

## PRELIMINARY STOMACH CONTENTS ANALYSIS OF BULLET TUNA *AUXIS ROCHEI* (RISSO, 1810) IN TUNISIAN WATERS

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### SUMMARY

*The diet composition of bullet tuna, Auxis rochei (Risso, 1810) was studied using 234 specimens collected from January 2015 to June 2016 in the coastal areas of Tunisian waters. Among 234 stomachs examined, 126 were empty (%VI = 53.85). After the stomach contents analysis, 13 prey taxa belonging to 11 families were identified. This study was based mainly on the evolution of the index of relative importance (IRI) with respect to sex, fish size and season. Auxis rochei are carnivorous fish that feed opportunistically on whatever abundant resource is available in the environment with a preference for Teleosts, crustaceans and cephalopods. Teleosts were found in the majority of stomachs, with a total relative importance (%IRI) of 80.65% and Sardinella aurita was the most important prey species (%IRI = 74.17). All other prey (crustaceans and molluscs) are secondary or incidental.*

### RÉSUMÉ

*La composition du régime alimentaire de 234 spécimens de bonitou (Auxis rochei) (Risso, 1810) recueillis entre janvier 2015 et juin 2016 dans les zones côtières des eaux tunisiennes a été étudiée. Parmi les 234 estomacs examinés, 126 étaient vides (%VI = 53,85). Au terme d'une analyse des contenus stomacaux, 13 taxons proie appartenant à 11 familles ont été identifiés. Cette étude reposait essentiellement sur l'évolution de l'indice de l'importance relative (IRI) en ce qui concerne le sexe, la taille des poissons et la saison. Auxis rochei est un poisson carnivore qui s'alimente de manière opportuniste en fonction de l'abondance des ressources disponibles dans son environnement, avec une préférence marquée pour les téléostéens, les crustacés et les céphalopodes. Les téléostéens ont été trouvés dans la majorité des estomacs, avec une importance relative totale (%IRI) de 80,65%, et Sardinella aurita était l'espèce-proie la plus importante (%IRI = 74,17). Toutes les autres proies (crustacés et mollusques) sont secondaires ou accidentelles.*

### RESUMEN

*Se estudió la composición de la dieta de la melvera (Auxis rochei, Risso 1810) utilizando 234 ejemplares recogidos desde enero de 2015 a junio de 2016 en las áreas costeras de las aguas tunecinas. De los 234 estómagos examinados, 126 estaban vacíos (%VI = 53,85). Tras el análisis de los contenidos estomacales, se identificaron un total de 13 taxones de presas pertenecientes a 11 familias. Este estudio se basó principalmente en la evolución del índice de importancia relativa (IRI) con respecto al sexo, talla del pez y la temporada. Auxis rochei es un pez carnívoro que se alimenta de forma oportunista de cualquier recurso abundante disponible en el medio, con una preferencia por los teleosteos, crustáceos y cefalópodos. Se hallaron teleosteos en la mayoría de los estómagos, con una importancia total relativa (%IRI) del 80,65% y Sardinella aurita fue la especie presa más importante (%IRI = 74,17). Todas las demás presas (crustáceos y moluscos) tienen una importancia secundaria o incidental.*

### KEYWORDS

*Auxis rochei, Stomach contents, Index of relative importance, Tunisian waters*

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## 1. Introduction

The bullet tuna, *Auxis rochei* (Perciformes; Scombridae), is a medium epipelagic fish distributed worldwide in tropical and sub-tropical waters around the world (Sabatés and Recasens, 2001). It appears along the continental shelf, forming large schools near the surface. The spawning season is reported to last from June to September (Allaya, 2013).

*Auxis rochei*, with *Sarda sarda* and *Euthynnus alletteratus*, is the most abundant small tuna species in the Tunisian waters, with average catches of approximately 23000 tn y<sup>-1</sup> (Anon., 2016). In this area, *A. rochei* is mainly harvested by using different fishing gears, such as purse seine, light fishing, gill nets, longlines, pelagic trawl, and beach seine (Hattour, 2000). Despite the evident economic importance of bullet tuna, there are very few studies on its trophic ecology in Tunisian waters. Thus, a knowledge of the feeding habits of this species is essential in determining its role in the pelagic food web and contributes to a better understanding of trophic dynamics, information which is needed as fisheries scientists apply ecosystem principles to fisheries management (Pauly *et al.*, 2000).

Analysis of stomach contents is the most direct method of investigating fish diet (Hynes, 1950; Windell, 1971; Wootton, 1994). Here we investigate the feeding habits of *A. rochei*, caught in Tunisian waters by examining the composition and relative occurrence of food items. Therefore, this study aims to provide more detailed information on the dietary composition, size-related in diets and feeding strategy of *A. rochei* in the coastal waters of Tunisia for the systematic management and conservation of its stocks, as the species is an economically and ecologically valuable fishery resource in Tunisian waters.

## 2. Material and methods

Between January 2015 and June 2016, 234 specimens of Scombrid fish species *Auxis rochei* (Risso, 1810) were collected in landing sites by random sampling from the commercial catches off the coastal areas of Tunisian waters. Samples were captured with different fishing gear (purse seine, light fishing, gill nets, longlines, pelagic trawl, and beach seine).

