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DIET COMPOSITION AND FEEDING STRATEGY OF ATLANTIC CHUB MACKEREL *SCOMBER COLIAS* IN THE ATLANTIC COAST OF MOROCCO

Nadia BOUZZAMMIT
Ibn Zohr University, Faculty of Sciences, Laboratory of Aquatic Systems: Marine and Continental Environments, P.O. Box 8106 - Dakhla Avenue, Agadir, Morocco
e-mail: nadia.bouzzammit@edu.uiz.ac.ma

Hammou EL HABOUZ
National Institute of Fisheries Research, Anza, Agadir, Morocco

El hassan AIT-TALBORJT, Zahra OKBA & Hassan EL OUIZGANI
Laboratory of Aquatic Systems: Marine and Continental Environments, P. O. Box 8106, Faculty of Sciences, Ibn Zohr University Dakhla Avenue, Agadir, Morocco

ABSTRACT

*The diet composition and feeding strategy of the Atlantic chub mackerel (*Scomber colias*) were studied in the Atlantic coast of Morocco in the winter of 2017. A total of 330 stomach contents of* S. colias *were examined. The study of the vacuity index indicated high feeding activity of* S. colias *in Safi (SF) (2%), and Laayoune (LA) (6%). However, low feeding activity was shown in El Jadida (JD) (25%) and Agadir (AG) (20%). The analysis of the diet composition of studied populations led to identifying 22 items. The most abundant prey was fish with high importance index, followed by copepods in three localities (AG, SF, and LA), where the dominant preys in El Jadida (JD) were crustaceans and mysids with a high importance index.* S. colias *is a carnivorous fish and a ferocious fish predator. We recorded several cases of cannibalism among the studied populations.*

Key words: Diet, *Scomber colias*, stomach contents, vacuity index, cannibalism

COMPOSIZIONE DELLA DIETA E STRATEGIA ALIMENTARE DELLO SGOMBRO OCCHIONE *SCOMBER COLIAS* LUNGO LA COSTA ATLANTICA DEL MAROCCO

SINTESI

*La composizione della dieta e la strategia alimentare dello sgombro occhione (*Scomber colias*) sono state studiate lungo la costa atlantica del Marocco nell'inverno del 2017. Sono stati esaminati 330 contenuti stomacali di* S. colias. *Lo studio dell'indice di vacuità ha indicato un'elevata attività alimentare di* S. colias *a Safi (SF) (2%) e Laayoune (LA) (6%). Tuttavia, è stata evidenziata una bassa attività alimentare a El Jadida (JD) (25%) e Agadir (AG) (20%). L'analisi della composizione della dieta delle popolazioni studiate ha portato all'identificazione di 22 elementi. La preda più abbondante sono stati i pesci, con un alto indice di importanza, seguiti dai copepodi in tre località (AG, SF e LA), mentre le prede dominanti a El Jadida (JD) sono state i crostacei e i misidi, con un alto indice di importanza.* S. colias *è un pesce carnivoro e un feroce predatore di pesci. Abbiamo registrato diversi casi di cannibalismo tra le popolazioni studiate.*

Parole chiave: dieta, *Scomber colias*, contenuto stomacale, indice di vacuità, cannibalismo

INTRODUCTION

The Atlantic chub mackerel *Scomber colias* (Gmelin, 1789) is an epipelagic to mesopelagic species observed over the continental slope in warm and temperate waters between 0-250 to 300 m (Collette & Nauen, 1983; (Čikeš Kec & Zorica, 2012)). It is widely distributed in the Atlantic Ocean of Northwest Africa including the Eastern Atlantic (the Canary and Azore Islands) to the Bay of Biscay, in the Mediterranean Sea, and the adjacent waters, such as the Black Sea (Collette & Nauen, 1983; Navarro *et al*., 2012). The Atlantic chub mackerel occupies a key position in the trophic web and is considered to be the link between the primary producers and the higher trophic levels. Thus, it is an important prey for large pelagic fish (tuna, sharks) and marine mammals (dolphins) (Velasco *et al*., 2011; Machado *et al*., 2022). The quantity of food available and the interaction between fish using the same food source represent the key factors that influence the size (length-weight) of fish. Hence, the length-weight relationship is an important biological parameter that provides information about the growth, health, habitat conditions, gonad maturity, life history, and fatness of a fish species (Froese, 2006; Froese *et al*., 2011; Jisr *et al*., 2018), and is helpful in comparing life histories and morphological aspects of populations inhabiting different habitats (Cherif *et al*., 2008, Hashemzadeh *et al*., 2015, Bouzzammit *et al*., 2019).

The analysis of the composition of stomach contents and dietary patterns can be used to assess habitat preferences, prey selection, effects of ontogenesis, and the development of conservation strategies (Chakraborty *et al*., 2019; Mishra, 2020). Besides providing important insights into ecological and biological aspects of fish behavior, habitat use, energy intake, and interaction between species in the ecosystem, the study of feeding habits contributes to understanding the ecosystem structure, community composition, and population dynamics (Litvaitis, 2000; Stergiou & Karpouzi, 2002; Zacharia & Abdurahiman, 2004; Ahlbeck *et al*., 2012; Manko, 2016; Atique & An, 2018; Rahman *et al*., 2020; Saeed *et al*., 2020). Also, the feeding habit analysis of aquatic species can yield an understanding of their growth, abundance, and productivity (Nansimole *et al*., 2014). Therefore, knowledge about dietary patterns and the diet of fish is indispensable in the decision-making process related to the sustainable management of aquatic ecosystems (Garvey & Chipps, 2012).

Several studies have been carried out about the food and feeding habits of fish in general, with many authors discussing in particular the inspection of fish stomach contents (including Hynes, 1950; Windell & Bowen, 1978; Hyslop, 1980; Mohan & Sankaran, 1988; Costello, 1990; Da Silveira *et al*., 2020), all agreeing that a food item should be counted, weighed, or measured by their volume. Still, the Atlantic chub mackerel (*S. colias*) remains poorly studied and very little is known about their behavioural patterns and feeding strategy in Moroccan waters. As the sustainable management of small pelagic stocks has become a scientific concern in Morocco, a study on the dietary pattern of *S. colias* and its interactions with the ecosystem will contribute to improving the knowledge of this species, especially in terms of stock management.

This study aims to examine the stomach contents composition and to determine the feeding strategy of *S. colias* from four localities in the Atlantic coast of Morocco during winter, in order to provide information on trophic ecology for a good management of this species in Moroccan waters.

MATERIAL AND METHODS

Sampling area

A total of 330 individuals of *Scomber colias* were collected from small-scale boats and purse seiners from four ports in the Atlantic coast of Morocco, located between 33°15′17″ N, -8°30′21″ O and 27°08′30″ N - 13°11′16″ O, namely El Jadida (JD), Safi (SF), Agadir (AG), and Laayoune (LA) (Fig. 1).

Analysis of stomach contents

All samples were measured for total length (TL) to the nearest 1 mm, and total weight (TW) to the nearest 0.1 g. The stomachs were carefully removed from the body, weighed, and preserved in 5% neutralised formalin. The stomachs were opened by making a small cut and the gut fullness was assessed on a visual scale from 0 (empty) to 1.0 (completely full) with intermediate values of 0.25 for 1/4 full, 0.5 for 1/2 full, and 0.75 for 3/4 full. The specimens with full and 3/4 full stomachs were considered to have been feeding actively. The gut contents were transferred into a petri dish. Each stomach content was examined under a compound inverted microscope (X40). All prey items were first identified to the lowest taxonomic level possible using the Boltovskoy (1999) and Rose (1933) identification keys. Diet composition was analysed and evaluated using the following indexes.

