeus, 1767).
		Elphidium macellum (Fichtel & Moll, 1798)
		Elphidium aculeatm (d'Orbigny, 1846)
		Peneroplis planatus (Lendenfeld, 1888)
		Peneroplis pertusus (Forskal, 1775)
		Cyclogyra carinata Havach and Collins, 1997
		Cibicides lobatulus (Walker and Jacob), 1798
		Spirolina arietina (Batsch, 1791)
		Spiroloculina antillarum (Fristedt, 1887)
		Spiroloculina sp.
		Spiroloculina ornata d´Orbigny, 1839
		Planorbulina mediterranensis (Walker & Jacob, 1798)
		Ammonia beccarii (Linne)
		Sorites variabilis Lacroix, 1941
		Globorotalia inflata d´Orbigny, 1839
		Cavolina inflexa (Lesueur, 1813)
		Articulina sagra (d´Orbigny, 1839)
		Triloculina trigonula (Topsent, 1892).
		Triloculina sidebottomi Koltun, 1964
		Globorotalia truncatuloides (d'Orbingny, 1839)
		Atlanta peroni (Lesueur, 1817)
		Gyroidina umbonata (Silvestri 1898)
		Quinqueloculina sp.
		Globigerinella aequilateralis (Brady) 1879
		Atlanta peroni (Lesueur, 1817)
		Nubecularia sp.
Coelenterata/ Siphonophora/ Calycophores	Diphydae	*Lensia conoidea* (Keferstein and Ehlers, 1860)
/ Hydrozoa/ Anthoathecatae	Pandeidae	*Amphinema dinema* (Peron and Lesueur, 1810)
/ Trachymedusa	Trachynematidae	*Homoeonema sp.*
/ Pseudo-siphonophorate/Chondrophoridae	Velellidae	*Velella sp.*
Annelida/ Polychaeta/ Canalipalpata	Serpulidae	*Vermiliopsis infundibulum* (Philippi, 1844)
Mollusca/Gasteropoda	Turritellidae	*Turritella sp.*
		Turitella communis Risso, 1826
	Cerithidae	*Ceruthium sp.*
	Assimineidae	*Assiminea sicana* (Brugnone, 1876)
	Aclididae	
	Neritidae	
	Littorinidae	*Littorina saxatilis* (Olivi, 1792)
	Buccinidae	
	Nassariidae	*Nassarius gibbosulus* (Linnaeus, 1758),
	Fissurellidae	*Diodora gibberula* (Lamarck, 1822),
	Colubrariidae	*Colubraria intertexta* (Helbling, 1779)
	Hydrobiidae	*Peringia ulvae* (Pennant, 1777)
	Melanellidae	*Melanella polita* (Linné,1758)
	Aclididae	
	Alvaniidae	
	Naticidae	*Naticairus hebraeus* (Martyn, 1786)
		Natica sp.
	Buccunidae	*Buccinum* hymphreysianum Linnaeus, 1758
	Limacinidae	*Limacina inflata* (d'Orbigny, 1836)
		Limacina trochiformis (d'Orbigny, 1836)
	Cavolinidae	*Euclio pyramidata* Linnaeus, 1767
	Trochidae	
	Patellidae	
	Melanellidae	*Eulima grandis* Adams, 1854
/ Scaphopoda		
/ Bivalvia	Mytilidae	*Littophaga littophaga* (Linné, 1758)

	Mactridae	*Mactra coralina* Linné, 1758
	Cartitidae	*Laevicardium sp.*
	Cardidae	*Fulvia fragilis* (Forskål, 1775)
		Cardium sp.
Arthropoda/ Crustacea/ Ostracoda		
/ Podocopa	Halocryptidae	*Conchoecia sp.*
/ Isopods	Sphaeromidae	*Sphaeroma sp.*
/ Mysidacea		
/ Gammaridea		
/ Amphipods		
/ Decapods/ Brachyura	.	
Echinodermata/ Echinoidea	Echinidae	*Paracentrotus lividus* Lamarck, 1810
Angiosperma/ Monocotyledona/ Juncaginales	Posidonae	*Posidonia oceanica* (L.) Delile, 1813
		Cymodocea nodosa (Ucria) Ascherson 1864

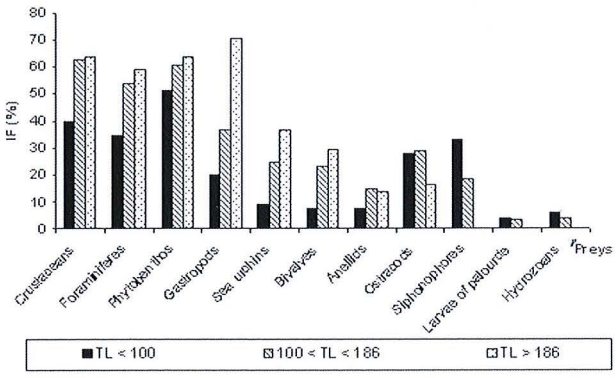

Figure 3. *Stephanolepis diaspros*. Variation in the diet composition according to the size (IF: index of frequency, TL: Total length in mm).

