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Feeding habits of the black anglerfish, *Lophius budegassa* (Osteichthyes: Lophiidae), off the Tunisian coast (central Mediterranean)

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Abstract: The feeding habits of the black anglerfish, *Lophius budegassa* Spinola, 1807 off the Tunisian coast, were investigated in relation to sex, size and seasons. Stomach contents of 416 specimens were collected on a monthly basis between November 2004 and January 2006. One hundred and twenty two stomachs were empty (29.32%), a proportion that significantly changed between males and females. The food composition suggests that the Tunisian black anglerfish is an active feeder. Seven zoological groups were identified in the stomach contents of *L. budegassa*: osteichthyans, chondrichthyans, cephalopods, bivalves, gastropods, crustaceans and echinoderms. Among the different zoological groups, osteichthyans were the most ingested (%IRI = 87.57). A total of 73 different prey species was recorded: *Merluccius merluccius* (%IRI = 21.51), *Trachurus mediterraneus* (%IRI = 18.62) and *T. trachurus* (%IRI = 17.34) being the most frequent prey species. The diet of *L. budegassa* changed qualitatively and quantitatively with special regard to size of specimens. Limited seasonal changes were observed in food spectrum. The trophic level (TROPH) of 4.47 calculated in the black anglerfish is high and indicates that the species is a top predator. The TROPH values ranged between 4.27 and 4.54, and increased asymptotically with size of specimens.

Résumé : *Nourriture et comportement alimentaire de la baudroie rousse,* Lophius budegassa *Spinola, 1807 de la côte tunisienne (Méditerranée centrale).* Le comportement alimentaire de la baudroie rousse, *Lophius budegassa* de la côte tunisienne a été étudié en relation avec le sexe, la taille et les saisons. Les contenus stomacaux de 416 spécimens, récoltés mensuellement de novembre 2004 à janvier 2006, ont été observés, dont 122 étaient vides (29,32%). La proportion des estomacs vides varie significativement entre mâles et femelles. La composition de la nourriture suggère que la baudroie rousse se nourrit activement. Sept groupes zoologiques ont été identifiés dans les contenus stomacaux: ostéichthyens, chondrichthyens, céphalopodes, bivalves, gastéropodes, crustacés et échinodermes. Les ostéichthyens sont les proies les plus consommées (%IRI = 87,57). Un total de 73 espèces de proies a été trouvé, *Merluccius merluccius* (%IRI = 21,51), *Trachurus mediterraneus* (%IRI = 18,62) et *T. trachurus* (%IRI = 17,34) sont les espèces proies les plus fréquentes. Le régime alimentaire de *L. budegassa* varie qualitativement et quantitativement avec la taille des spécimens. Il y a de faibles variations saisonnières du spectre alimentaire. Les ostéichthyens, plus particulièrement les carangidés, sont les proies

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dominantes tout au long de l'année. Le niveau trophique (TROPH) de 4,47, calculé chez la baudroie rousse, est élevé et il indique que l'espèce est un super-prédateur. Les valeurs de TROPH sont comprises entre 4,27 et 454, et elles augmentent asymptotiquement avec la taille.

Keywords: Osteichthyes • Lophiidae • *Lophius budegassa* • Diet • Feeding habits • Tunisian coast • Central Mediterranean.

Introduction

Two species of anglerfish, *Lophius budegassa* Spinola, 1807, and *L. piscatorius* Linnaeus, 1758 are found off the Tunisian coast as other Mediterranean regions (Dieuzeide et al., 1954; Quignard & Tomasini, 2000). Both species have high commercial interest and during the last decade, production of both species in the area considerably increased. *L. budegassa* and *L. piscatorius* were targeted for local consumption but mainly assigned for exportation. The lantern fish production ranged between 30 and 47 tons approximately per year between 1997 and 2004 for both species. *L. budegassa* and *L. piscatorius* off the Tunisian coast were found in sandy-muddy bottoms deeper than 200 m depth, that could explain why they are generally caught by trawl rather than by craft fishery. However, the available data showed that both species were not frequently landed throughout the year, but a peak occurred in June. Moreover, it appeared that *L. budegassa* is more abundantly fished than *L. piscatorius* off the Tunisian coast such as in other marine Mediterranean areas (Ungaro et al., 2002). Production of anglerfishes was not very important in relation with total fish production from the Tunisian waters according to Bradaï (2000), however its impact is not clearly defined, due to fact that the production of southern Tunisian areas are generally occulted in statistics.

L. budegassa as other lophiid species is a sit-and-wait predator with ambush behaviour that attracts preys that pass within range or make use of their angling apparatus or illicium (Chadwick, 1929; Armstrong et al., 1996). Despite this interesting predatory method and its economic importance, rare studies were the focus of the feeding habits of the species (Tsimenides, 1980; Azevedo, 1996; Preciado et al., 2006).

The aim of this paper is to describe the diet of black anglerfish off the Tunisian coast, analysing seasonal variations in its composition and feeding intensity in relation to sex and size. The results of the present work contribute to the knowledge about its feeding habits, and also to assess its environmental role. This study is a first step in determining prey consumption by the black anglerfish in the Tunisian marine waters, a main information for improving fishery monitoring and management in the study area.

Materials and Methods

Samples of black anglerfish were taken from different fishing sites located along the Tunisian coast (Fig. 1). Random samples were taken from commercial and demersal trawlers. Monthly samples were collected between November 2004 and January 2006. A total of 416 specimens ranging between 150 and 700 mm in total length (TL) were examined. After landing, commercially caught specimens were preserved on ice, and transported to the laboratory, where they immediately processed. For each specimen the total length (TL in mm), the weight (g wet weight) and sexes were registered. The stomach contents were examined and weighed.