The empty stomachs were counted in order to calculate the vacuity index (*VI*), which corresponds to the percentage of empty stomachs (*ES*) in the total number of analysed stomachs (TS):

$$\mathbf{VI\% = ES / TS * 100}$$

The importance index indicates the relative importance, and the volumetric analysis index indicates the relative abundance of specific items found in the stomach samples (Lima-Junior & Goitein, 2001). They were used to identify important prey groups in the diet of *S. colias*:

$$AI_i = F_i * V_i$$

$$Q = \%F * Cp\%$$

where F_i = frequency of occurrence, V_i = volumetric analysis index of item (Lima Junior *et al.*, 2001), Q = feeding coefficient, $\%F$ = frequency index of prey i, and $Cp\%$ = percentage of the prey item's volume.

By applying the food coefficient Q and the frequency index F (the Geistdoerfer index [1978]), the prey is divided into three categories, with each further subdivided into two subcategories:

Q>100 indicates main prey, which can be preferential (F>0.30) or occasional (F<0.30); 10<Q<100 indicates secondary prey, which can be frequent (F>0.10) or accessory (F<0.10); Q<10 indicates complementary prey, which can be first order (F>0.10) or second order (F<0.10).

While the importance of prey items and feeding strategy were analysed via a graphical method (Amundsen *et al.*, 1996), plots were constructed using a modified Costello method (Amundsen *et al.*, 1996). The graphical analysis of feeding strategy (P_i) is based on a two-dimensional representation of prey-specific

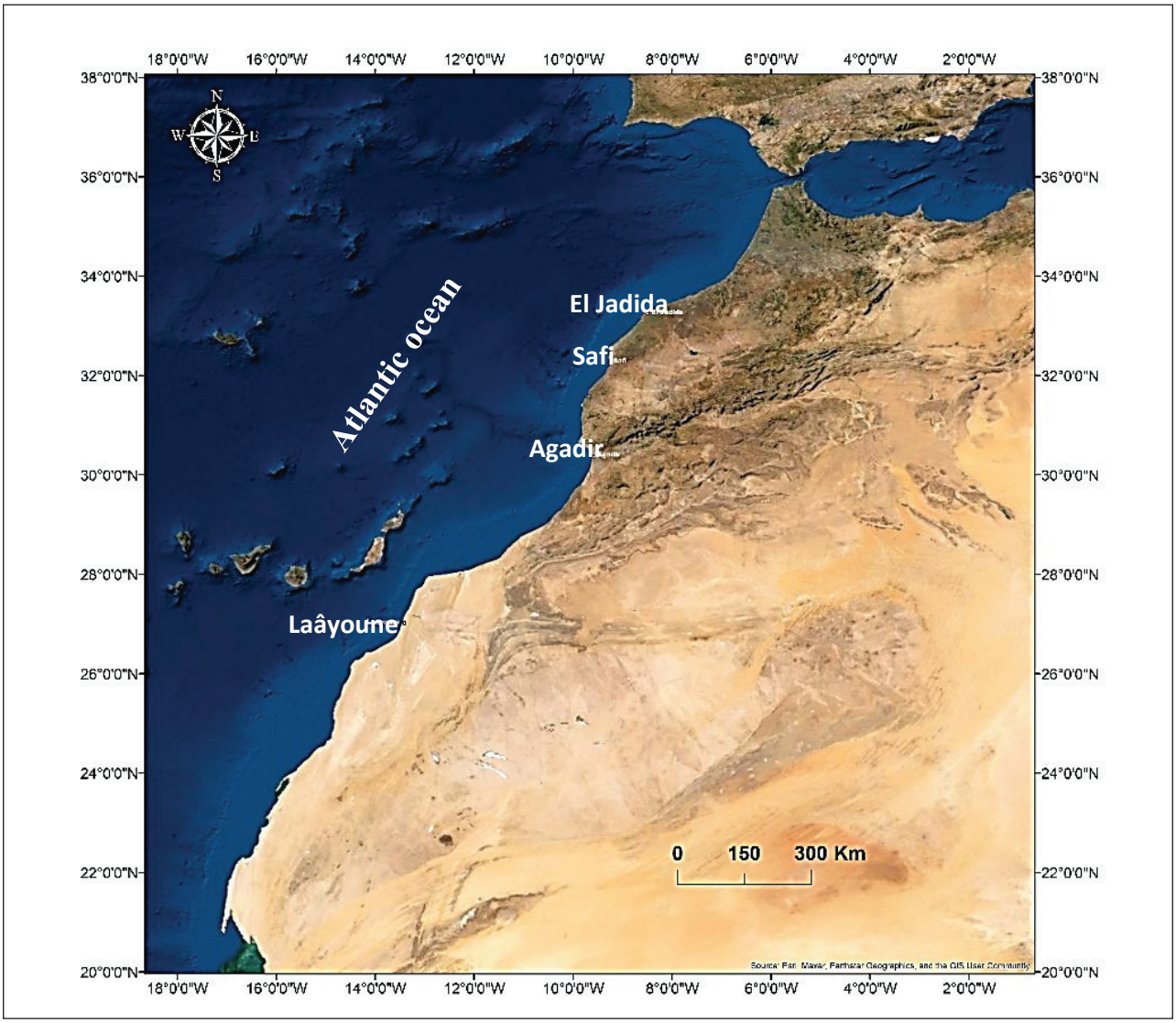

Fig. 1: Sampling areas of** Scomber colias **on the Atlantic coast of Morocco.
Sl. 1: Vzorčevalni predeli, kjer so vzorčili vrsto** Scomber colias **ob atlantski obali Maroka.

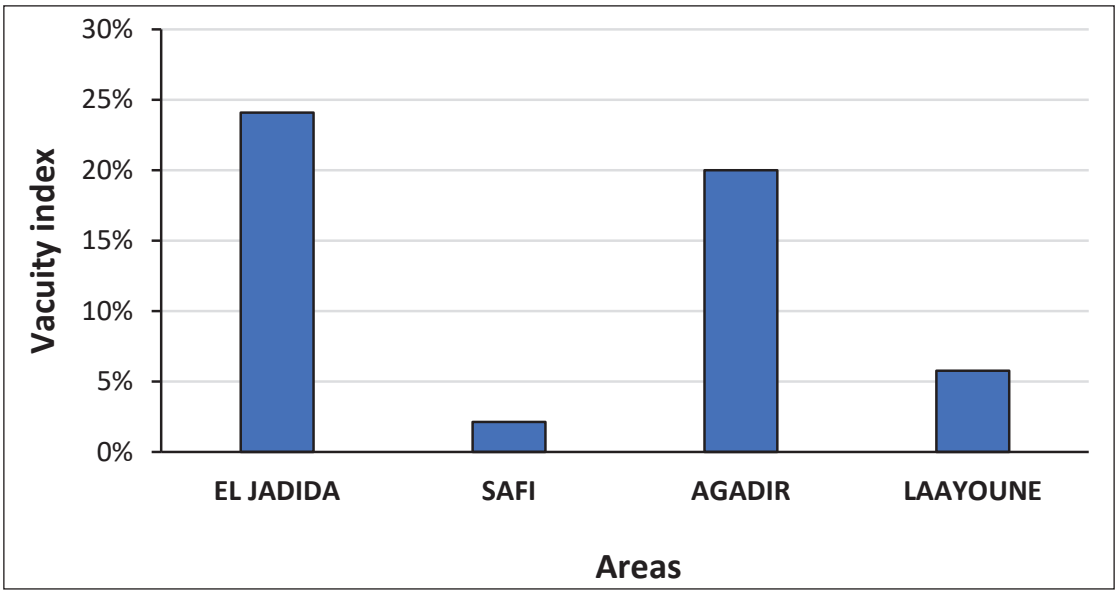

Fig. 2: Variation of vacuity index in the four areas (El Jadida, Safi, Agadir, and Laayoune).
Sl. 2: Variabilnost indeksa praznosti na štirih predelih (El Jadida, Safi, Agadir in Laayoune).

