Feeding habits and some biological aspects of the Atlantic horse mackerel, *Trachurus trachurus*, (Linnaeus, 1758) in the Western Coast of Libya

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***Keywords**:* Atlantic horse mackerel*, Trachurus trachurus,* food composition.

Abstract

A total of 1334 *Trachurus trachurus* was collected the Western Coast of Libya from February 2019 to February 2020, fish ranged in total lengths from 100 to 360 mm and weighted from 13 to 409g. The growth of *T. trachurus* .as positive allometry, but it was a significant difference between males and females, whereas females were larger than males. 109 full stomachs of *T. trachurus* .ere examined to define the prey. The Prey-Specific Index of Relative Importance (PSIRI%) was calculated for phylum and classes. The analysis indicates that the fish stomachs contain 4758 individual prey items classified into six phyla and four classes. The main food item was Decapoda (shrimp and crab) and the trophic level of *T. trachurus* is 2.98. The changes of the food composition of *T. trachurus* were related to growth, sex, gonad stages, and seasons. The results reveal that no differences have been considered, this species is an omnivore consuming a wide variety of invertebrate prey with a preference for animal material.

***Keywords**: Trachurus trachurus,* food composition, trophic level.

Introduction

Atlantic horse mackerel, *Trachurus trachur*us formerly known as *T. trachurus*. belonging to of the Carangidae family (about 140 species). It is widespread from Norway and Iceland to Western Africa (Froese & Pauly, 2022), also in the Mediterranean and Black Sea (Smith-Vaniz, 1986). *T. trachurus* is a benthopelagic fish species near the continental shelf especially above the mud and sand bottom (Šantić *et al*., 2011). It usually found at 100 to 200m depths. And sometimes at 1050m (FAO, 2021). In Libyan coast this species is generally found in deep water between 70 - 300 m depths (Qassem *et al*., 2009). *T. trachurus* prefer crustaceans (Copepods and shrimp), a tiny fish and squid. Galiya *et al*. (2020) studied the feeding habits of *T. trachurus* .n Syrian water, they noticed this species feeds on fish, crustaceans, molluscs and annelida. *T. trachurus* grazes on a many prey species in Turkey's Aegean Sea, which are divided into five phyla with seasonal and size variations. (Bayhan & Sever, 2009). Thirty prey species of the horse mackerel, included the major items, Crustacea (Euphausiacea, Mysidacea, Decapoda), then Cephalopoda, and Teleostei families, were identified by Santic *et al*. (2005) in the central Adriatic Sea. In Portugal, Cabral & Murta (2002) mentioned that *T. trachurus* feed on plankto-phagousa. Olaso-Toca *et al*. (1999), Ben Salem (1988) and Dahl & kirkegaard (1986 &1988) studied the diet of *T. trachurus* and concluded that the immature stage is primarily zooplanktivorous, whereas the adult stage feed on the fish. Some researches were based on relative numbers of prey, however, several researchers focused on some factors, such as the diversity preys and the locations *T. trachurus* grazes during the day. Pillar & Barange (1998) noticed that this species feeds mostly in the late afternoon before rising into mid-water at nightfall. Garrido and Murta (2011) noticed that this species can shift their trophic niche quickly and easily to adapt changes in prey abundance and availability. Further details about the connection between *T. trachurus*, geographic distribution and feeding habits are provided by Rumolo *et al*. (2017). *T. trachurus* is one of the main target species at Libyan stock fisheries, but it has not received much attention. Therefore, this study aims to investigate the diet and feeding habits of *T. trachurus*.