In order to assess changes in diet *versus* total length, the sample was divided into six size classes: the first ($TL \leq 200$ mm, N = 4), the second ($200 < TL \leq 300$ mm, N = 126), the third ($300 < TL \leq 400$ mm, N = 142), the fourth ($400 < TL \leq 500$ mm, N = 94), the fifth ($500 < TL \leq 600$ mm, N = 35) and the sixth ($600 < TL \leq 700$ mm, N = 15). The stomach contents were removed, sorted and identified to the lowest possible taxon using keys and fields (Fischer et al., 1987). The preys were counted and weighed to the nearest decigram.

To analyse the food and feeding habits of *L. budegassa*, we used some indices following Hureau (1970), Zander (1982) and Rosecchi & Nouaze (1987): Vacuity index (VI = number of empty stomachs/total number of stomachs x 100), percentage frequency of occurrence (%F = number of stomachs containing prey i/total number of full stomachs x 100), percentage numerical abundance (%N = number of prey i/total number of prey x 100) and percentage gravimetric composition (%W = weight of prey i/total weight of all prey x 100). The index of relative importance (IRI) of Pinkas et al. (1971), as modified by Hacunda (1981): IRI = %F x (%N + %W). This index, that integrates the three previous percentages, allows an interpretation much more real

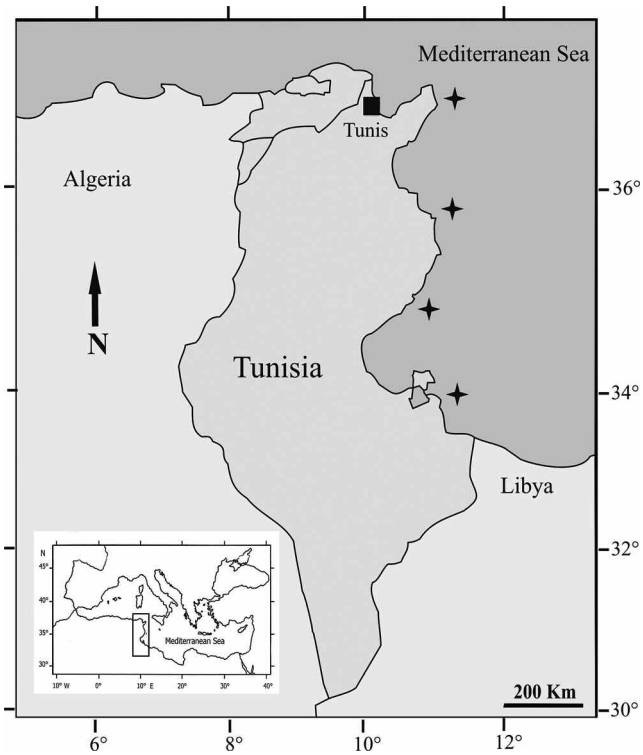


Figure 1. *Lophius budegassa.* Sampling sites (black stars) along the Tunisian coast.

Figure 1. *Lophius budegassa.* Sites d'échantillonnage (étoiles noires) le long de la côte tunisienne.

for food by minimizing the skews caused by each one of these percentage.

In order to be able to determine the different categories of food, this food has been regrouped according to the classification proposed by Rosecchi & Nouaze (1987). The value of the index of every item is expressed in percentage of the sum of all indices (∑ IRI). Prey species were stored in decreasing order according to their percentage IRI contribution and then cumulative %IRI was calculated. In this order, the %IRI of first prey are gradually added until to obtain 50% or more, these items are main food; this calculation is pursued until has get 25% or more, these items are called secondary food; the other items are accidentally food.

The trophic level for any consumer species i is (Pauly et al., 1998; Pauly & Christensen, 2000; Pauly & Palomares, 2000):

$$\mathrm{TROPH}_i = 1 + \sum_{j=1}^{G} CD_{ij}\ \mathrm{TROPH}_j \qquad (1)$$

Where TROPH_j is the fractional trophic level of prey j, CD_{ij} represents the fraction of j in the diet of i and G is the total number of prey species.

The TROPH and (SE) standard errors of black anglerfish in the study area were calculated using TrophLab (Pauly et al., 2000); a standalone Microsoft Access routine for estimating trophic levels, downloadable from www.fishbase.org. The relationship between TROPH and the mid point of each length class considered here was quantified using the following equation (Cortés, 1999):

$$\mathrm{TROPH}_{Li} = \mathrm{TROPH}_{L\infty}\ (1\text{-}e^{-\mathrm{KL}_i}) \qquad (2)$$

where $\mathrm{TROPH}_{L\infty}$ is the asymptotic TROPH and K is the rate at which $\mathrm{TROPH}_{L\infty}$ is approached. Statistical differences ($p < 0.05$) in basic diet composition as a function of size and season were established by applying a Chi-square test (Sokhal & Rohlf, 1987).

Results

Overall analysis of the diet

Of the 416 stomachs examined, 122 were empty. The preys consumed by *L. budegassa* were from seven zoological groups: osteichthyans, chondrichthyans, cephalopods, bivalves, gastropods, crustaceans and echinoderms, including 42 families and 73 species (Table 1). Our study showed that of the 73 species recorded in stomach contents, 54 were osteichthyans, whilst 10 were molluscs, 6 crustaceans, 2 chondrichthyans and a single one echinoderm.

The three diet indices (Table 1) showed that osteichthyans were preferentially consumed, and identified in higher abundance (78.05%), weight (87.91%) and occurrence (175.82%). *Merluccius merluccius* (%F = 18.71), *Trachurus mediterraneus* (%F = 18.71) and *T. trachurus* (%F = 18.03) were prey species the most recorded in stomach contents.

L. budegassa fed occasionally on mollusc species which were identified in relative abundance 3.98% and weight 5.85%. Among them, *Sepia orbignyana* (%F = 3.06) and *Illex coindetii* (%F = 2.72) were the most recorded. Additionally, *S. orbignyana* ranked first by mass and number in cephalopod species (Table 1). Crustaceans were observed in less abundance (12.24%) and weight (3.59%). At least six species were recorded (Table 1), such as *Parapenaeus longirostris* (%F = 11.57) and *Penaeus kerathurus* (%F = 5.10).