abundance and frequency of occurrence of the different prey types in the diet, and calculated according to the formulae:

$$P_i = (\sum S_i / \sum St_i) * 100$$

$$F_i = 100 * (N_i/N)$$

where S_i is the stomach content (volume, weight, or number) composed by prey i, and St_i is the total stomach content of all stomachs in the entire sample. N_i is the number of predators with prey i in their stomachs, and N is the total number of predators with stomach contents of any kind (Amundsen *et al.*, 1996).

Length-weight relationships and condition factor

The length-weight relationship was studied for different samples collected in the aforementioned areas (EL Jadida, Safi, Agadir, and Laayoune). The body weight was calculated using the equation $\mathbf{Wt = a.TL^b}$, where *Wt* is the total weight, *TL* is the total length, *a* is a coefficient related to body shape, and *b* is an exponent that indicates isometric growth in body proportions if b=3 (Froese 2006). The parameters (*a*, *b*) are important in stock assessment studies (Froese 1998; Froese *et al.*, 2011). The relationships between length and weight may also be used for determining the fish condition, comparing fish growth among areas, and as a complement to species-specific reproduction and feeding studies (Koutrakis & Tsikliras, 2003; Froese, 2006; Froese *et al.*, 2011).

The condition factor (K) was calculated to compare the change in size based on weight variation: $\mathbf{K= (Wt/TL^3) * 100}$ (Pauly, 1983), where *Wt* is the total body weight in grams, and *TL* is the total length in cm.

Statistical analysis

For statistical analysis, one-way ANOVA was used to test the difference in total length (TL) between four localities. The data were analysed statistically using the SPSS (version 21) statistical software package.

RESULTS

Feeding intensity

Among a total of 330 stomachs of *S. colias* examined, 20 empty stomachs were recorded in the Agadir sample (VI%=20%), 3 empty stomachs were recorded in the Laayoune sample (VI%=6%), 2 empty stomachs in the Safi sample (2%), and 19 empty stomachs in the El Jadida sample (VI%=23%). The highest numbers of empty stomachs were found in the Agadir and El Jadida samples, the lowest in the Safi and Laayoune samples (Fig. 2).

Diet composition and feeding strategy

An analysis of the diet composition of 330 individuals led to the identification of 22 items (Tab. 1), manifesting that the diet of *S. colias* is characterized by a wide spectrum of prey groups and species. The relative importance index showed the most common preys to occur in stomachs of *S. colias* from the different

Tab. 1: Composition of** Scomber colias' **stomach contents with Occurrence Frequency (Fi%) and Importance Index (AI) recorded for each food item.
Tab. 1: Vsebina prehrane lokarde na podlagi frekvence pojavljanja (Fi%) in indeksa pomembnosti (AI) za vsako prehranjevalno kategorijo.

Taxon	Occurrence Frequency				Importance Index			
	Eljadida	Safi	Agadir	Laayoune	Eljadida	Safi	Agadir	Laayoune
Copepoda	52.4	78	40	0	**520**	**689**	**144**	0.1
Shrimp	4.8	0	26.3	0	24	0	0	0
Debris of crustaceans	79.4	1.1	1.3	0	**2567**	0.3	3	0
Crab	3.2	0	0	0	11	0	0	0
Mysids	46	1.1	21.3	0	**1370**	0.1	53	0
Amphipoda	6.4	0	0	0	20	0	0	0
Ostracoda	11.1	3.3	2.5	0	13	1.3	0	0
Cladocera	19	29.4	10	0	45	**100**	1.6	0
Isopod	47.6	1.1	16.3	0	**123**	0.1	33	0
Chaetognathes	33.3	23.9	45	8.2	**185**	49	56	21
Sardina pilchardus	0	35.9	26.3	93.9	0	**731**	**701**	**8767**
Engraulis encrasicolus	0	65.2	27.5	0	0	**2100**	**687**	0
Scomber colias	3.2	21.7	11.3	14.3	5	**390**	**181**	**284**
Debris of fish	4.8	8.7	3.8	0	8	14	0	0
Larvae	19	44.6	1.3	0	79	**321**	0.98	0
Egg	11.1	43.5	3.8	0	42	**248**	0	0
Loligo	0	0	1.3	0	0	0	0.78	0
Annelida	11.1	3.3	0	0	24.2	1.3	0	0
Lammelibranchs	0	0	2.5	0	0	0	0.78	0
Cnidaire	3.2	2.2	0	0	1.3	0.3	0	0
Appendicularia	0	2.2	0	0	0	0.9	0	0
Sand, debris, plastic	3.2	0	2.5	0	3.8	0	2.73	0

studied localities (El Jadida [JD], Safi [SF], and Agadir [AG]) were fish, copepods, crustaceans, chaetognaths, and mysids. However, in Laayoune, the single most important prey recorded was fish, with chaetognaths a distant second.

The statistical analysis revealed a significant difference ($p<0.05$) between the four localities. The Laayoune sample represents the largest sample, followed by Agadir and El Jadida. The Safi sample was the smallest (Fig. 3).

Fish were the predominant prey in AG, SF, and LA because those samples contained a higher number of (adult) mackerel individuals, which prefer to consume fish (sardines, anchovy, and mackerel), compared to smaller individuals (juveniles), which tend to consume zooplankton (copepods, mysids, isopods, amphipods, cladocerans, chaetognaths, and ostracodes). We plotted the prey-specific abundance *Pi* against the frequency of occurrence *Fi* to assess the feeding strategy of *S. colias*. Figures 4 and Figure 5 indicate differences in the feeding strategies of specimens from the four areas (El Jadida, Safi, Agadir, and Laayoune). Many kinds of prey were found in the stomachs of the Atlantic chub mackerel, with fish being the most abundant in three of the four studied populations (Agadir, Safi, and Laayoune)