Material and methods

Collection

A total of 1334 individuals were caught by trawling from the Tripoli in the western Libyan coast (Figure 1). The study period was collected during one year from February 2019 to February 2020 (i.e. about 70 fish per month). Fish were stored in iceboxe and transferred to the laboratory. The fish were measured, the total length (TL), the fork length (FL) to the nearest mm and the total weight to the nearest g. Fish were dissected and removed the stomachs and gonads, then weighed to nearest g. The stomachs were preserved in 10% neutral formalin. Finally, their gonads were examined macroscopically (Costa, 2009) (Table 1)

Table 1: Macroscopic maturity stages of the gonads of *T.trachurus*

Maturity stage	Macroscopic appearance
I. Immature	Gonads small. Ovaries wine red and clear, torpedo-shaped.
II. Early ripening	Gonads occupying 1/4 to 3/4 body cavity. Opaque eggs visible in ovaries giving pale pink to yellowish colorations, largest eggs without oil globule.
III. Late ripening	Gonads occupying 3/4 to almost filling body cavity. Ovaries yellow to orange. Largest eggs may have oil globules
IV. Ripening	Ovaries characterized by external visible hyaline eggs no matter how few or how early the stage of hydration. Ovaries with hyaline eggs only in the lumen are not included. Ovary size variable from full to 1/4.
V. Partly spent	Gonads occupying 3/4 to ,1/4 body cavity. Ovaries slacker than in stage 3 and often bloodshot.
VI. Spent/recovering spent	Gonads occupying 1/4 or less of body cavity. Ovaries reddish and often murky in appearance, sometimes with a scattering or patch of opaque eggs.

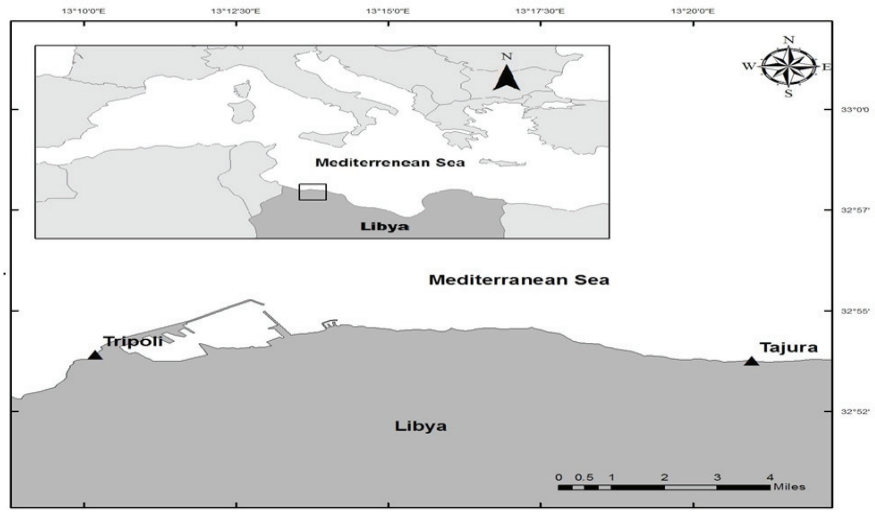

Figure 1: Scaled map indicating the study site and places referred to in the text.

A total of individuals 109 stomachs were examined to analyze the diet of *T. trachurus*. The analysis reveals were made up of a subsample of 10 stomachs per sampling. Stomachs were opened, then their contents were removed into a petri dish and sorted into taxa. The number of individual groups was counted. while colonial and algae organisms that could not be counted were scored to one. Each category group was added to a measuring flask to estimate the volume.

Statistical analysis

Five diet indices were calculated for each prey species:

1. Average percent volume (V%) is the relative volume of prey items in the total volume of non-empty stomach.
2. Average percent number (N%) is the relative abundance of prey items in the total number of non-empty stomachs.
3. The percent prey-specific volume (PV%) is the average volume of a specific prey item in the total volume of stomachs containing that specific item.
4. The percent prey-specific number (PN%) is the average number of a specific prey item in the total number of stomachs containing that specific item.
5. The percentage frequency of occurrence (FO%) is the frequency the occurrence of prey items in the total number

of non-empty stomachs.

After calculating those indices, a prey-specific index of relative importance (PSIRI%) for each prey was estimated according to Brown *et al.,* (2012). Then the trophic levels of prey were obtained from Stergiou & Karpouzi (2002)

Length Weight Relationship

Linear regression was used to demonstrate the link between total length and total weight (Ricker 1973).