Analysis based on the feeding index (%IRI) showed that osteichthyans were mostly ingested by *L. budegassa* while *Merluccius merluccius* (%IRI = 21.51), *Trachurus mediterraneus* (%IRI = 18.62) and *T. trachurus* (%IRI = 17.34)

Table 1. *Lophius budegassa.* Diet composition: (%N) percentage by number, (%W) percentage by weight, (%F) percentage by occurrence and (%IRI) index of relative importance.

Tableau 1. *Lophius budegassa.* Composition du régime alimentaire : (%N) pourcentage en nombre, (%W) pourcentage en poids, (%F) pourcentage d'occurrence et (%IRI) indice d'importance relative.

Prey items	Indices	%N	%W	%F	%IRI
OSTEICHTHYES		**78.05**	**87.91**	**175.82**	**87.57**
Anguillidae	*Anguilla anguilla* (Linnaeus, 1758)	0.58	0.44	1.70	0.08
Congridae	*Conger conger* (Linnaeus, 1758)	0.47	0.29	1.36	0.05
	Gnathophis mystax (Delaroche, 1809)	0.35	0.04	1.02	0.02
Ophichthidae	*Echelus myrus* (Linnaeus, 1758)	0.12	0.02	0.34	0.00
	Ophichthus rufus (Rafinesque, 1810)	0.12	0.01	0.34	0.00
Chlorophthalmidae	*Chlorophthalmus agassizi* Bonaparte, 1840	0.47	0.10	1.02	0.03
Clupeidae	*Alosa fallax* (Lacepède, 1803)	0.47	0.44	1.02	0.05
	Sardinella maderensis (Lowe, 1839)	0.12	0.02	0.34	0.00
	Sardinella aurita Valenciennes, 1847	0.12	0.20	0.34	0.01
	Sardina pilchardus (Walbum, 1792)	0.12	0.17	0.34	0.00
Gadidae	*Gadiculus argenteus argenteus* Guichenot, 1850	1.28	0.36	2.04	0.16
Phycidae	*Phycis blennoides* (Brünnich, 1768)	0.35	0.33	1.02	0.03
Merlucciidae	*Merluccius merluccius* (Linnaeus, 1758)	8.38	15.23	18.71	21.51
Macroramphosidae	*Macroramphosus scolopax* (Linnaeus, 1758)	1.17	0.25	2.38	0.17
Argentinidae	*Argentina sphyraena* Linnaeus, 1758	4.08	2.30	7.48	2.32
Callionymidae	*Callionymus maculatus*Rafinesque, 1810	0.58	0.15	1.70	0.06
Carangidae	*Trachurus trachurus* (Linnaeus, 1758)	8.74	11.01	18.03	17.34
	Trachurus mediterraneus(Steindachner, 1863)	9.91	10.53	18.71	18.62
	Trachurus picturatus (Bowdich, 1825)	2.33	4.13	5.10	1.60
Centracanthidae	*Spicara flexuosa* Rafinesque, 1810	3.03	3.72	7.14	2.35
	Spicara maena (Linnaeus, 1758)	1.28	1.67	3.40	0.49
	Spicara smaris (Linnaeus, 1758)	0.12	0.19	0.34	0.01
Cepolidae	*Cepola macrophthalma* (Linnaeus, 1758)	0.23	0.11	0.68	0.01
Mullidae	*Mullus barbatus* Linnaeus, 1758	6.99	11.68	14.63	13.30
	Mullus surmuletus Linnaeus, 1758	0.12	0.22	0.34	0.01
Scombridae	*Scomber scombrus* Linnaeus, 1758	0.58	0.87	0.68	0.05
Serranidae	*Serranus hepatus* (Linnaeus, 1758)	3.38	1.95	8.50	2.21
	Serranus cabrilla (Linnaeus, 1758)	0.35	0.17	1.02	0.03
Sparidea	*Boops boops* (Linnaeus, 1758)	1.05	1.71	2.38	0.32
	Dentex gibbosus (Rafinesque, 1810)	0.23	0.29	0.68	0.02
	Dentex macroccanus Valenciennes, 1810	0.70	1.36	1.36	0.14
	Dentex macrophthalmus (Bloch, 1791)	0.47	0.59	1.36	0.07
	Diplodus sargus sargus (Linnaeus, 1758)	0.47	0.89	1.36	0.09
	Pagellus acarne (Risso, 1826)	2.33	2.20	5.44	1.20
	Pagellus erythrinus (Linnaeus, 1758)	1.28	2.25	2.72	0.47
	Pagrus pagrus (Linnaeus, 1758)	0.12	0.36	0.34	0.01
	Pagrus caeruleostictus (Valenciennes, 1830)	0.12	0.15	0.34	0.00
Trachinidae	*Trachinus draco* Linnaeus, 1758	1.05	1.97	2.72	0.40
	Trachinus radiatus Cuvier, 1829	0.23	0.21	0.68	0.01
Trichiuridae	*Lepidopus caudatus* (Euphrasen, 1788)	1.63	1.49	3.06	0.46
Bothidae	*Arnoglossus lanterna* (Walbaum, 1792)	0.23	0.14	0.68	0.01
Citharidae	*Citharus linguatula* (Linnaeus, 1758)	2.45	1.20	6.80	1.21
Scophthalmidae	*Lepidorhombus boscii* (Risso, 1810)	0.35	0.12	1.02	0.02
	Lepidorhombus whiffiagonis (Walbaum, 1792)	1.80	0.92	4.08	0.54
Soleidae	*Microchirus ocellatus* (Linnaeus, 1758)	0.12	0.15	0.34	0.00
Scorpaenidae	*Helicolenus dactylopterus* (Delaroche, 1809)	0.93	0.59	2.38	0.18
	Scopaena scrofa Linnaeus, 1758	0.35	0.21	1.02	0.03
Triglidae	*Eutrigla gurnardus* (Linnaeus, 1758)	0.23	0.27	0.68	0.02
	Lepidotrigla cavillone (Lacepède, 1801)	0.58	0.43	1.36	0.07
	Trigla lucerna Linnaeus, 1758	0.23	0.33	0.68	0.02
	Trigla lyra Linnaeus, 1758	0.58	0.28	1.36	0.06