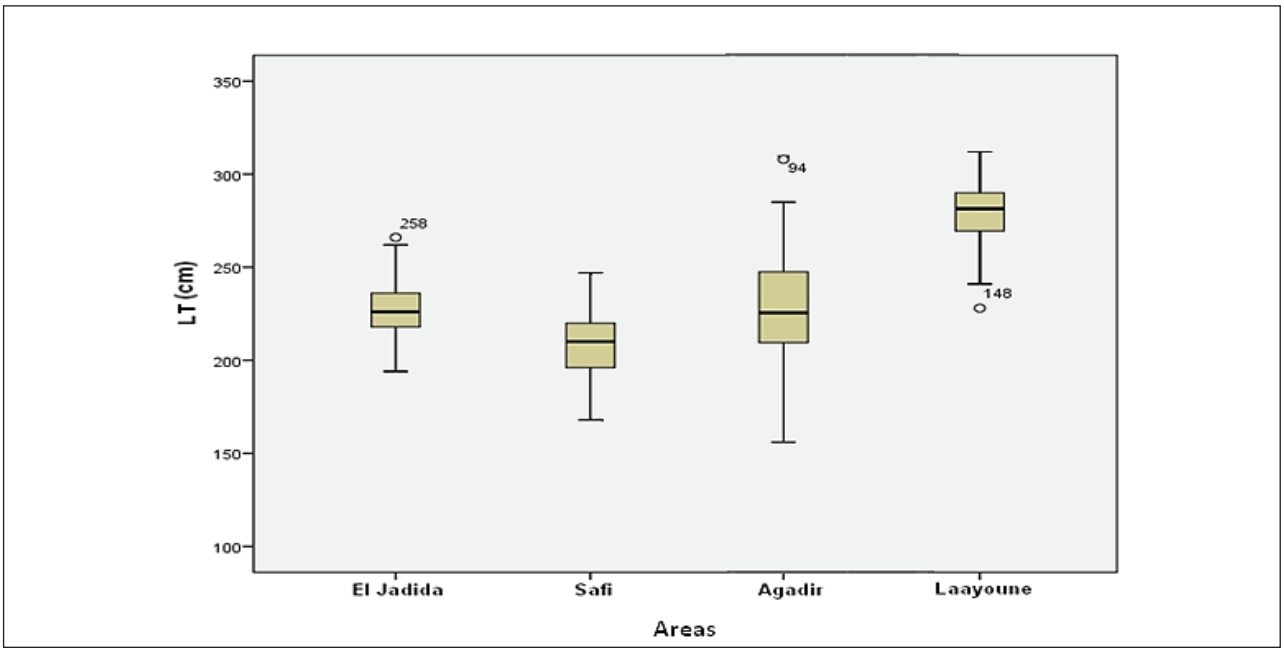

Fig. 3: *Scomber colias* ***total length in the four areas.***
Sl. 3: Celotna dolžina vrste *Scomber colias* ***na štirih predelih.***

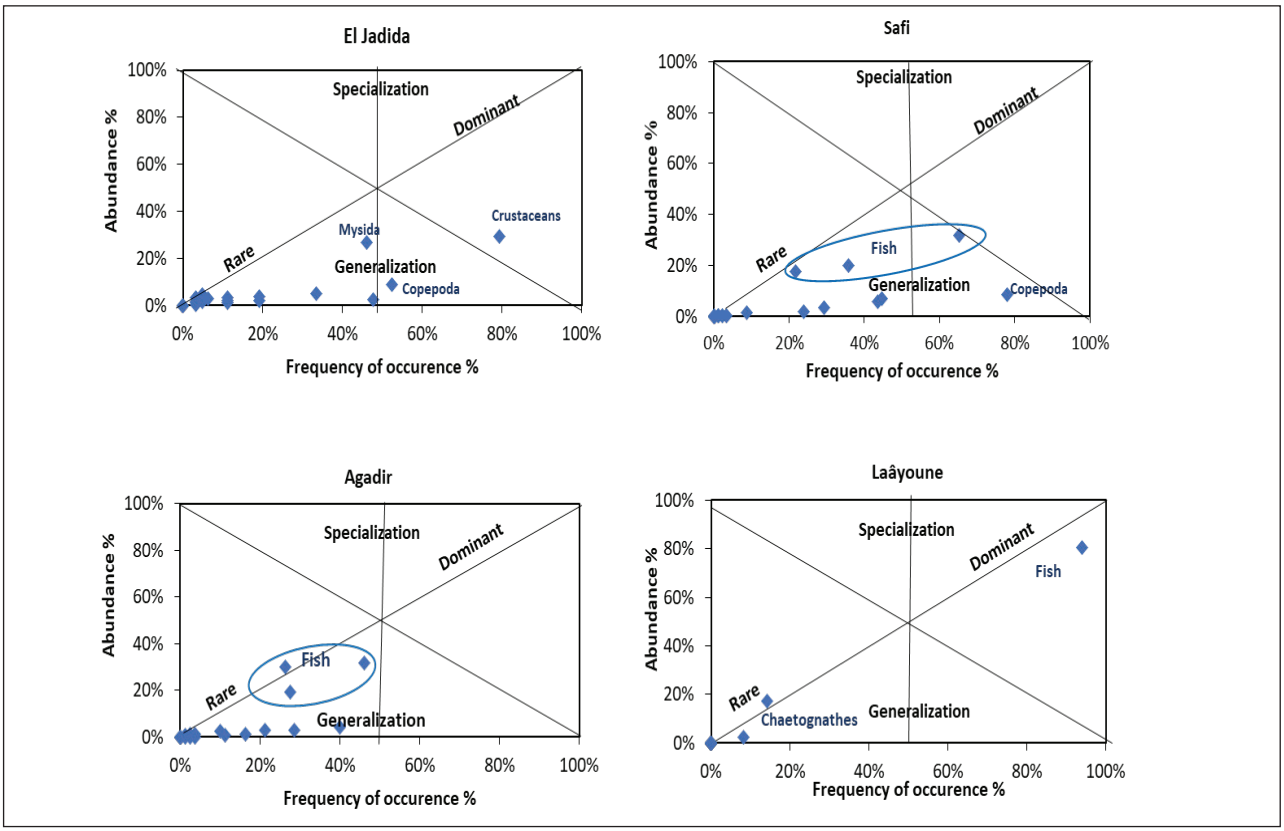

Fig. 4: Graphical explanation of feeding strategy plots of *Scomber colias* ***adapted from Amundsen et al. (1996).***
Sl. 4: Grafična razlaga prehranjevalnih strategij lokarde, prirejena po Amundsenu in sod. (1996).