$W = aTL^{b}$. where the W is weight, TL is the total length, a and b are constants.

Condition Factor

The condition factor was calculated for males and females monthly by Le Cren's (1951) alternate condition factor was applied:

$K_{rel} = \frac{W}{aL^{b}}$.

The Gastro Somatic Index (GaSI)

It was calculated as follows:

$GaSI = \frac{stomach\ mass(g)}{(fish\ mass(g) - stomach\ mass(g))} x\ 100$ (Desai 1970)

The Kruskal-Wallis (1952) was used to test difference in the season on the GaSI of mature fish for each sex.

Multivariate Analyses

Multivariate techniques (PRIMER 6) were used to describe and compare the percentage volumes for the various prey items of *T. trachurus* (Clarke & Warwick 2001). Percentage volume data was square-root transformed to prevent super-abundant prey species from dominating the analysis. A resemblance matrix was calculated by the Bray-Curtis index of similarity, the group average procedure used to construct a Multidimensional Scaling Plot (MDS). The one-way Analysis of similarities (ANOSIM) test showed the significance variations of diets across the participants separately.

Results

The analyses of stomachs content showed 4758 individual prey items of *T. trachurus*, belonged to four classes in six phyla. PSIRI% revealed that Arthropoda and Chordata were almost dominant phyla, at 74% and 20% respectively, also other phyla included seagrass, Annelida, Mollusca and Rhodophyta (Figure 2), while Algae as phyla was less than one on the PSIRI% scale. The dominant orders of animal prey were Decapoda (68%) including shrimp 29% and crab 4%, unknown fish (15%) and unknown seagrass (2%) (Table 2). Overall, most prey was small invertebrates, sessile filter-feeders or mobile benthic herbivores. The prey items were 2.3% sessile, 38.1% free living benthic animals and 18.4% pelagic. The most common prey items

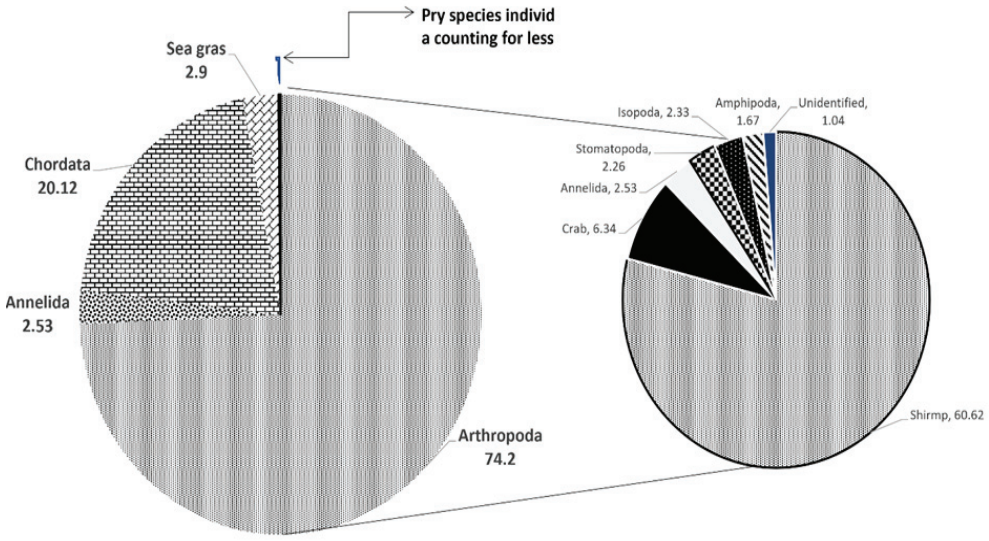

Figure 2: PSIRI% of main prey species in the diet of *T.* ***trachurus*** from Western Coast of Libya