	Trigloporus lastoviza (Bonnaterre, 1788)	1.40	1.28	4.08	0.53
Caproidae	*Capros asper* Linnaeus, 1758	0.82	0.93	2.38	0.20
Zeidae	*Zeus faber* Linnaeus, 1758	0.12	0.26	0.34	0.01
Unidentified teleosts		2.34	0.73	6.46	0.97
CHONDRICHTHYES		**0.24**	**1.15**	**0.68**	**0.03**
Rajidae	*Raja miraletus* Linnaeus, 1758	0.12	0.79	0.34	0.02
Scyliorhinidae	*Scyliorhinus canicula* (Linnaeus, 1758)	0.12	0.36	0.34	0.01
CEPHALOPODA		**3.50**	**5.79**	**7.48**	**0.90**
Octopodidae	*Scaeurgus unicirrhus* (Orbigny,1840)	0.12	0.03	0.34	0.00
Ommastrephidae	*Illex coindetii* (Verany, 1839)	0.93	1.23	2.72	0.29
	Todaropsis eblanae (Ball, 1841)	0.35	2.09	0.68	0.08
Sepiidae	*Sepia elegans* Blainville, 1827	0.58	0.27	0.34	0.01
	Sepia officinalis Linnaeus, 1758	0.12	0.08	0.34	0.00
	Sepia orbignyana Ferussac,1826	1.40	2.09	3.06	0.52
BIVALVIA		**0.36**	**$2.08\ 10^{-3}$**	**1.02**	**0.00**
Veneridae	*Circomphalus casinus* (Linnaeus, 1758)	0.12	$1.67\ 10^{-3}$	0.34	0.00
	Ruditapes decussatus (Linnaeus, 1758)	0.12	$1.85\ 10^{-4}$	0.34	0.00
Tellinidae	*Tellina albicans* Gmelin, 1791	0.12	$2.33\ 10^{-4}$	0.34	0.00
GASTROPODA		**0.12**	**0.03**	**0.34**	**0.00**
Aplysiidae	*Aplysia* sp.	0.12	0.03	0.34	0.00
CRUSTACEA		**12.24**	**3.59**	**20.75**	**6.60**
Pandalidae	*Plesionika heterocarpus* (Costa,1871)	0.12	0.01	0.34	0.00
Penaeidae	*Penaeus kerathurus* (Forsskål, 1775)	3.49	1.06	5.10	1.13
	Parapenaeus longirostris (Lucas, 1846)	7.34	2.06	11.57	5.30
Doripiidae	*Medorippe lanata* (Linnaeus, 1767)	0.12	0.07	0.34	0.00
Nephropidae	*Nephrops norvegicus* (Linnaeus, 1758)	0.12	0.01	0.34	0.00
Pseudosquillidae	*Pseudosquillopsis cerissi* (Roux, 1828)	0.12	0.06	0.34	0.00
Unidentified Crustacea		0.93	0.32	2.72	0.17
ECHINODERMATA		**0.12**	**0.19**	**0.34**	**0.01**
Diadematidae	*Centrostephanus longispinus* (Philippi,1845)	0.12	0.19	0.34	0.01
Unidentified items		**5.37**	**1.31**	**14.97**	**4.89**

were the prey species preferentially eaten by the black anglerfish (Table 1).The TROPH of black anglerfish in the Tunisian coast was 4.47 (SE = 0.52) witch indicated that *L. budegassa* is a tertiary consumer (TROPH > 4).

Diet related to sex

Of the 136 male stomach contents examined, 49 were empty (VI = 36.03%), whilst of the 280 female stomach contents examined, 73 were empty (VI = 26.07%): VI significantly differed between males and females (χ^2 = 4.72, df = 1). Three classes of preys, osteichthyans, cephalopods and crustaceans, were found in the diet of both males and females. Additionally, chondrichthyans, bivalves, gastropods and the single echinoderm species were recorded only in female stomach contents. The specific richness in female stomach contents was significantly higher than this of the males, 42 families in females *versus* 25 families in males (Table 2).

The %IRI index indicated that the main prey group was carangids for both males and females, %IRI = 50.24 and %IRI = 52.84, respectively (Table 2). The trophic level did not change with sex, it was 4.45 (SE = 0.55) for males and 4.48 (SE = 0.52) for females (χ^2 = 0.0001, df = 1).

Diet related to size

The diet of *L. budegassa* showed changes related to size (Table 3). Chondrichthyans and echinoderms were found only in the largest size class of black anglerfishs (600 < TL ≤ 700 mm). %IRI index analysis applied to all size-classes showed that osteichthyans constituted the principal prey category. However *Carangidae* were the preferential prey families in all size-classes.

The percentage of the index of relative importance (% IRI) of osteichthyans and crustaceans varied significantly between size categories (χ^2 = 422.51, df = 5). The mean number of preys per stomach was 3.00, 2.20, 3.25, 2.54, 4.40 and 3.78 for the six size-classes, respectively. Nevertheless, the average stomach content was 34.00, 30.83, 62.55, 65.21, 120.48 and 122.28 g by classes for every category of specimens, respectively.