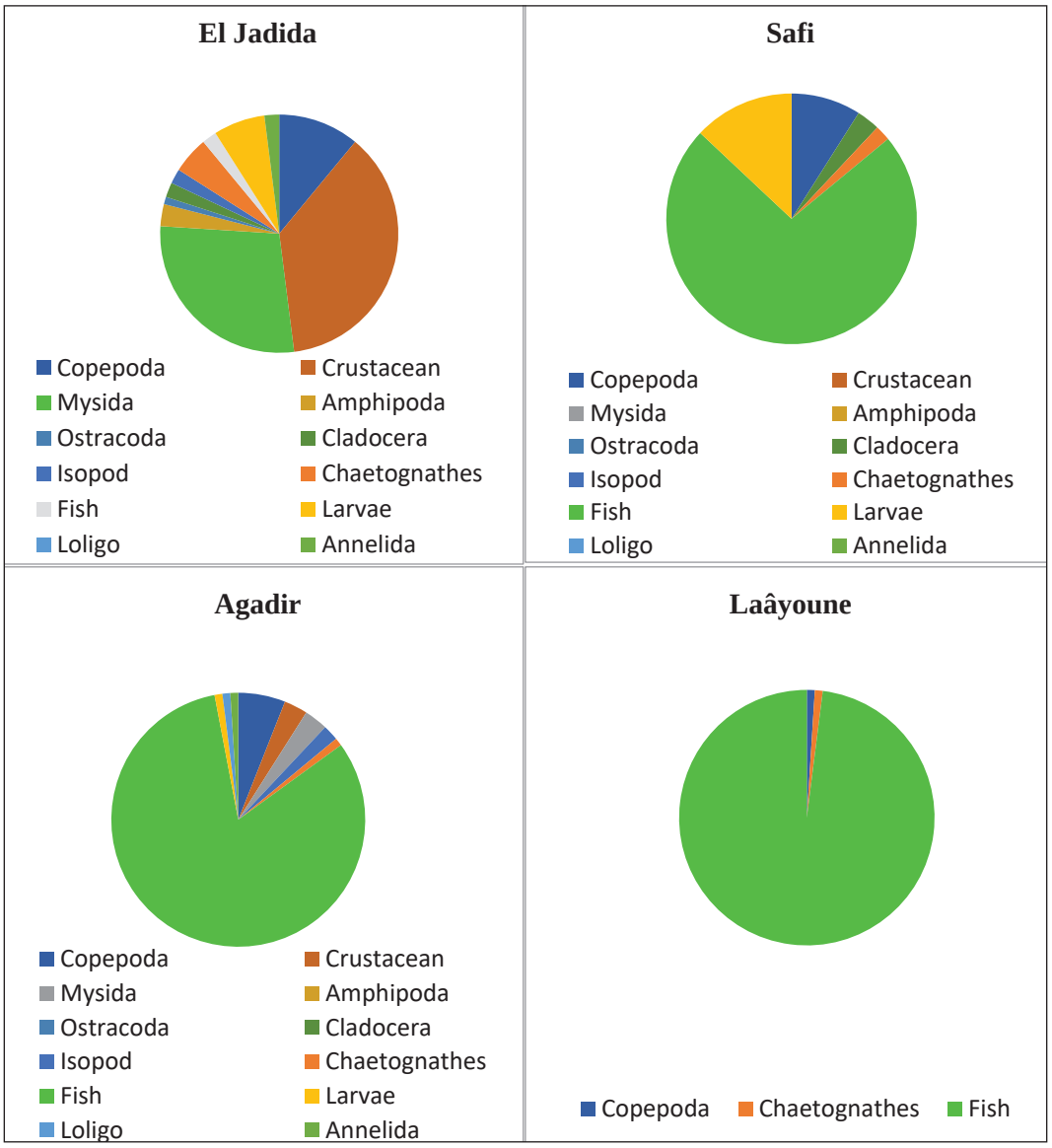

Fig. 5: Distribution of prey abundance among the four areas.
Sl. 5: Porazdelitev številčnosti plena na štirih predelih.

(Fig. 5). The El Jadida prey sample was dominated by crustaceans, such as mysids and fragments of shrimp, followed by copepods (Fig. 5).

The results obtained from the graphical method of Amundsen *et al*. (1996) showed that fish was the most important prey in the diet of *S. colias* from the Atlantic coast, followed by copepods and mysids (Fig. 4).

Estimation of length-weight relationship and condition factor K

The sample size, the length, and the weight characteristics, as well as the estimation of the length-weight relationship parameters *a* and *b*, are presented in Table 2, the length-weight relationships in Figure 6. The Agadir area had the highest number of fish sampled (N=100), with their total lengths ranging from 15 to 34 cm, and weights from 17 and 306 g; Safi ranked second (N=94), with the specimens' total lengths ranging from 14 to 25 cm, and weights from 15 to 100 g; the third largest sample was from the area of El Jadida (N=83), with the specimens' total lengths ranging from19 to 30 cm and total weights from 42 to 187g; the Laayoune sample was the smallest sample (N=53) and only composed of adult fish with the total lengths ranging from 23 to 31 cm and total weight from 75 to 302 g.

Tab. 2: Length-weight relationship parameters (a = intercept of the regression line; b = slope of the regression line; R2 = coefficient of determination; N = number of specimens; TL = total length; Wt = total weight, F = females; M = males; Comb = combined).
Tab. 2: Parametri dolžinsko-masnega odnosa (a = presek regresijske premice; b = naklon regresijske premice; R2 = koeficient determinacije; N = število osebkov; TL = celotna dolžina; Wt = totalna teža, F = samice; M = samci; Comb = kombinirano).

Area	N	TL (cm) (Min-Max)	Wt (g) (Min-Max)	a	b	R^2	K		
							F	M	comb
El Jadida	83	19-30	42-187	0,0023	3,3485	0.8943	0.64	0.64	0.64
Safi	94	14-25	15-100	0,0023	3,3219	0.9221	0.61	0.62	0.62
Agadir	100	15-34	17-306	0,0018	3,4421	0.9206	0.71	0.71	0.71
Laayoune	53	23-31	75-302	0,0009	3,6755	0.9055	0.9	0.9	0.9