Table 2: Diet of *T.trachurs* from Western Coast of Libya

Phylum	Subphylum	Class	Order		O	%FO	%PN	%N	%PV	%V	%PSIRI
Arthropoda	Crustacea	Malacostraca	Isopoda		6	4.26	50.8	0.59	33.9	0.68	1.80
			Amphipoda		4	2.86	43.8	0.34	46.9	0.42	1.29
			Stomatopoda		4	0.02	0.54	0.105	68.7	1.40	1.74
			Decapoda		80	73.39	93.4	32..96	91.8	72.9	67.9
				Shrimp	71	50.3	94.2	95.31	19.8	68.9	28.74
				Crab	11	7.80	60.7	0.78	64.8	3.05	4.90
				Unidentified	3	2.13	36.8	0.23	38.9	0.99	0.81
Total					**86**	**78.8**	**95.0**	**97.3**	**93.2**	**75.4**	**74.2**
Mollusca	Pelecypoda	Bivalves			4	0.71	28.5	0.04	4.35	0.02	0.12
Chordata	Vertebrata	Osteichthyes	Unidentified		1	19.86	73.4	2.19	81.5	23.9	15.39
Annelida		Polychaeta			8	5.67	40.37	0.32	28.6	0.27	1.96
Rhodophyta					11	0.71	5.56	0.02	1.54	0.01	0.02
Seagrass					1	2.83	78.5	0.08	79.3	0.31	2.23

of *T. trachurus* .arvae were shrimp and crab as benthic animals. The Trophic level of *T. trachurus* .as 2.98.

In order to investigate the effects of sex, season, and length on food composition, a Permanova model was used. The total length was represented by eight 25 mm bins, ranging from 150 to 375 mm. There is an equal distribution of sexes across the size spectrum. No significant difference in diet composition among *T. trachurus* size and sex (R=0.042, p=0.118 and R= -0.036, p=0.943 respectively).

On other hand, the diet composition of *T. trachurus* did not differ significantly among the stages of maturity gonad and seasons (R=0.006, P=0.391 and R=-0.012, p=0.692 respectively). Displays the findings from the MDS of diet composition based on seasons. A stress coefficient of 0.05 emphasizes, the rather good representation of similarities in the 4-dimensional MDS plot. Prey items from the different seasons are grouped in clusters with overlap, underlining strong seasonal .similarity in diet composition

Morphometric and meristic analysis

A total of 1334 *T. trachurus* were sampled during this study (Table 4). The females predominated in size ranged from 120 to 370 mm TL and males ranged from 100 to 349mm TL. The analysis of total length structure of *T. trachurus* revealed that the catch of both sex is divided to

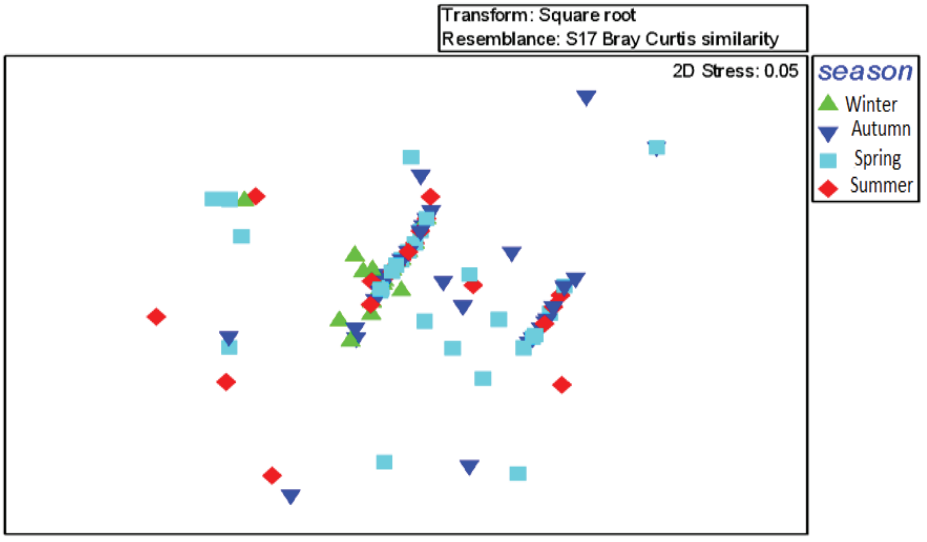

Figure 3 : The MDS similarity of preys composition among the seasons.

