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OVERVIEW OF TROPHIC LEVELS RECORDED IN TELEOST SPECIES FROM NORTHERN TUNISIAN WATERS (CENTRAL MEDITERRANEAN SEA)

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ABSTRACT

This paper reports about the observations made with regard to 21 teleost species comprising 1657 specimens from the northern Tunisian coast. These specimens were found in an area with sufficient prey species to allow them to live and develop, as confirmed by the size to total body weight relationship. The high values of vacuity index are probably due to both sampling and fishing methods. Crustaceans and teleosts are the prey most frequently consumed by these species. Additionally, the high trophic levels (TROPH) (± 3.00) indicated that these teleost species belong among carnivores. Of all the species examined, only one, Sarpa salpa *with TROPH = 2.00, was found to be herbivorous.*

Key words: Teleost species, trophic level, vacuity index, relation the total length *vs* the total body weight, competition for food, Tunisian coast

REVISIONE DEI LIVELLI TROFICI DI SPECIE DI TELEOSTEI IN ACQUE TUNISINE SETTENTRIONALI (MEDITERRANEO CENTRAE)

SINTESI

L'articolo riporta le osservazioni fatte su 21 specie di teleostei comprendenti 1657 esemplari provenienti dalla costa settentrionale tunisina. Gli esemplari sono stati trovati in un'area con una quantità di prede sufficiente per consentire loro di vivere e svilupparsi, come confermato dal rapporto tra le dimensioni corporee e il peso corporeo totale. Gli alti valori dell'indice di vacuità sono probabilmente dovuti sia al campionamento che ai metodi di pesca. Crostacei e teleostei sono le prede più frequentemente consumate da queste specie. Gli alti livelli trofici (TROPH) (± 3,00) hanno inoltre evidenziato che tali specie di teleostei sono carnivore. Di tutte le specie esaminate solo una, Sarpa salpa*, con TROPH = 2,00, è risultata erbivora.*

Parole chiave: teleostei, livello trofico, indice di vacuità, relazione tra lunghezza totale e peso corporeo totale, competizione alimentare, costa tunisina

INTRODUCTION

Fishery and aquaculture are believed to play an important role in Tunisian economy, which explains why studies related to these patterns have been the subject of several papers (see Bradaï, 2000; Rafrafi-Nouira, 2016). The entire Tunisian coast, including lagoons, has been continuously investigated since Vinciguerra (1882) to assess, in qualitative and quantitative terms, the status and the biodiversity of local ichthyofauna. Several studies focused on fish species occurring in northern areas (Castany, 1955; Ben Mustapha, 1966; Lubet & Azzouz, 1969; El Kamel-Moutalibi, 2014; Mnasri-Sioudi, 2014; Rafrafi-Nouira, 2016).

The aim of this paper is to point out the interrelationships between fish species caught off Ras Jebel and its closely related areas, and their potential preys. Thus, the trophic levels were determined for some species of commercial interest commonly observed in fish markets. Following Stergiou & Karpouzi (2002), estimation of trophic level plays a major role in monitoring fishery resources and their effect on ecosystems. Additionally, following Froese *et al.* (2011), the size *versus* total body weight relationship was calculated for each species to point out if they found sufficient food in the wild to live and develop.