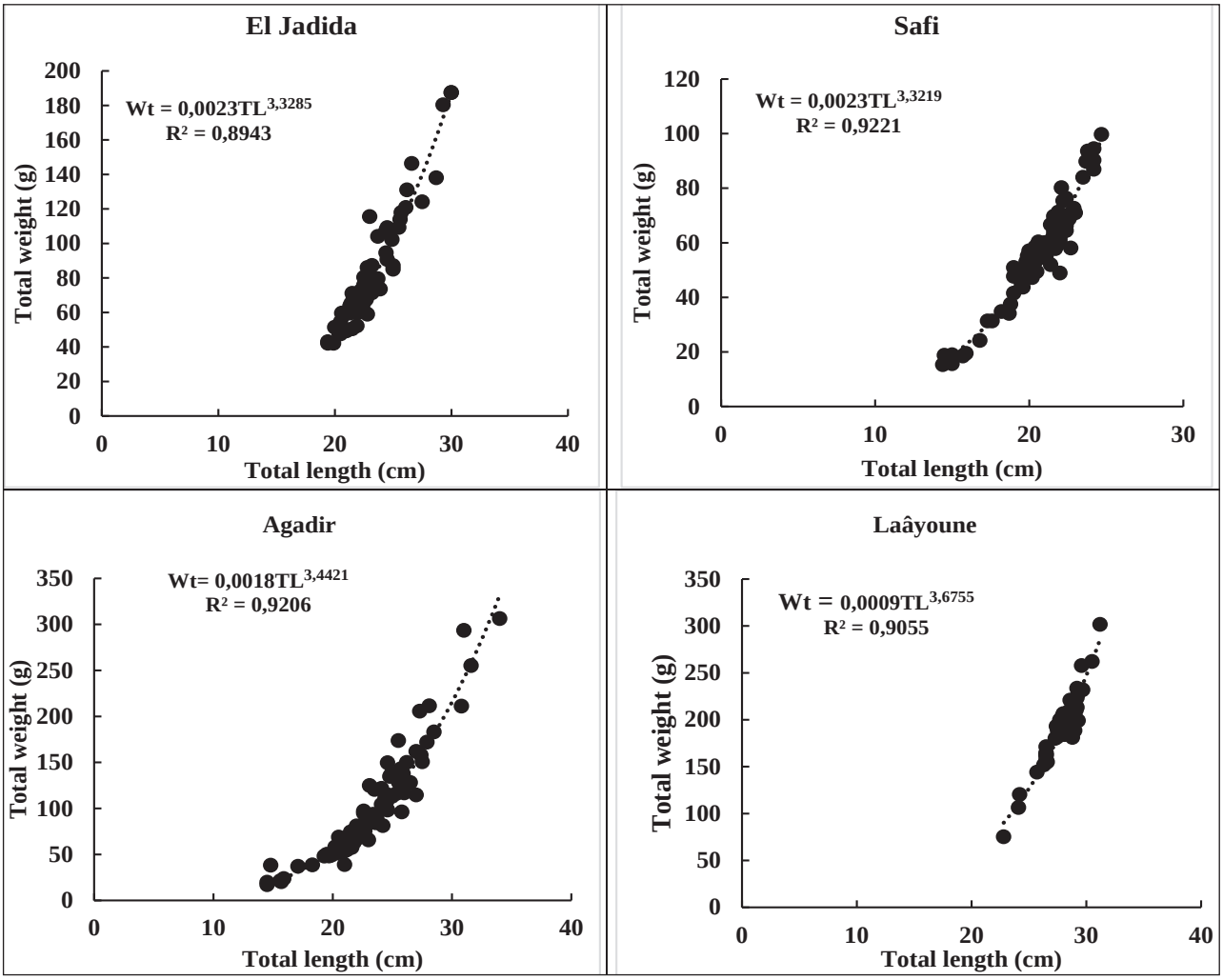

Fig. 6: Plot of length-weight relationships of** Scomber colias **from the Atlantic coast of Morocco.
Sl. 6: Dolžinsko-masni odnos lokarde na atlantski obali Maroka.

The correlation coefficient R2≥0.9 was very important for all areas (Safi, Agadir, Laayoune, and El Jadida). The allometric coefficient for all samples of *S. colias* in total was b>3, whereas the allometric coefficients for El Jadida, Safi, Agadir, and Laayoune separately were b=3.35, b=3.22, b=3.44, and b=3.67, respectively. The pattern observed among the samples is that of positive allometric growth, where the weight gain exceeds the increase in length.

The mean values of condition factor (K) were K=0.64 for El Jadida, K=0.61 for Safi, K=0.71 for Agadir, K=0.87 for Laayoune.

DISCUSSION

All four *S. colias* populations studied (from El Jadida, Safi, Agadir, and Laayoune) exhibited low percentages of specimens with empty stomachs; the slightly higher percentages observed in samples from Agadir (20 %) and El Jadida (23 %) may be due to a reduced availability of food or frequency of feeding activity.

The study was carried out in winter 2017 and the majority of the individuals treated appeared to be in an advanced stage of sexual maturity (mature gonads). The period of sampling thus coincided with the reproduction period of *S. colias* on the Atlantic coast of Morocco, where the spawning of the species takes place between December and March, peaking in January (Techetach *et al*., 2010; Bouzzammit *et al*., 2022).

The majority of the examined stomachs contained food, with the prey in different stages of digestion. Nikolsky (1976) mentioned that fish feeding intensity decreases during the spawning season, but his hypothesis that the mackerel fasts during the reproduction period is not applicable to our case. Our suggestion is consistent with that of Hernandez & Ortega (2000) who indicated that the mackerel from the Atlantic coast of northwest Africa feed continuously, even during the breeding season.

The diet composition of the Atlantic chub mackerel from the Atlantic coast of Morocco indicates that fish (sardines, anchovies, mackerel) and zooplankton (copepods, mysids, euphausiids) are two main and preferential prey groups of this species. Preferences vary according to the size of the individual and the availability of prey in their environment. The differences in food preferences between different localities may be due to differences in the size structure of the studied populations or different environmental conditions. The total length across all samples varied from 145 to 340 mm. The total lengths recorded in El Jadida were between 194 and 300 mm, in Safi between 144 and 247 mm, in Agadir between 145 and 340 mm, and in Laayoune between 228 and 312 mm, with the respective averages of 229 ± 2.2 (JD), 206 ± 2.1 (SF), 228±3.5 (AG), and 279 ± 2.1 (LA). The Atlantic chub mackerel is characterised by different food intake strategies: feeding on plankton through filtration in juvenile fish, and predation in large adult fish (Ait Talborjt, 2020). Consequently, the diet composition changes according to the size of the fish, but the switch to larger prey richer in energy may also be prompted by scarcity of the optimum/preferred food source in the environment (Kvaavik *et al*., 2019). Likewise, Castro (1993) found that in the Canary Islands mackerel fed on different categories of prey, from zooplankton (copepods, mysids, isopods, crustacean larvae), to clupeids as one of the most important prey groups, followed by *Engraulis encrasicolus* and *Scomber colias*. Our results are also in agreement with Angelescu (1979), Angelescu (1980) and Pájaro (1993) with regard to the coasts of Argentina, who mentioned that the diet of the Atlantic chub mackerel was very flexible, both in terms of diversity (20 prey species) and size of prey (ranging from quite small, such as crustaceans, especially copepods, to rather large, such as fish).

The graphical method of Amundsen *et al*. (1996) shows that fish are the main and preferential prey in the diet of *S. colias*, followed by copepods. This result is in agreement with the results of Castro (1991; 1993; 1998), who stated that the diet of the Spanish mackerel was based on fish and copepods. In addition, the populations of *Scomber colias* from the Atlantic coast focus on three types of prey: fish, copepods, and mysids, with the feeding habits changing according to the size of the fish. These form the bulk of the species' diet during the winter. It follows that the Atlantic chub mackerel is an opportunistically feeding carnivorous fish whose selection of prey is based on availability and geographic abundance. This result is similar to the finding of Sever *et al*. (2006) with regard to the Bay of Izmir, indicating that the diet of mackerel is influenced by abundance of prey and availability of food in the environment.

In this study, we also recorded several cases of cannibalism: 22 in the Agadir sample, 18 in the Safi sample, seven in the Laayoune sample, and two in the El Jadida sample. According to Garrido *et al*. (2015), the juveniles of sardines and Atlantic chub mackerel were the main predators of the fish eggs of their species, possibly affecting the mortality rate of their own populations. Furthermore, three cases of Spanish mackerel cannibalism were recorded in the Canary Islands by Castro (1993), while Hunter and Kimbrell (1980), Hernández & Ortega (2000) reported cannibalism in the chub mackerel, associating it with sexual cannibalism where the females kill and consume the males.

The length-weight relationship results indicated positive allometric growth (b>3) for all samples (El Jadida, Safi, Agadir, and Laayoune), with fish weight increasing faster than its length. Coefficient *b* is related to both length and weight. In the sample from Laayoune, for example, which contains large and heavy

individuals, the coefficient *b* is expectedly higher and attributable to good environmental conditions and availability of food. The coefficient of determination R^2 for the length-weight relationship was high ($R^2 \geq 0.9$) in all areas (EL Jadida, Safi, Agadir, and Laayoune), indicating that the length increased with the increase in the weight of fish. The differences recorded in condition factor (K) among areas are directly proportional to differences in weight. For example, the condition factor (K) in the Laayoune area was K=0.9, and the weights of specimens ranged between 75 to 306 g, while the condition factor (K) in the Safi area was K=0.62 and the weights ranged between 15 and 100 g. Generally, the condition factor (K) indicates the physiological condition of fish (Getso *et al*., 2017). The increase in the K value indicates the fatness and gonadal development of fish (Maguire & Mace, 1993). Ujjania *et al*. (2012) also reported that when the value of condition factor (K) is superior to or equals 1, it indicates a good level of feeding and appropriate environmental conditions. The length-weight relationship parameters and the condition factor (K) has been confirmedly affected by feeding intensity, availability of food, fish size, stage of maturation, season, fullness of gut, amount of fat reserves, and life history (Ujjania *et al*., 2012; Gupta & Banerjee, 2015).