27 of length group. The most abundant group for females was from 210 to 219 mm with the maximum length 361 mm and minimum length 123 mm while the most abundant group for males was from 160 to 169 mm with the maximum length 340mm and minimum length 104mm. The majority of *T. trachurus* samples were caught in February and June (Figure 4).

Length-weight relationships

The total weight of females and males from 13 to 409 g, and 9 to 340 g respectively. There was a significant difference in the length-weight relationships between males and females ($t=5.3$, $p<005$; Figure 5). Fitted length-mass relationships for females were: $W(g) = 7.18 \times 10^{-6} TL^{3.02}$; n=798,

Table 4: Sample size of *T. trachurus*. from Western Coast of Libya.

Months	Sample size		TL range (mm)	
	♀	♂	♀	♂
January	37	43	140-259	160-249
February	127	55	170-359	200-349
Marsh	59	41	200-349	130-339
April	44	34	220-279	220-279
May	69	39	190-370	190-319
June	114	66	129-229	130-269
July	43	58	140-219	130-239
August	54	47	140-209	120-209
September	70	29	150-219	110-209
October	59	44	130-239	100-229
November	68	41	200-279	130-289
December	54	39	200-279	200-269

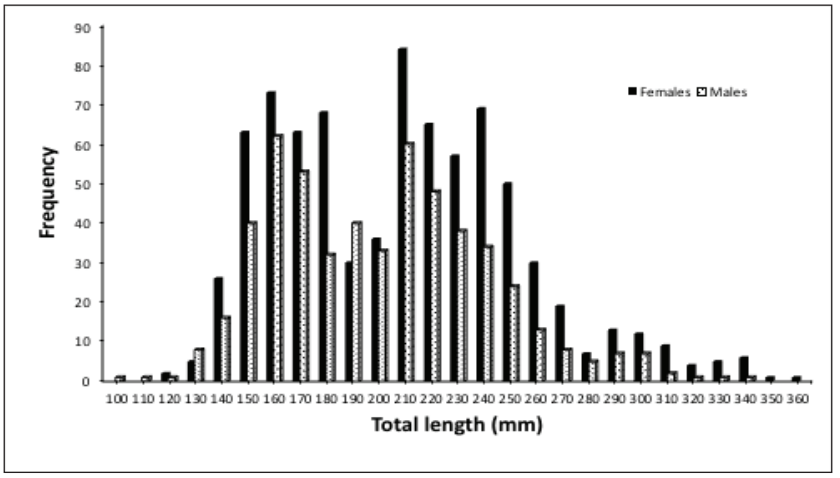

Figure 4: Number of female and male of *T. trachurus* .ampled from Western Coast of Libya (2019-2020; n=1334, Females=798, Males=536).

=0.975 and, males were: W(g) = 8.63 x 10^{-6} $TL^{2.98}$; n=536, =0.97. *T. trachurus* .oes not exhibit isometric growth; therefore, Fulton condition index was not suitable for this species, so Le Cren equation was good alternate.

The condition of individual *T. trachurus* ranged from 0.42 to 1.96 (SD=0.09). The highest condition factor of both sexes was in July (Figure 6). The Kruskal-Walli's rank revealed no statistically significant differences of females (P=1.45) and males (P=1.59).