Figure 3. *Stephanolepis diaspros*. Variation des contenus stomacaux selon la taille (IF : indice de fréquence, TL : longueur totale en mm).

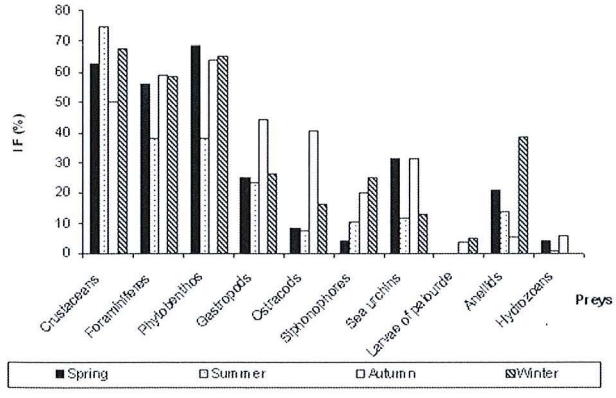

Figure 4. *Stephanolepis diaspros*. Seasonal variation in the diet composition.

Figure 4. *Stephanolepis diaspros*. Variation saisonnière des contenus stomacaux.

Thus, crustaceans were the predominant preys during all year (IF = 60.3%), especially during summer (IF = 74.6%). The phytobenthos and foraminifers occurred also during all seasons (IF = 59.7% and 51.9% respectively), but their occurrence decreased during summer in favour of crustaceans.

Gastropods, ostracods, sea urchins and hydrozoans occurred more frequent in autumn, whereas siphonophores and anellids were more frequent in winter. Sea urchins and hydrozoans seemed to decrease with the low and the high temperatures, thus, they were more frequent in the stomachs especially during spring and autumn. The larvae of Veneridae were ingested only in autumn and winter.

Discussion

The number of stomachs examined in this study was sufficient to describe accurately the diet of the Lessepsian species *Stephanolepis diaspros*, including the analyses of its changes according to size and seasons.

The diet of *S. diaspros* is strictly dependent on benthic organisms, where crustaceans, foraminifers, sea urchins, gastropods and phytobenthos predominated. This species may ingest phytobenthos to collect their epiphyte diatoms (Joubert & Hanekon, 1980), to extract nutrients directly from them (Mann & Buxton, 1992) or to optimise the digestion of animals (Lobel, 1981). Several other prey groups of minor importance were consumed occasionally and they were even absent in the largest specimens. The presence of small grains of sand in some stomachs confirms the fact that *S. diaspros* forages on the bottom.

Results for *S. diaspros* partly agree with previous works that describe the feeding habits of the indigenous species *Balistes capriscus* (Balistidae) as a benthic omnivore, its diet being composed mainly of mollusks, sea urchins, crustaceans and generally, of all the invertebrates. Also, the grey triggerfish consumes, in marginal manner, algae macrophytes

(Caverivière, 1982; Vose & Nelson, 1994).

Feeding intensity is negatively related to the percentage of empty stomachs (Bowman & Bowman, 1980). Feeding intensity of *S. diaspros* decreased during winter months (VI > 50%). This can be explained either by availability of the main prey or the temperature-dependent physiologic process. The maximum values of VI observed in February and March suggest a strong temperature-dependent regulation on food intake, as assessed for the horse mackerel by Temming & Herrmann (2001), since these lower values corresponded exactly to the months in which seawater temperatures achieve minimum values in the eastern Mediterranean Sea. The lesser abundance of prey and the lowered metabolism of the fish probably reduce predation during the winter. Favourable environmental conditions during the warmer months and an abundant food supply probably support the highest feeding intensity of this exotic species. During the summer, *S. diaspros* intensively exploits food resources and store excess energy for the subsequent over-wintering period.

The predominant groups of preys (crustaceans, foraminifers, phytobenthos, gastropods, bivalves and sea urchins) were present in the diet of all size classes, but their frequencies increased with the size. This could reveal that larger specimens are more active predators than the smaller, as shown also by their higher feeding intensity. On the contrary, ostracods were more frequent in small and medium size classes than in the largest one. Siphonophores, hydrozoans and larvae of Veneridae occurred only in small and medium size classes.

The diet composition of *S. diaspros* was almost uniform throughout the year, but with seasonal changes in frequency of various prey categories. This is a feature that may be caused by either the life history pattern of food organisms or the feeding activity of the fishes themselves (Snyder, 1984; Lucena et al., 2000).

S. diaspros is able to feed on a wide food spectrum of benthic organisms and many stomach contents were composed by nearly all prey groups identified. These adaptations broaden the feeding niche of the reticulated leatherjacket, allowing a feeding flexibility which includes both armored and unarmored invertebrate preys and phytobenthos as well. This characteristic allows the species to adapt in very different ecosystems, as are the Red Sea and the Mediterranean Sea. It is an omnivorous species and could be considered an opportunistic predator. This type of trophic niche may be an important reason for explaining the successful spreading and establishment of this Lessepsian species into the Mediterranean Sea (Golani, 1998).

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