CONCLUSIONS

The diet of *S. colias* was characterized by a high diversity of prey groups, including fish (sardines, anchovy, and chub mackerels), copepods, crustaceans (crab, shrimp), mysids, annelids, isopods, chaetognaths, amphipods, larvae, fish eggs, cladocerans, ostracods, and cephalopods. The Atlantic chub mackerel (*S. colias*) is an opportunistic predator that feeds on available food in its habitat. The shift in the diet composition of this species could be interpreted as a result of change in the abundance of prey in its ecosystem. The size of prey targeted by the Atlantic chub mackerel increases in correlation with increase in body size, but the species also predates the smallest prey according to their availability in their habitat. The length-weight relationship parameters and the condition factor (K) are affected by feeding intensity, availability of food, fish size, fullness of gut, and amount of fat reserves.

PREHRANA IN PREHRANJEVALNA STRATEGIJA LOKARDE (*SCOMBER COLIAS)* OB ATLANTSKI OBALI MAROKA

Nadia BOUZZAMMIT
Ibn Zohr University, Faculty of Sciences, Laboratory of Aquatic Systems: Marine and Continental Environments, P.O. Box 8106 - Dakhla Avenue, Agadir, Morocco

e-mail: nadia.bouzzammit@edu.uiz.ac.ma

Hammou EL HABOUZ
National Institute of Fisheries Research, Anza, Agadir, Morocco

El hassan AIT-TALBORJT, Zahra OKBA & Hassan EL OUIZGANI
Laboratory of Aquatic Systems: Marine and Continental Environments, P. O. Box 8106, Faculty of Sciences, Ibn Zohr University Dakhla Avenue, Agadir, Morocco

POVZETEK

*Avtorji so raziskovali sestavo prehrane in prehranjevalno strategijo lokarde (*Scomber colias*) ob atlantski obali Maroka pozimi 2017. Preiskali so skupno 330 vsebin želodcev. Indeks praznosti želodca je pokazal veliko intenziteto hranjenja na lokalitetah Safi (SF) (2%) in Laayoune (LA) (6%), nižjo pa v El Jadida (JD) (25%) in Agadirju (AG) (20%). V preiskavi prehrane so določili 22 prehranjevalnih kategorij. Najbolj številen plen z najvišjim indeksom relativne pomembnosti so bile ribe, sledili so raki ceponožci na treh lokalitetah (AG, SF, and LA), medtem ko so bili na lokaliteti El Jadida (JD) najpomembnejši raki in mizidi.* S. colias *je mesojeda riba in krvoločni plenilec drugih rib. Avtorji so med raziskanimi populacijami zasledili več primerov kanibalizma.*

Ključne besede: prehrana, *Scomber colias*, vsebina želodcev, indeks praznosti, kanibalizem

REFERENCES

Ait Talborjt, E. (2020): Analyse temporelle de l'abondance, de la biomasse et du spectre de taille du zooplancton de la baie d'Imessouane par la méthode d'imagerie numérique Zooscan-Zooprocesse– Ecotaxa. Thèse. Biologie et Ecologie Animale, université Ibn Zohr, 199 pp.

Ahlbeck, I., S. Hansson & O. Hjerne (2012): Evaluating fish diet analysis methods by individual-based modelling. Can. J. Fish. Aquat. Sci., 69, 1184-1201.

Amundson, P.A., H.M Gabler & F.J. Staldvik (1996): A new approach to graphical analysis of feeding strategy from stomach contents: Data modification of the Costello method (1990). J. Fish Biol., 48, 607-614.

Angelescu, V. (1980): Ecologia trofica de la caballa (Scombridae, *Scomber japonicus marplatensis*) del Atlantico sudoccidental. Biol.Isnt.Oceanogr., Sao Paulo, 29, 6-7.

Angelescu, V. (1979): Trophic ecology of the mackerel of Argentine continental shelf. (Scombridae, *Scomber japonicus marplatensis*) part I. Rev. Invest Desarr, Pesq, 1, 6-44.

Atique, U. & K.G. An (2018): Stream health evaluation using a combined approach of multimetric chemical pollution and biological integrity models. Water, 661 pp.

Boltovskoy, D. (1999): South Atlantic Zooplankton. Backhuys Publishers, Leiden, The Netherlands, 1706 pp.

Bouzzammit, N. & H. El Ouizgani (2019): Morphometric and meristic variation in the Atlantic chub mackerel *Scomber colias* Gmelin, 1789 from the Moroccan coast. Indian J. Fish., 66(2), 8-15.

Bouzzammit, N., H. El Habouz, A. Ben-Bani & H. El Ouizgani (2022): Spawning season, size at first maturity, and fecundity in chub mackerel (*Scomber colias* Gmelin, 1789) from the Atlantic coast of Morocco. Reg. Stud. Mar. Sci., 102451.

Castro, J.J. (1991): Ecología trófica de la caballa (*Scomber japonicus* Houttuyn, 1780), en aguas del Archipiélago Canario.Tesis Doctoral, universidade de Las palmas de gran Canaria, 313 pp.

Castro, J.J. (1993): Feeding ecology of chub mackerel *Scomber japonicus* in the Canary Islands area, South Afr. J. Mar. Sci., 13, 323-328.

Castro, J.J. (1998): Mysids and euphausiids in the diet of *Scomber japonicus* Houttuyn, 1782 off the Canary Islands. Oceanographic Literature Review, 1234.

Chakraborty, B.K., M.H. Shahroz, A.B. Bhuiyan, S. Bhattacharjee & S. Chattoraj (2019): Status of Indian major carps spawns in the Halda River along with marketing and economic condition of the Fishers and related collectors. Int. J. Biol. Innov., 1, 40-50.

Cherif, M., R. Zarrad, H. Gharbi, H. Missaout, O. Jarbout (2008): Length-weight relationships for 11 fish species from the Gulf of Tunis (SW Mediterranean Sea, Tunisia). Pan-Am. J. Aquat. Sci., 3(1), 1-5.

Čikeš Keč, V. & B. Zorica (2012): Mesenteric fat and condition of chub mackerel, *Scomber colias* in the Adriatic Sea. Ribar. Croat. J. Fish., 70, 19-30.

Collette, B.B. & C.E. Nauen (1983): Scombrids of the World. FAO Fisheries Synopsis, no. 125. FAO, Rome, Italy.

Costello, M.J. (1990): Predator feeding strategy and prey importance: a new graphical analysis. J. Fish Biol., 36, 261-263.

Da Silveira, E.L., N. Semmar, J.E. Cartes, V.M. Tuset, A. Lombarte, E.L.C. Ballester & A.M. Vazdos-Santos (2020): Methods for trophic ecology assessment in fishes: a critical review of stomach analyses. Reviews in Fisheries Science & Aquaculture, 28, 71-106.

Froese, R. (1998): Length–weight relationships for 18 less-studied fish species. J Appl Ichthyol., 14, 117-118.

Froese, R. (2006): Cube law, condition factor and weight–length relationships: History, meta-analysis and recommendations. J. Appl. Ichthyol., 22(4), 241-253.