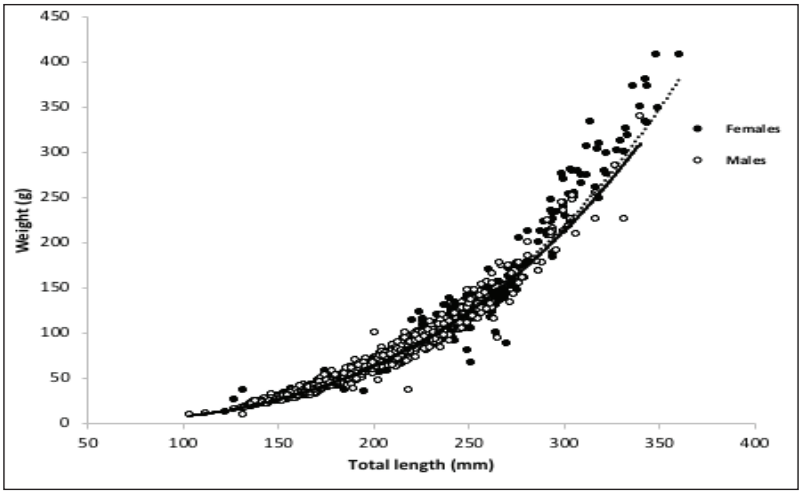

Figure 5: Relationship between weight (g) and total length (mm) between male and female of *T. trachurus*. from Western Coast of Libya

Gastro Somatic Index

Figure 7 (a) exhibited the GaSI of males and females of *T. trachurus*. GaSI values of mature *T. trachurus* .anged from 1.4±0.04 to 5.31 ±0.30. The highest value of feeding was recorded in July. There was a relationship between GaSI and maturity stages, whereas, the highest value of GaSI was at stage

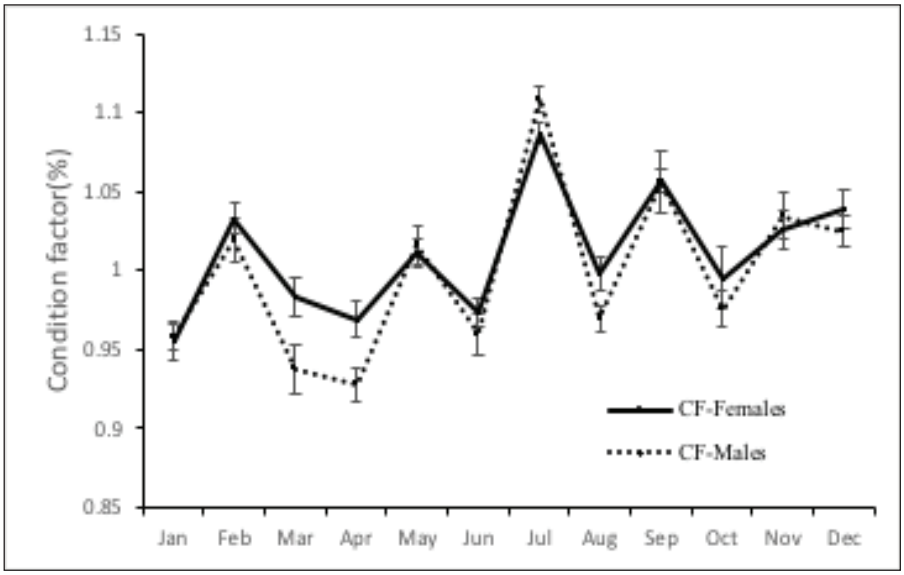

Figure 6: Condition factor of males and females *T. trachurus*. in Western Coast of Libya (Error bars calculated by SD).

III (late ripening) and stage IV (ripening) of females and males of *T. trachurus* .2.45±0.15, 2.34±0.21 respectively). (Figure 7 (b)). Seasonally, the Kruskal-Walli's rank of GaSIs indicated highly significant difference between mature females and males among the seasons (W=19.8, X^2 =7.8, df = 3, p = 0.001 and W=35.6, X^2 = 7.8, df = 3, p = 0.008 respectively).