In the three first size-classes (TL ≤ 200 mm, 200 < TL ≤ 300 mm and 300 < TL ≤ 400 mm), the feeding IRI indicated

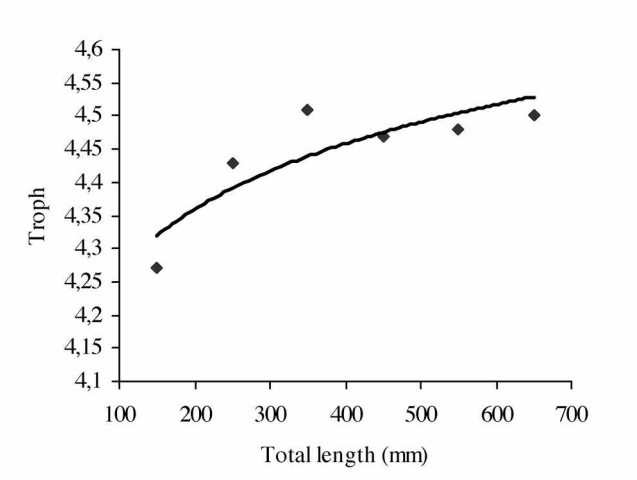
Table 2. *Lophius budegassa.* Diet composition for males and females: (%N) percentage by number, (%W) percentage by weight, (%F) percentage by occurrence and (%IRI) index of relative importance.

Tableau 2. *Lophius budegassa.* Composition du régime alimentaire des mâles et femelles : (%N) pourcentage en nombre, (%W) pourcentage en poids, (%F) pourcentage d'occurrence et (%IRI) indice d'importance relative.

	Males				**Females**			
Food items	%N	%W	%F	%IRI	%N	%W	%F	%IRI
OSTEICHTHYES	**77.37**	**90.22**	**155.18**	**85.40**	**78.36**	**87.36**	**183.83**	**91.19**
Anguillidae					0.76	0.54	2.41	0.08
Congridae	2.51	0.68	5.75	0.56	0.30	0.25	0.70	0.01
Ophichthidae	0.50	0.09	1.15	0.02	0.15	0.01	0.48	0.00
Chlorophthalmidae					0.61	0.12	1.45	0.03
Clupeidae	0.50	0.10	1.15	0.02	0.91	0.99	2.41	0.12
Gadidae	1.00	0.32	1.15	0.05	1.36	0.37	2.41	0.10
Phycidae	0.50	0.58	1.15	0.04	0.30	0.27	0.97	0.01
Merlucciidae	7.03	8.36	13.80	6.53	8.79	16.80	21.27	13.78
Macroramphosidae	1.51	0.26	1.15	0.06	1.06	0.25	2.90	0.10
Argentinidae	1.00	0.42	2.30	0.10	5.00	2.73	9.66	1.89
Callionymidae	2.01	0.64	4.60	0.37	0.15	0.03	0.48	0.00
Carangidae	18.60	27.28	35.63	50.24	21.67	25.31	44.44	52.84
Centracanthidae	4.52	6.60	10.34	3.53	4.39	5.36	11.11	2.74
Cepolidae	0.50	0.29	1.15	0.03	0.15	0.07	0.48	0.00
Mullidae	5.53	12.84	10.34	5.84	7.58	11.68	16.99	8.28
Scombridae					0.76	1.07	0.97	0.05
Serranidae	6.03	4.10	12.64	3.94	3.03	1.66	8.21	0.97
Sparidea	6.53	12.04	12.64	7.22	6.82	9.30	17.39	7.10
Trachinidae	1.51	3.64	2.30	0.36	1.21	1.84	3.86	0.30
Trichiuridae	1.00	1.25	2.30	0.16	1.82	1.55	3.38	0.29
Bothidae	0.50	0.43	1.15	0.03	0.15	0.07	0.48	0.00
Citharidae	3.01	1.56	6.90	0.97	2.27	1.12	6.76	0.58
Scophthalmidae	2.01	0.81	4.60	0.40	2.43	1.09	5.31	0.47
Soleidae					0.15	0.17	0.48	0.00
Scorpaenidae	2.51	1.89	5.75	0.78	0.91	0.55	2.41	0.09
Triglidae	5.02	4.98	10.34	3.17	2.43	2.05	6.76	0.77
Caproidae					1.06	1.14	3.38	0.19
Zeidae					0.15	0.32	0.48	0.01
Unidentified teleostes	3.54	1.06	6.90	0.98	1.99	0.65	5.80	0.39
CHONDRICHTHYES					**0.30**	**1.42**	**0.96**	**0.02**
Rajidea					0.15	0.97	0.48	0.01
Scyliorhinidae					0.15	0.45	0.48	0.01
CEPHALOPODA	**2.51**	**4.23**	**5.79**	**0.62**	**3.79**	**6.15**	**8.21**	**0.96**
Octopodidae					0.15	0.04	0.48	0.00
Ommastrephidae	1.51	2.45	3.49	0.42	1.21	3.52	3.38	0.41
Sepiidae	1.00	1.78	2.30	0.20	2.43	2.59	4.35	0.55
BIVALVIA					**0.45**	**$2.56\ 10^{-3}$**	**1.45**	**0.01**
Veneridae					0.30	$2.28\ 10^{-3}$	0.97	0.01
Tellinidae					0.15	$2.86\ 10^{-4}$	0.48	0.00
GASTROPODA					**0.15**	**0.04**	**0.48**	**0.00**
CRUSTACEA	**14.57**	**4.31**	**19.54**	**11.34**	**11.48**	**3.43**	**20.76**	**5.04**
Pandalidae					0.15	0.01	0.48	0.00
Penaeidae	14.57	4.31	19.54	11.34	9.67	2.85	15.46	4.90
Doripiidae					0.15	0.08	0.48	0.00
Nephropidae					0.15	0.02	0.48	0.00
Pseudosquillidae					0.15	0.07	0.48	0.00
Unidentified Crustacea					1.21	0.40	3.38	0.14
ECHINODERMATA					**0.15**	**0.23**	**0.48**	**0.01**
Unidentified items	**5.55**	**1.24**	**12.64**	**2.64**	**5.50**	**1.37**	**15.94**	**2.77**

Figure 2. *Lophius budegassa.* Relationship between trophic level (TROPH) and total length.