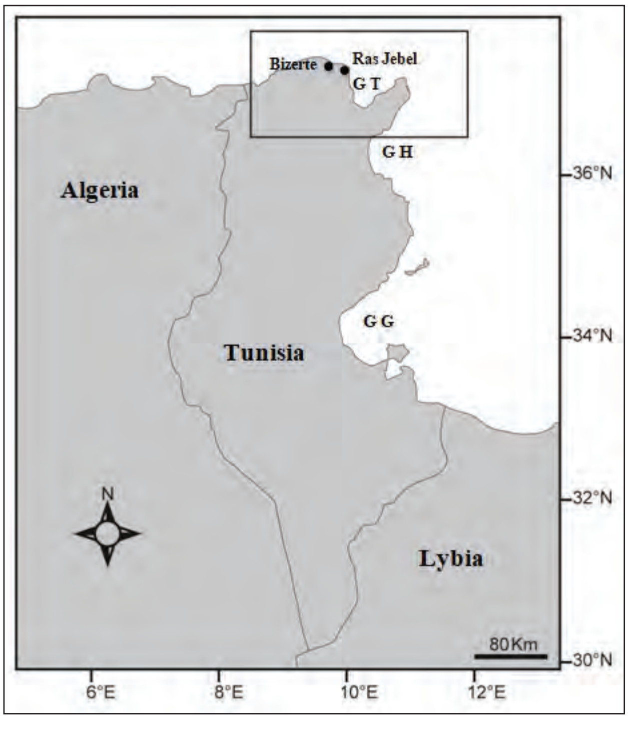

Fig. 1: Map of Tunisia indicating the capture area (rectangle) of 21 teleost species from the northern Tunisian coast. GT: Gulf of Tunis; GH: Gulf of Hammamet; GG: Gulf of Gabès.
Sl. 1: Zemljevid Tunizije z označeno lokaliteto (pravokotnik) ulova 21 vrst kostnic ob severni tunizijski obali. GT: Tuniški zaliv; GH: Hamameški zaliv; GG: Gabeški zaliv.

MATERIAL AND METHODS

Of the 124 fish species captured in northern Tunisian waters, 21 teleost species were targeted, comprising 1657 specimens sampled for this study between 2010 and 2015. According to the information provided by experienced local fishermen, the specimens were collected throughout the year off the northern and northeastern Tunisian coast, including the Gulf of Tunis (Fig. 1), by commercial fishing vessels using trawl over sandy and muddy bottoms, and gill nets and longlines on rocky bottoms, at depths ranging from 50 to 200 m. Each sampled specimen was identified using books and field guides, such as Whitehead *et al.* (1984-1986), Louisy (2002) and Quéro *et al.* (2003). All fresh specimens were delivered to the laboratory, where they were measured for total length (TL) to the nearest millimetre and weighed for total body weight (TBW) to the nearest gram.

For each specific sample the Shapiro–Wilk's test of normality was performed, with $P < 0.05$. The Chi-square test was used to determine significance ($P < 0.05$). The total length (TL) to total body weight (TBW) relation was used to complement the feeding studies following Froese *et al.* (2011). This relationship is $TBW = aTL^b$, and was converted into its linear regression, expressed in decimal logarithmic coordinates, and correlations were assessed by least-squares regression. Like so: $\log TBW = \log a + b \log TL$. Significance of constant b differences was assessed to the hypotheses of isometric growth if $b = 3$, positive allometry if $b > 3$, and negative isometry if $b > 3$ (Pauly, 1983). Comparison of means was carried out using ANOVA. These two latter tests were performed using the STAT VIEW 5.0 logistic model.

Once the fresh specimens were collected, their stomach contents were immediately removed by dissection, sorted and identified to the lowest taxonomic level (species level where possible), using taxonomic keys and field guides (Perrier 1964, 1975, Louisy, 2002). The prey items were counted and weighed to the nearest decigram after removal of surface water by blotting them with tissue paper. When prey items found in the stomachs were incomplete, the prey count was based on the number of different typical parts, such as beaks for cephalopods, claws and legs for crustaceans, carapaces for decapod crabs, shell and foot for bivalves, operculum and shell for gastropods, and the whole vertebral column and otoliths for teleost species. We assumed two or more prey species if the legs of crustaceans were different in size and shape, and a single prey species if they were very similar. The same methodology was used for determining vegetal preys. Preys not identified in the laboratory were preserved in 10% buffered formalin to be subsequently examined by specialists.