Discussion

The present study provides basic information on the food and feeding habits of *T. trachurus* in the Libyan coast. Crustaceans were the dominant diet of *T. trachurus* (PSIRI=74%), whereas, the most Crustaceans were Decapoda (68%PSIRI). Also, *T. trachurus* can ingest considerable volumes of small fish and seagrass which contributed the greatest

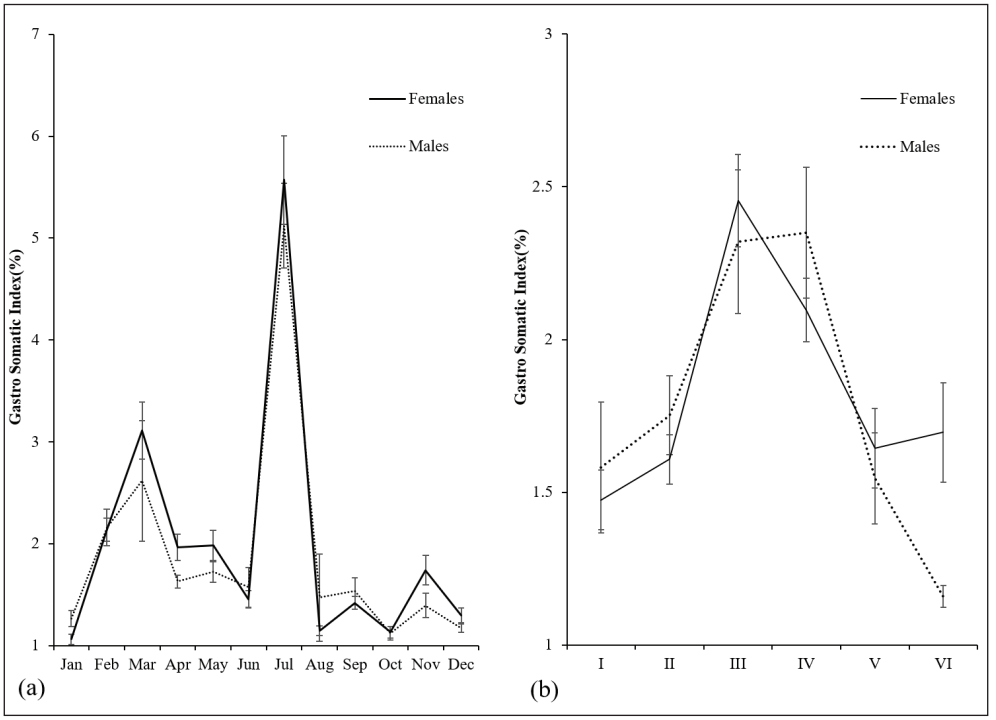

Figure 7: Gastro Somatic Index (GaSI) of mature females and males of *T. trachurus* with (a) seasons, (b) maturity stages *T. trachurus* (Error bars indicate to standard error).

amount to the diet (PSIRI=15%, PSIRI=2%) respectively. This species is regarded as an opportunities filter feeder that fed on zooplankton, the same result was given by Kerstan and Leslie (1994). There were no significant dietary changes according to size, gender and season. *T. trachurus* Fed on all water layers and different habitat types during the year, maybe due to it was an omnivore behavior with a preference for animal material; but benthopelagic species such as shrimp and crab have a high value. According to Stergiou and Karpouzi (2002), trophic levels of *T. trachurus* In the Mediterranean ranged from 3.4 to 3.9 (mean=3.6). Although, showed the trophic levels is less than that mean in the present result, but still in the range for omnivore behavior (2.9< Trophic <3.7). In fact, collecting samples in a limited amount of time and space was insufficient to define the food composition and trophic level of fish because predators can easily and quickly adjust to changes in food abundance, availability and changing their trophic level (Garrido & Murta 2011). Concerning the value of the present study, the maximum length (L_{max}=361mm)

was much lower than those given by Carrillo (1978) in Mediterranean (L_{max} =372mm) and Šantić (2008) in Adriatic (L_{max} =370mm), while in Spain and Portuguese coast were much bigger (L_{max} =590mm and L_{max} =436 mm respectively) (Costa, 2010 & Fariña Pérez, 1983). Also if we consider the whole sample, females and males have similar total length composition with slight annual variation. Although, both sexes of *T. trachurus* .elationship have positive allometry. So, the values of the slop (b) for females was slightly higher than three which means the weight increased faster than the total length; while, the (b) values in males was relatively close to three this indicated the males were slow in growth. The (b) value varies slightly from place to another and over the time, but the most previous studies confirmed that it is close to three.