All fish were measured to the nearest 1 mm fork length (FL), weighed to the nearest 0.1 g and their stomachs were extracted and fixed in 10% formalin solution for later analysis. In the laboratory, prey items were identified to the lowest possible taxon and counted.

The number of empty stomachs was recorded and used to calculate the vacuity index (%VI= number of empty stomach\*100/total number of analysed stomachs).

The importance of the different prey types was evaluated using the following dietary indexes:

- percentage frequency of occurrence (%O) = number of stomachs in which a food item was found \*100/ total number of full stomachs;
- percentage numerical abundance (%N) = number of each prey item \*100/the total number of prey in all stomachs;
- percentage gravimetric composition (%W) = wet weight of each prey item ×100/the total weight of stomach contents.

To estimate the importance of each food items among the forage, an Index of Relative Importance IRI (Pinkas *et al.*, 1971) was calculated as follows,  $IRI = \%O (\%N + \%W)$  for the major forage categories (Hyslop, 1980) and compared among different groups according to season, sex and size. This index was examined for two size-groups that corresponded roughly to juveniles (<33 cm FL) and adults (>33 cm FL) of *Auxis rochei*.

Although the IRI may not be good index as pointed out by MacDonald and Green (1983), this index was used in this paper because IRI was often used in other studies on stomach contents and it is easy to compare with the results of other studies. The index was expressed in percentage as follows:  $\%IRI = (IRI / \sum IRI) * 100$ .

Statistical differences ( $P < 0.05$ ) in diet composition with respect to length-class, sex and season were assessed by the Chi-square test of the frequencies of a given prey (Sokal and Rohlf, 1981). The variation in vacuity index (%VI) was also tested using the Chi-square test over a contingency table of the number of empty stomachs.

### 3. Results

#### 3.1 Feeding intensity

Among the 234 stomachs of *Auxis rochei* examined, 126 were empty (VI% = 53.85). The highest number of empty stomachs was found in June (94.59%) and July (90.63%), while the lowest was observed in December (18.18%) (**Figure 1**). The proportion of empty stomachs was not significantly different among the two size-classes ( $\chi^2 = 0.31$ ,  $P > 0.05$ ), and corresponded to juveniles (VI% = 48.39) and adults (VI% = 55.81), respectively.

Fish is an equally important component in the diet of both sexes, occurring in 75% of both male and female stomachs containing food. The proportion of empty stomachs varied significantly between sexes ( $\chi^2 = 8.32$ ,  $P < 0.05$ ).

#### 3.2 Diet composition

The analysis of stomach contents led to the identification of 835 prey individuals, for a total weight of 1028.8 g. The overall diet consisted of 13 prey taxa belonging to 11 families (**Table 1**). Teleosts constitute the most frequently observed group, with 80.65% of the total %IRI, followed by crustaceans (%IRI = 17.98), while the other taxa, i.e. molluscs and vegetal were scarcely found (%IRI < 1) (**Table 1**). At the family level, Clupeidae (*Sardinella aurita*) was the major prey consumed by *A. rochei* (%IRI = 74.17).

#### 3.3 Diet composition in relation to the sex

Overall, teleosts had a slightly higher percentage of IRI in males than in females. Female teleosts had an IRI of 64.4% and crustaceans 33.53%, while males had 78.31% and 21.35% of teleosts and crustaceans respectively) (**Figure 2**). Based on the frequency of prey, the diet composition varied significantly between males and females for teleosts ( $\chi^2 = 8.35$ ;  $P < 0.05$ ) and crustaceans ( $\chi^2 = 6.12$ ;  $P < 0.05$ ). However, no significant differences were detected for molluscs ( $\chi^2 = 2.65$ ;  $P > 0.05$ ) and vegetal ( $\chi^2 = 0.89$ ;  $P > 0.05$ ).

#### 3.4 Seasonal and size-related variation in diet

The total number of prey taxa consumed by bullet tuna differed between seasons ( $\chi^2 = 31.25$ ,  $P < 0.05$ ), with fish having the most diverse diet in winter (%IRI = 89.02) and the least diverse diet in autumn (%IRI = 56.10) (**Figure 3**).

Teleosts with six families (Clupeidae, Sparidae, Belonidae, Scombridae, Engraulidae, and Atherinidae) were the dominant prey group present in the diet of all size-classes (**Figure 4**). Crustaceans were the most important prey group in the small size-class (<33 cm FL) (%IRI = 58.19), while the contribution of teleosts was comparatively low (%IRI = 33.84). The frequency of crustaceans significantly decreased with increasing size ( $\chi^2 = 13.26$ ,  $P < 0.05$ ), whereas the frequency of teleosts significantly increased ( $\chi^2 = 86.59$ ,  $P < 0.05$ ). Furthermore, our results show that the predation of Vegetal is not related to the size of the fish. Indeed, no significant differences among size-classes were found between the ingestion of Vegetal ( $\chi^2 = 1.11$ ,  $P > 0.05$ ).