The analyses of food composition and feeding habits of these 21 species were based on the following indices suggested by Hureau (1970), Hyslop (1980) and Rosecchi & Nouaze (1987). The food composition and feeding habits of *C. conger* were studied using the following indices suggested by Hyslop (1980):

- Vacuity Index, VI = number of empty stomachs/ total number of stomachs x 100;
- Mean number of prey per stomachs: MN = total number of prey ingested/total number of full stomachs;
- Percentage of numerical abundance: %N = (number of prey item *i*/total number of prey) x 100;
- Percentage in weight: %W = (weight of prey item *i*/total weight of all prey) x 100;
- Percentage of frequency of occurrence: %F = (number of stomachs containing prey item *i*/total number of full stomachs) x 100.

The trophic level (TROPH) of each species area was calculated using TrophLab (Pauly *et al.*, 2000), a standalone Microsoft Access routine for estimating trophic levels, downloadable from FishBase (Froese & Pauly, 2014). Statistical differences ($P < 0.05$) in basic diet composition as a function of size and season were established by applying the Chi-square test (Sokhal & Rohlf, 1987).

The trophic level for any consumer species *i* is

$$troph = 1 + \sum_{j=1}^{G} DC_{ij} \cdot troph_j$$

where Troph*j* is the fractional trophic level of prey *j*, DC*ij* is the fraction of *j* in the diet of *i*, and G is the total number of prey species (Pauly *et al*., 1998; Pauly & Christensen, 2000; Pauly & Palomares, 2000):

All categories of preys identified in the present study were used to evaluate the trophic level of each teleostean species.

Following Stergiou & Karpouzi (2002), the trophic level values ranging from 2.0 to 4.5 and 3 categories of species were taken into consideration: pure herbivores = 2.0–2.1, omnivores with a preference for vegetable material = 2.1–2.9, omnivores with a preference for animal preys 2.9–3.7, carnivores feeding exclusively on animal preys =3.7–4.5.

RESULTS

All data recorded and calculated in the present paper are summarized in Table 1. The TL-TBW relationships revealed positive allometry in 13 species, low negative allometry in 3 species, and negative allometry in 5 species. The lowest negative allometry was recorded in *Dicentrarchus labrax* with *b*=1.23.

The vacuity index (VI) reached high values in 16 species, low values in 5 species, and in a single species, *Sarpa salpa*, it equalled 0.00. In this species, all the stomachs observed contained food or remains of food already described in materials and methods.

Overall, the two important zoological groups found in the guts were crustaceans and teleosts. Both groups were found together in 11 species, while teleosts were present in 20 species altogether. A single species, *S. salpa*, did not consume such preys, rather foraging for algae and seagrass. Among other groups also found in the stomach contents, cephalopods, annelids and sipunculids were the most frequent.

The trophic level (TROPH) reached high values - *i.e.*, close to or higher than 3.00 - in 16 species. Conversely, it displayed low values in 5 species: *Dentex dentex* (2.37), *Diplodus annularis* (2.57), *D. puntazzo* (2.24), *D. vulgaris* (2.73), which belong among omnivorous species, and in *S. salpa* (2.00), which is a pure herbivorous species. The TROPH of species caught in Tunisian waters is generally close to the data recorded by Stergiou and Karpouzi (2002), except in those concerning sparid species, which ranged between 3.80 and 4.50.

DISCUSSION

The size (TL) *versus* total body weight relationships exhibited positive allometry for most of the species studied in the present paper, indicating that they found in the wild sufficient prey to be able to live and develop in this area. The northern coast of Tunisia revealed high biodiversity, including potential prey species belonging to several zoological groups (Rafrafi-Nouira, 2016). All species presented herein are targeted by fishermen for local consumption or export, which enhances their commercial interest and increases their value for the local economy. Conversely, only 7 species displayed negative allometry, which phenomenon could be explained by sampling hazards, but competitive pressure for food, which reduces the availability of prey familiar to certain species, cannot be totally ruled out either.