Šantić *et al.* (2011) studied *T. trachurus* .n the eastern Adriatic Sea, and presented that the growth was isometric (b=3). Also, Cost (2010) in Portugal the estimated relation`s parameter b showed that the growth of both sexes was isometric. While in Syrian water the males of *T. trachurus* Were larger than females with negative allometric growth for both (Galiya *et al.,* 2020). Furthermore, Cherif *et al.* (2006) estimated the growth of *T. trachurus* in the Tunisian coast which is close to the value of the present study. Maybe this disparity of the value due to the sampling assessment procedures. Erdoğan *et al.* (2016) stated that the reason for the length and weight relationship is not constant, possible due to difference factors such as food availability, fish feeding rate, gonad development and spawning period, whether daily and/or seasonal change (Cost, 2010). Condition factors and fattening of individual are impacted by environmental conditions and food supply regulations (Gomiero & de Souza Braga, 2005). When the condition factor is greater than one that indicate to the good condition and the fish is heavy for its length (Le Cren, 1951). Although, there are no statistically significant differences were observed between sex and among the seasons. The noticeable increase in condition factor in July is related to increased feeding activity and gastro somatic index during the summer. Based on macroscopic examination of the gonad, the present study noticed that the spawning period begins at the end of the winter and the spring. The average gastro

somatic index reached of *T. trachurus* at a peak point in autumn before its breeding season. Condition factor and gastro somatic index can thus be used as predictors of spawning potential across the season, and it can also be utilized as an indicator for total egg production when combined with population size (Marshall *et al.,* 1999 & Wuenschel *et al.,* 2013).

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عادات التغذية وبعض المظاهر البيولوجية لإسماك الصاورو الأسود، *Trachurus trachurus*، (لينيوس، 1758) في الساحل الغربي لليبيا

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الملخص

تهدف هذه الدراسة للتعريف بطبيعة وعادات التغذية عند اسماك الصاوروالأسود من خلال دراستها لمدة سنة كاملة من 2019 وحتى 2020. تم تجميع 1334 سمكة باستخدام شباك الجرف من الساحل الغربي الليبي وتحديدا من الساحل المقابل لمدينة طرابلس. تراوح الطول الكلى لهذه العينات من 100 الى 360 مليمتر ووزنها من 13 إلى 409 جرام واظهرت الدراسة أن الإناث تصل الى احجام أكبر مقارنة بالذكور وكان نموها الومترى موجبا، ولدراسة الغذاء في اسماك الصاورو الأسود تم اختيار 109 معدة ممتلئة من خلالها تم احتساب مؤشر الفريسة الخاص بالأهمية النسبية (RSIRI٪) على مستوى الشعبة والطائفة. اشارت التحاليل أن معدات الصاورو الأسود ضمت 4758 من الفرائس الفردية التي تنتمى الي ستة شعب و أربع طوائف، وكانت الوجبة الرئيسية لها عشاريات الأرجل المتمثلة في الجمبري والسرطانات البحرية يليها يرقات الأسماك العظمية الصغيرة والأعشاب البحرية، ولم يلاحظ تغير واضح في تركيبة الغذاء عند ربطها بالنمو والجنس ومراحل النضج وفصول السنة. ومن عادات التغذية تم وضع الصاورو الأسود في المستوى الغذائي المحدد له والمساوي 2.98 الذي يعكس حقيقة أن هذا النوع من الأسماك يتغذى بشراهة على مدى واسع من اللافقاريات والأعشاب مع ميل واضح الى اكل اللحوم.