Froese, R., A.C. Tsikliras & K.I. Stergiou (2011): Editorial note on weight-length relations of fishes. Acta Ichthyol. Piscat., 41(4), 261-263.

Garrido, S., A. Silva, J. Pastor, R. Dominguez, A.V. Silva, A.M. Santos (2015): Trophic ecology of pelagic fish species off the Iberian coast: diet overlap, cannibalism and intraguild predation. Mar. Ecol. Prog. Ser., 539, 271-286.

Garvey, J.E. & S.R. Chipps (2012): Diets and energy flow. In: Zale AV, Parrish DL, Sutton TM, editors. Fisheries Techniques. 3rd ed. Bethesda (MD): American Fisheries Society, pp. 733-779.

Getso, B.U., J.M. Abdullahi & I.A. Yola (2017): Length-weight relationship and condition factor of *Clarias gariepinus* and *Oreochromis niloticus* of Wudil River, Kano, Nigeria. Agro-Science, 16(1), 1-4.

Hashemzadeh, I., S.N. Tabatabaei, A. Mansouri, A. Abdoli, M. Ghalenoei, & K. Golzarianpour (2015): Length-weight relationships of Garra rufa, in the Tigris and Persian Gulf basins of Iran. Int. J. Aquat. Biol., 3(1), 25-27.

Hernández, J.J.C. & A.T.S. Ortega (2000): Synopsis of biological data on the chub mackerel (*Scomber japonicus* Houttuyn, 1782). FAO, Fisheries Synopsis, 157.

Hynes, H.B.N. (1950): The food of freshwater sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius) with a review of methods used in studies of the food of fishes. J. Anim. Ecol., Oxford, 19, 36-58.

Hyslop, E.J. (1980): Stomach content analysis: a review of methods and their applications. J. Fish Biol., 17, 411-429.

INRH (2017): Annual report on the state of Moroccan stocks and fisheries. National Institute of Fisheries Research, Casablanca (Maroc), 287 pp.

Jisr, N., G. Younes, C. Sukhn, & M.H. El-Dakdouki (2018): Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. Egypt. J. Aquat. Res., 44(4), 299-305.

Koutrakis, E.T., A.C. Tsikliras (2003): Length–weight relationships of fishes from three northern Aegean estuarine systems (Greece). J. Appl. Ichthyol., 19(4), 258-260.

Kvaavik, C., G.J. Óskarsson, A.K. Daníelsdóttir & G. Marteinsdóttir (2019): Diet and feeding strategy of Northeast Atlantic mackerel (*Scomber scombrus*) in Icelandic waters. PLoS one, 14, (12), p. e0225552.

Lima-Junior, S.E. & R. Goitein (2001): A new method for the analysis of fish stomach contents. Acta Scientiarum, 23(2), 421-424.

Litvaitis, J.A. (2000): Investigating food habits of terrestrial vertebrates. In: Boitani L. & Fuller T.K (Eds.) Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York, pp. 165-190.

Machado, A.M., A. Gomes-dos-Santos, M.M. Fonseca, R.R. Da Fonseca, A. Veríssimo, M. Felício, R. Capela N. Alves, M. Santos, F. Salvador-Caramelo, M. Domingues, R. Ruivo, E. Froufe, L. Filipe C. Castro (2022): A genome assembly of the Atlantic chub mackerel (*Scomber colias*): a valuable teleost fishing resource. Gigabyte, https://doi.org/10.46471/gigabyte.40.

Maguire J.J. and P.M. Mace (1993): Biological reference points for Canadian Atlantic Gadoid stocks. In:Smith S.J., Hunt J.J. and Rivard D. (eds.), Risk Evaluation and Biological Reference Points for Fisheries Management. Can. Spec. Publ. Fish. Aquat. Sci., 120, 67-82.

Manko, P. (2016): Stomach content analysis in freshwater fish feeding ecology. University of Prešov, 1-116.

Mishra, S.P. (2020): Seasonal variation in gut contents of Indian major Carp *Cirrhinus mrigala* from Meeranpur lake, India. Int. J. Biol. Innov., 2, 202-208.

Mohan, M.V. & T.M. Sankaran (1988): Two new indices for stomach content analysis of fishes. J. Fish. Biol., 33, 289-292.

Navarro, M.R., B. Villamor, S. Myklevoll, J. Gil, P. Abaunza & J. Canoura (2012): Maximum size of Atlantic mackerel (*Scomber scombrus*) and Atlantic chub mackerel (*Scomber colias*) in the Northeast Atlantic. Cybium, 36, 406-408.

Nikolsky, G.V. (1976): The Ecology of Fishes. Academic Press, London, 352 pp.

Pájaro, M. (1993): Consideraciones sobre la alimentacíon de la caballa con especial énfasis en la depredacíon de huevos y larvas de peces. INIDEP Documento Cientifico, 2, 19-29.

Pauly, D. (1983): Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical paper, FAO, Rome, Italy. 234 pp.

Rahman, M.M., S.M. Haque, M.A. Islam, A.K. Paul, S. Iqbal, U. Atique, A. Wahab, H. Egna & C. Brown (2020): Assessment of mud crab fattening and culture practices in coastal Bangladesh: understanding the current technologies and development. Aquaculture, Aquarium, Conservation & Legislation, 13, 582-596.

Rose, M. (1933): Faune de France. Copépodes pélagiques. Fédération Française des Sociétés de Sciences Naturelles Office Central de Faunistique, 26, 337 pp.

Saeed, F., K.J. Iqbal, U. Atique, A. Javid, N. khan, S. Iqbal, H. Majeed, H. Azmat, B.Y.A. Khan, I. Baboo, M.T. Shahid & G. Afzal (2020): Toxic trace metals assessment in selected organs of edible fish species, sediment and water in Head Punjnad, Punjab, Pakistan. Punjab University Journal of Zoology, 35, 43-50.

Sever, T.M., B. Bayhan, M. Bilecenoglu & S. Mavili (2006): Diet composition of the juvenile chub mackerel (*Scomber japonicus*) in the Aegean Sea (Izmir Bay, Turkey). J. Appl. Ichthyol., 22,145-148.

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

Techetach, M., J.A. Hernando-Casal, Y. Saoud & M.H. Benajiba (2010): Reproductive biology of chub mackerel *Scomber japonicus* in Larache area, Moroccan North Atlantic coast. Cybium, 34, 159-165.

Ujjania, N.C., M.P.S. Kohli & L.L. Sharma (2012): Length-weight relationship and condition factors of Indian major carps (*C. catla, L. rohita and C. mrigala*) in Mahi Bajaj Sagar, India. Res. J. Biol., 2(1), 30-36.

Velasco, E.M., J. del Arbol, J. Baro & I. Sobrino (2011): Age and growth of the Spanish chub mackerel *Scomber colias* off southern Spain: a comparison between samples from the NE Atlantic and the SW Mediterranean. Rev. Biol. Mar. Oceanogr., 46, 27-34.

Windell, J.T. & S.H. Bowen (1978): Methods for study of fish diets based on analysis of stomach contents. In: Methods for Assessment of Fish Production in Fresh Waters, IBP Handbook No. 3 (T. Bagenal, ed.), Oxford: Blackwell Scientific, pp. 219-226.

Zacharia, P.U. & K.P. Abdurahiman (2004): Methods of stomach content analysis of fishes. Winter School on Towards Ecosystem Based Management of Marine Fisheries–Building Mass Balance Trophic and Simulation Models, 200 pp.