Figure 2. *Lophius budegassa.* Relation entre le niveau trophique (TROPH) et la longueur totale.



that the main prey groups were *Carangidae* with 87.30%, 54.23% and 59.85% respectively, whereas *Penaeidae* were the secondary important preys (Table 3). *Carangidae* (%IRI = 28.67), *Argentinidae* (%IRI = 21.26) and *Merlucciidae* (%IRI = 13.67) were the preferential prey families in the largest size class (Table 3). The trophic level of *L. budegassa* increased with size (Fig. 2). The relation between TROPH and size (TL, mm) was asymptotic:

$$TROPH_{Li} = 4.51\ (1\text{-}e^{-0.032Li}), \quad (3)$$

($n = 416$, $R^2 = 0.57$, $p < 0.001$)

Seasonal variation in the diet composition

Osteichthyans, mainly carangid species, were the dominant prey group during all seasons, especially in summer and autumn (%IRI > 85). Crustaceans occurred in stomach contents throughout the year, with a value maximum recorded in summer (%IRI = 9.00). Cephalopods were also present in the contents during all seasons, while bivalves were only found in winter (Table 4).

Seasonal significant differences were found for carangid species ($\chi^2 = 48.47$, df = 3). Additionally, carangid species occurred in stomach contents all year round. The TROPH of black anglerfish did not show significant changes with season; 4.38 in spring, 4.50 in summer, 4.52 in autumn, and 4.54 in winter ($\chi^2 = 0.007$, df = 3).

Discussion

The present study showed that *Lophius budegassa* from the Tunisian coast feeds mainly on osteichthyans, although crustaceans were secondary preys while chondrichthyans, gastropods, bivalves and echinoderms were of minor importance in stomach contents. This diet composition was partially in agreement with previous studies carried out in other marine areas. In the Balearic Sea, Macpherson (1979) found that black anglerfish fed on osteichthyans (77.4%) and on crustaceans (22.6%). Tsimenides (1980) noted that diet consisted of 88.0% osteichthyans, 10.0% cephalopods and 2.0% crustaceans in the Greek waters. Preciado et al. (2006) showed that the diet *L. budegassa* from the Cantabrian Sea (North Atlantic coast of Spain) comprised osteichthyans, crustaceans and a single cephalopod species. However, *Lophius* spp from both Atlantic and Mediterranean Sea are considered as ichthyophagous predator (Macpherson, 1979; Tsimenides, 1980; Crozier, 1985; Laurenson & Priede, 2005; Preciado et al., 2006). The large spectrum of prey groups and species recorded in Tunisian black anglerfish stomachs suggests that the species could be an opportunist feeder seeking for preys at different trophic levels, including pelagic and benthic organisms, and a wide range of prey size and morphology.

In this study, the proportion of empty stomachs was low during all years; this suggests that *Lophius budegassa* from the Tunisian coast was an active feeder, probably due to the zoological environment richness of the Tunisian marine waters (Azzouz, 1971; Bradaï, 2000; Bradaï et al., 2004). Similar patterns were found in the area for the sandbar shark, *Carcharhinus plumbeus* (Nardo, 1827) by Saïdi et al. (2007). In contrast, Preciado et al. (2006) noted 52.48% of empty stomachs in *L. budegassa* from the Cantabrian Sea, Fulton (1903) and Crozier (1985) found 48% and 40% in the white anglerfish *L. piscatorius* off Scotland and from the northern Irish Sea, respectively. Additionally, Armstrong et al. (1996) found 91% of stomachs containing food in small *L. americanus* off New England coast, *versus* 54-58% in larger specimens: this phenomenon maybe due to fact that the former requested food in relation with a rapid growth during this period of their life (Armstrong et al., 1992), while the latter presented infrequent periods of feeding (Wilson, 1937; Tsimenides, 1980).

The feeding intensity of *L. budegassa* from the Tunisian coast showed seasonal variations with a significant decrease in winter. Firstly, it could have been due to the higher percentage of empty stomachs found in winter. Secondly, it could also have been related to the dominance of preys in the area at this time of year. However feeding intensity of other species of Lophiidae showed considerable variation throughout the year (Crozier, 1985; Kosaka, 1966; Laurenson & Priede, 2005).

In our sample, largest specimens of black anglerfish fed significantly more than smallest sized specimens. In contrast, Laurenson & Priede (2005) found that in *L. piscatorius* from the Shetland Islands (UK), feeding rate decreased with size increasing. However, the prey spectrum

Table 3. *Lophius budegassa.* Diet composition for each size-class: (%N) percentage by number, (%W) percentage by weight, (%F) percentage by occurrence and (%IRI) index of relative importance.

Tableau 3. *Lophius budegassa.* Composition du régime alimentaire : (%N) pourcentage en nombre, (%W) pourcentage en poids, (%F) pourcentage d'occurrence et (%IRI) indice d'importance relative.