Conversely, the vacuity index (VI) displayed high values in most species, which could be explained by the non-availability of prey in the wild despite the local biodiversity richness. Such a pattern could also be the result of sampling periods, and the availability of certain prey could vary according to the season (Rafrafi-Nouira, 2016). Sampling methods and use of fishing gears cannot be totally excluded either (Sallami *et al*., 2014; Rafrafi-Nouira *et al*., 2016). All specimens sampled off the northern Tunisian coast were caught by trawling and generally spent considerable time in nets prior to being landed, therefore certain prey was completely digested and the stomachs of predators were thus found empty when analysed. This hypothesis is corroborated by the digested remains of prey found in the stomach contents

Tab. 1: Parameters recorded in 21 teleost species collected from the northern coast of Tunisia. * Data from Sellami et al. (2015); ** Data from Rafrafi-Nouira et al. (2015); VI: vacuity index; C: crustaceans; T: teleosts; OG: other groups. TROPH 2: data from Stergiou & Karpouzi (2002).

Tab. 1: Izračunani parametri za 21 vrst kostnic, ujetih ob severni tunizijski obali. * Podatki iz vira Sellami et al. (2015); ** Podatki iz vira Rafrafi-Nouira et al. (2015); VI: indeks polnosti; C: raki; T: kostnice; OG: druge skupine. TROPH 2: podatki iz Stergiou & Karpouzi (2002).

Species	Total length (TL) vs total body weight (TBW)	%VI	C	T	OG	TROPH 1	TROPH 2
Gnathophis mystax (Delaroche, 1809) *	log TBW = – 5.88 + 3.09log TL, n = 48, r = 0.96	60.41	+	+	+	3.51	3.55
Belone belone (Linnaeus, 1758)	log TBW = – 5.79 + 2.94log TL, n =13, r = 0.97	69.23	-	+	-	4.50	-
Epinephelus marginatus (Lowe, 1834)	log TBW = – 5.14 + 3.11 log TL, n = 20, r = 0.99	65.00	+	+	+	3.51	4.13
Serranus scriba (Linnaeus, 1758)	log TBW = – 5.17 + 3.13 log TL, n = 76, r = 0.98	21.05	+	+	+	3.27	3.70
Dicentrarchus labrax (Linnaeus, 1758)	log TBW = – 0.58 + 1.23 log TL, n = 16, r = 0.91	75.00	+	+	-	4.20	-
Sciena umbra (Linnaeus, 1758)	log TBW = – 5.32 + 3.15 log TL, n = 63, r = 0.98	69.84	+	+	+	3.41	3.80
Dentex dentex (Linnaeus, 1758)	log TBW = – 4.34 + 2.75 log TL, n = 16, r = 0.97	81.25	+	+	+	2.37	4.50
Diplodus annularis (Linnaeus, 1758)	log TBW = – 3.88 + 2.58 log TL, n = 120, r = 0.96	70.45	+	+	-	2.57	3.40
Diplodus puntazzo (Cetti, 1777)	log TBW = – 4.77 + 2.98log TL, n = 31, r = 0.99	56.10	-	+	+	2.24	3.30
Diplodus sargus (Linnaeus, 1758)	log TBW = – 4.89 + 3.04log TL, n = 58, r = 0.98	23.07	+	+	+	3.09	3.38
Diplodus vulgaris (Linnaeus, 1758)	log TBW = – 4.89 + 3.02 log TL, n = 112, r = 0.96	94.00	-	+	+	2.73	3.70
Lithognathus mormyrus (Linnaeus, 1758)	log TBW = – 5.16 + 3.10 log TL, n = 43, r = 0.96	93.02	-	+	-	3.50	3.50
Oblada melanura (Linnaeus, 1758)	log TBW = – 5.18 + 3.11 log TL, n =32, r = 0.98	68.75	-	+	-	2.80	3.10
Sarpa salpa (Linnaeus, 1758)	log TBW =– 4.93 + 3.03 log TL, n =109, r = 0.93	0.00	-	-	+	2.00	2.50
Sparus aurata Linnaeus, 1758	log TBW = – 4.69 + 2.91 log TL, n = 80, r = 0.98	37.5	+	+	+	3.81	3.42
Labrus merula Linnaeus, 1758	log TBW = – 5.49 + 3.27 log TL, n =51, r = 0.99	80.40	+	+	-	3.20	3.47
Labrus viridis Linnaeus, 1758	log TBW = – 3.79 + 2.53 log TL, n = 65, r = 0.97	65.00	-	+	+	3.38	3.84
Symphodus melops (Linnaeus, 1758)	log TBW = –5.05 + 3.12 log TL, n = 68, r = 0.97	76.19	-	+	+	3.26	-
Symphodus tinca (Linnaeus, 1758)	log TBW = – 5.16 + 3.10 log TL, n =42, r = 0.97	68.96	-	+	+	3.32	3.26
Chelon labrosus (Risso, 1827)	log TBW = – 4.09 + 2.61 log TL, n =14, r = 0.89	95-94	-	+	-	3.50	-
Scorpaena porcus Linnaeus, 1758 **	log TBW = – 4.60 + 3.09 log TL, n =715, r = 0.96	41.11	+	+	+	3.48	3.82