Food items	**TL < 200** % IRI	**200 < TL ≤ 300** % IRI	**300 < TL ≤ 400** % IRI	**400 < TL ≤ 500** % IRI	**500 < TL ≤ 600** % IRI	**600 < TL ≤ 700** % IRI
OSTEICHTHYES	**87.30**	**82.46**	**91.55**	**90.44**	**92.19**	**90.38**
Anguillidae			0.01	0.35	0.06	
Congridae		0.44	0.12			
Ophichthidae		0.02		0.02		
Chlorophthalmidae			0.06			0.38
Clupeidae		0.30	0.14		0.11	
Gadidae			0.68			
Phycidae		0.05	0.07			
Merlucciidae		7.32	7.19	19.38	11.10	13.67
Macroramphosidae		0.03	0.01	0.30	0.17	0.38
Argentinidae		0.12	1.32	0.39	1.95	21.26
Callionymidae		0.26		0.10		
Carangidae	87.30	54.23	59.85	41.88	35.90	28.67
Centracanthidae		6.10	3.65	0.50	1.12	8.60
Cepolidae		0.14				
Mullidae		1.31	6.69	6.90	30.08	3.03
Scombridae			0.08	0.06		
Serranidae		2.20	0.22	2.68	4.36	0.49
Sparidea		1.41	7.30	16.00	2.88	7.98
Trachinidae		0.96	0.06	0.20	0.54	0.61
Trichiuridae		0.49	0.42	0.06		2.66
Bothidae			0.01		0.07	
Citharidae		0.93	1.03	0.44	0.34	
Scophthalmidae		0.28	0.31	0.50	2.02	1.65
Soleidae				0.04		
Scorpaenidae		1.42	0.19			0.61
Triglidae		1.65	1.60	0.59	0.69	
Caproidae		0.11	0.05	0.03	0.68	
Zeidae			0.03			
Unidentified teleosts		2.69	0.46	0.02	0.12	0.39
CHONDRICHTHYES						**2.86**
Rajidae						1.84
Scyliorhinidae						1.02
CEPHALOPODA		**0.60**	**1.36**	**0.45**	**1.79**	**1.06**
Octopodidae					0.06	
Ommastrephidae		0.26	0.18	0.28	1.73	
Sepiidae		0.34	1.18	0.17		1.06
BIVALVIA				**0.10**		
Veneridae				0.08		
Tellinidae				0.02		
GASTROPODA					**0.06**	
CRUSTACEA	**12.70**	**15.10**	**5.47**	**4.14**	**1.47**	**4.64**
Pandalidae			0.01			
Penaeidae	12.70	14.87	5.44	3.84	1.40	4.20
Doripiidae				0.03		
Nephropidae			0.01			
Pseudosquillidae			0.01			
Unidentified Crustacea		0.23		0.27	0.07	0.44
ECHINODERMATA						**0.69**
Unidentified items		**1.84**	**1.62**	**4.87**	**4.49**	**0.39**

Table 4. *Lophius budegassa.* Seasonal changes of diet based on the %IRI values of major prey groups.

Tableau 4. *Lophius budegassa.* Variations saisonnières du régime alimentaire fondées sur les valeurs de l'IRI des principaux groupes de proies.

Prey items	Winter % IRI	Spring % IRI	Summer % IRI	Autumn % IRI
Osteichthyes	84.84	79.50	85.55	92.56
Chondrichthyes	0.36	0.11		
Cephalopods	0.19	0.79	3.27	0.15
Bivalves	0.16			
Gastropods		0.04		
Crustaceans	1.10	6.97	8.99	6.52
Echinoderms			0.03	

of *L. budegassa* showed a little seasonal variation. However, carangid species formed the main preys throughout the year; this is consistent with their abundance in the area (Ben Salem, 1990; Bradaï *et al*., 2004).

A *L. budegassa* preference for carangids can not be totally excluded; for instance, Wilson (1937) noted that *L. piscatorius* placed in captivity showed a marked preference for osteichthyan species such as gadids, clupeids and flat-fishes. In addition, Gordoa & Macpherson (1990) investigated prey selection by the monkfish, *L. upsicephalus* from Namibian waters and noted that cannibalism was relatively important. Similar patterns were reported by Armstrong et al. (1996) in *L. americanus*, who added that predation by older conspecifics is the most common type of cannibalism reported in teleost species (see Smith & Reay, 1991).

Following the classification of fishes in functional groups based on trophic levels (TROPH, see Stergiou & Karpouzi, 2002), black anglerfish is a carnivore species with preference to large decapods, cephalopods and fish. Stergiou & Karpouzi (2002) assigned a trophic level of 3.90 to *L. budegassa* preying on fish and crustaceans, and 4.40 to black anglerfish feeding on fish, cephalopods and crustaceans.

TROPH value of black anglerfish is higher than those estimated for sharks which generally ranged between 3.10 and 4.70 (Cortés, 1999), and many marine mammals, which generally ranged between 3.20 and 4.50 (Pauly et al., 1998) with members of both groups being considered as top predators. These results generally suggest that the black anglerfish utilizes similar resources as other high-level marine consumers.

References

Armstrong M.P., Musick J.A. & Colvocoveresses J.A. 1992. Age, growth and reproduction of the goose fish *Lophius americanus* (Pisces: Lophiiformes). *Fishery Bulletin of the United States*, **90**: 217-230.

Armstrong M.P., Musick J.A. & Colvocoveresses J.A. 1996. Food and ontogenic shifts in feeding of the goosefish, *Lophius americanus*. *Journal of the Northwest Atlantic Fishery Science*, **18**: 99-103.

Azzouz A. 1971. Etude des biocénoses benthiques et de la faune icthyologique des fonds chalutables de la Tunisie. Thesis. Faculté des Sciences de Caen, France, 143 pp.

Azevedo M. 1996. Studying the feeding habits of Anglerfish (*Lophius* spp.) in Portuguese waters: a qualitative approach. *International Council for the Exploration of the Sea (CM Papers and Reports)*, *CM* 1996/G:19, 9 pp.

Ben Salem M. 1990. Révision du genre *Trachurus* Rafinesque, 1810. Biologie et génétique des espèces tunisiennes. Thesis. Faculté des Sciences de Tunis, Tunisie, 351 pp.

Bradaï M.N. 2000. Diversité du peuplement icthyque et contribution à la connaissance des sparidae du golfe de Gabès. Thesis. Faculté des Sciences de Sfax, Tunisie, 600 pp.

Bradaï M.N., Quignard J.P., Bouain A., Jarboui O., Ouannes-Ghorbel A., Ben Abdallah L., Zaouali J. & Ben Salem S. 2004. Ichtyofaune autochtone et exotique des côtes tunisiennes : Recensement et biogéographie. *Cybium,* **28**: 315-328.

Chadwick H.C. 1929. Feeding habits of the angler fish, *Lophius piscatorius*. *Nature*, **124**: 337.

Cortés E. 1999. Standardized diet compositions and trophic levels of sharks. *ICES Journal of marine science*, **56**: 707-717.

Crozier W.W. 1985. Observations on the food and feeding of the angler-fish, *Lophius piscatorius* L., in the northern Irish Sea. *Journal of Fish Biology,* **27**: 655-665.

Dieuzeide R., Novella M. & Roland J. 1954. Catalogue des poissons des côtes algériennes. *Bulletin de la Station d'Aquiculture et de Pêche de Castiglione,* **6**: 1-384.

Fischer W., Bauchot M.L. & Schneider M. 1987. Fiches FAO d'identification des espèces pour les besoins de la pêche (Révision.1). Méditerranée et Mer Noire. Zone de pêche 37. Vol. I & II. Rome FAO. 1530 pp.

Fulton T.W. 1903. The distribution, growth and food of the angler (*Lophius piscatorius*). *Twenty-first Annual Report of Fishery Board for Scotland,* **3**: 187-217.

Gordoa A. & Macpherson E. 1990. Food selection by a sit-and-wait predator, the monkfish, *Lophius upsicephalus*, off Namibia (South West Africa). *Environmental Biology of Fishes,* **27**: 71-76.

Hacunda J.S. 1981. Trophic relationships among demersal fishes in coastal area of the Golf of Main. *Fisheries Bulletin,* **79**: 775-788.

Hureau J.C. 1970. Biologie comparée de quelques poissons antarctiques (*Notothenidae*). *Bulletin de l'Institut Océanographique de Monaco*, **68**: 1-244.

Kosaka M. 1966. Feeding habits of anglerfish, *Lophius litulon. Journal of the Faculty of Oceanography,* **1**: 49-70.

Laurenson C.H. & Priede I.G. 2005. The diet and trophic ecology of anglerfish *Lophius piscatorius* at the Shetland Islands, UK. *Journal of the Marine Biological Association of the United Kingdom,* **85**: 419-424.

Macpherson E. 1979. Relations trophiques des poissons dans la Méditerranée occidentale. *Rapport de la Commission Internationale pour l'Exploration scientifique de la Mer Méditerranée,* **25/26**: 49-58.

Pauly D. & Christensen V. 2000. Trophic levels of fishes. In: Fishbase 2000: Concepts, design and Data Sources, (R. Froese. & D. Pauly eds), pp. 181. Manila: ICLARM.

Pauly D., Froese R., Sa-a P.S., Palomares M.L., Christensen V. & Rius J. 2000. TrophLab Manual. ICLARM, Manila.

Pauly D. & Palomares M.L. 2000. Approaches for dealing with three sources of bias when studying the fishing down marine food web phenomenon. In: *Fishing Down the Mediterranean Food Webs?* (F. Briand ed.). *CIESM Workshop Series,* **12**: 61-66.

Pauly D., Trites A., Capuli E. & Christensen V. 1998. Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Science*, **55**: 467-481.

Pinkas L., Oliphant M.S. & Iverson I.L.K. 1971. Food habits of albacore, blue-fin tuna, and bonito in California waters. *Fish Bulletin of California,* **152**: 1-105.

Preciado I., Velasco F., Olaso I. & Landa J. 2006. Feeding ecology of black anglerfish *Lophius budegassa*: seasonal, bathymetric and ontogenetic shifts. *Journal of the Marine Biological Association of the United Kingdom,* **86**: 877-884.

Quignard J.P. & Tomasini J.A., 2000. Mediterranean fish biodiversity. *Biologia marina Mediterranea*, **7**: 1-66.

Rosecchi E. & Nouaze Y. 1987. Comparaison de cinq indices alimentaires utilisés dans l'analyse des contenus stomacaux. *Revue de l'Institut des Pêches maritimes,* **49**: 111-123.

Saïdi B., Bradaï M.N., Bouaïn A. & Capapé C. 2007. Feeding habits of the sandbar shark *Carcharhinus plumbeus* (Chondrichthyes: Carcharhinidae) from the Gulf of Gabès, Tunisia. *Cahiers de Biologie Marine*, **48**: 139-144.

Smith C. & Reay P. 1991. Cannibalism in teleost fish. *Reviews in Fish biology and Fisheries,* **1**: 41-64.

Sokhal R.R. & Rohlf F.J. 1987. *Biometry*. Freeman: San Francisco, Ca. 859 pp.

Stergiou K.I. & Karpouzi V.S. 2002. Feeding habits and trophic levels of Mediterranean fish. *Reviews in Fish biology and Fisheries*, **11**: 217-254.

Tsimenides N. 1980. Contribution to the study of the anglerfishes *Lophius budegassa* Spinola, 1807 and *L. piscatorius* L. 1758 in Greek seas. *Special Publication of the Institute of Oceanography and Fisheries Research,* **4**: 1-190.

Ungaro N., Marano G., Auteri R., Voliani A., Massutí E., García-Rodríguez M. & Osmani K. 2002. Distribution, abundance and biological features of anglerfish (*Lophius piscatorius* and *Lophius budegassa*) (Osteichthyes: Lophiiformes) in the Mediterranean Sea. *Scientia Marina*, **66** (Suppl. 2): 55-63.

Wilson D.P. 1937. The habits of the anglerfish, *Lophius piscatorius*, in the Polymouth Aquarium. *Journal of the Marine Biological Association of the United Kingdom,* **21**: 477-496.

Zander C.D. 1982. Feeding ecology of littoral gobiid and blennioid fish of the Banyuls area (Mediterranean Sea). Item Main Food and trophic dimension of niche and ecotope. *Vie et Milieu,* **32**: 1-10.