which remained unidentifiable. Similar patterns were observed in previous studies about food and feeding habits of species from northern Tunisian waters (Mnasri *et al.*, 2012; El Kamel-Moutalibi *et al.*, 2013; Sallami *et al.*, 2014; Rafrafi-Nouira *et al.*, 2016).

Two zoological groups prevailed in the stomach contents: crustaceans and osteichthyans, thus confirming previous observations concerning other species inhabiting the same marine areas (Rafrafi-Nouira, 2016). Similarly, other preys were found, such as cephalopods, annelids, bivalves, and echinoderms, the number and weight of these animals depending on the species, and on the prey and predator sizes. Additionally, ontogenic changes were probably related to the biological environment and therefore prey availability.

The trophic levels of the 21 sampled species from northern Tunisian waters are similar to those estimated by Stergiou & Karpouzi (2002). Of these species, 17 could be considered top predators playing an important role in the regulation of the local marine ecosystem. Inter- and intraspecific competitive pressure for food cannot be completely avoided, which was probably the case with the sparid species, which occupied a lower TROPH level than other species, as sea grass and algae were recorded in their guts. Such findings could be considered as occasional or at least the result of a local abundance of marine plants that fishes would feed on in addition to other prey items. *S. salpa* is the best example of the effect of such abundance, as indicated by its low TROPH = 2.00 and VI = 0.00; namely, large amounts of algae and seagrass were found in the guts of the examined specimens throughout the year.

The study of food and feeding habits presented in this paper not only showed that viable populations of several animal species occurred in the area, but also enhanced the knowledge of local biodiversity. However, monitoring of fishery activities following recommendations and suggestions included in CIESM (2018) should be carried out to avoid drastic declines of populations, as was the case in other marine areas throughout the Mediterranean Sea.

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PREGLED TROFIČNIH NIVOJEV PRI RIBAH KOSTNICAH VZDOLŽ SEVERNOTUNIZIJSKIH VODA (OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

V prispevku avtorji poročajo o rezultatih, ki se nanašajo na 1657 primerkov rib kostnic, ujetih vzdolž severnotunizijske obale, ki pripadajo 21 vrstam. Primerki so bili ujeti v okolju, bogatem s plenom, kar je razvidno iz odnosa med velikostjo in telesno maso. Visoke vrednosti indeksa polnosti prebavila so verjetno posledica vzorčevalnih in ribiških metod. Najbolj pogosti skupini plena so raki in kostnice. Poleg tega visoki trofični nivo (TROPH) (± 3.00) potrjuje, da so obravnavane kostnice predvsem plenilke. Med vsemi obravnavanimi vrstami je le salpa rastlinojeda (TROPH = 2.00).

Ključne besede: kostnice, trofični nivo, indeks polnosti, odnos med telesno dolžino in maso, kompeticija za hrano, obala Tunizije

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