### 4. Discussion

In this study, a high percentage (51.95%) of *A. rochei* stomachs was empty. High percentages of empty *A. rochei* stomachs in other waters, such as the Ligurian Sea (43.4%), Coastal Waters of Iloilo (Philippines) and Indian waters (60.3%) were also reported by several researchers (Plandri *et al.*, 2009; Jasmine *et al.*, 2013; Baeck *et al.*, 2014). This indicates that the high percentage of empty *A. rochei* stomachs could be a characteristic of the species.

Feeding intensity is negatively related to the percentage of empty stomachs (Bowman and Bowman, 1980). In our study, vacuity index (%VI) values are increased in June, July, August and September. This period coincides with the spawning season of bullet tuna in Tunisian waters (Allaya *et al.*, 2013). In accordance with a previous study (Hattour, 2000), the need for this species to take in enough energy for the breeding period has probably resulted in an increase in their feeding intensities from January to May, which corresponds to the prespawning

period, and this may also explain the decrease in the %VI values. The greater feeding intensity of *A. rochei* extended between October and December, corresponding to the post-spawning period where the animal must consumed more to palliate the deficit due to the spawning event.

According to the literature bullet tuna is an epipelagic off shore carnivore, feeding on various prey items such as shrimps, copepods, crab larvae, amphipods, cephalopods, gastropods, stomatopods, bivalves, and ostracods, while depending primarily on small fish species (Mostarda *et al.*, 2007; Baeck *et al.*, 2014). However, the present study and the study of Plandri *et al.* (2009) from the Ligurian Sea showed different results with the former studies.

The results of our study indicated that *A. rochei*, are carnivorous fish that feed opportunistically and her diet, was composed mainly of fish and secondarily of crustaceans and molluscs. Therefore, *A. rochei* is considered an opportunistic carnivore, whose prey are selected on the basis of their availability and geographic abundance (Pihl, 1985; Gkenas *et al.*, 2012).

In comparison to other Scombridae, the diet of *Auxis rochei* in the Tunisian waters most closely resembles that of little tunny *Euthynnus alletteratus* (Hattour, 2000; Hattour, 2009; Hajje *et al.*, 2016), both species feeding primarily on teleosts. Teleosts, the dominant prey item, shows a high prey specific abundance value (IRI% = 78.61). Among fishes, clupeids is the main prey group preferred by bullet tuna mostly *Sardinella aurita* which represented the main feeding source of *Auxis rochei* (IRI%= 71.6). This importance of *S. aurita* in diet composition may be due to their abundance and nutritional profitability. However, Mostarda *et al.* (2007) reported that in the southern Tyrrhenian Sea, *A. rochei* foraged mainly on planktonic crustaceans, small cephalopods and fish larvae. Consoli *et al.* (2008) described that the feeding strategy of *A. rochei* could be related to the abundance of dominant prey items and its ability to take advantage of the most profitable food source at a particular time.

All other prey (crustaceans and molluscs) are secondary or incidental. Our results clearly confirm those reported in the Mediterranean Sea (Hattour, 2000; Baeck *et al.*, 2014). Based on our results, crustaceans are mainly represented by Penaeid and small organisms such as isopods and amphipods. The presence of crustacean species in the diet of *A. rochei* was already reported in other studies conducted in the Mediterranean Sea (Hattour, 2000; Mostarda *et al.*, 2007; Baeck *et al.*, 2014) and in the Indian waters (Jasmine *et al.*, 2013).

Molluscs, mainly represented by cephalopods, are occasional prey by bullet tuna in the Tunisian coast. Nevertheless, the contribution of cephalopods in the diet of bullet tuna was very low compared to that recorded for other Scombridae species such as blue fin tuna (*Thunnus thynnus*) and little tunny (*Euthynnus alletteratus*) (Mostarda *et al.*, 2007; Hajje *et al.*, 2016).

In other hand, the occurrence of Vegetal in bullet tuna diet is incidental. Among the 234 analyzed stomachs in this study, 4 contains vegetal. Hattour (2000) has already registered vegetal in the stomachs of bullet tuna in shallow depths of the same area. However, several studies in the Mediterranean Sea had not reported the presence of vegetal in dietary of this species (Mostarda *et al.*, 2007; Baeck *et al.*, 2014).

Differences in the diet of males and females is supportive of the proposed inter-sexual differences in schooling behaviour (Oxenford, 1985). Males take a higher proportion of free swimming pelagic species than females, which is consistent with the suggestion that they spend more time away from flotsam. The sexes have differ in the proportion of fish with empty stomachs and in the average number of prey consumed.

In our study, the stomach contents of *A. rochei* showed seasonal variations, but teleosts were the dominant prey group during all seasons with a peak value recorded in winter. Crustaceans were also present in the stomachs throughout the year, with a peak value recorded in autumn. Molluscs were found mainly in summer. Bullet tuna respond to seasonal changes in food availability, which reflects the species' opportunistic behaviour and trophic adaptability, allowing them to take advantage of the most readily available prey in the environment at any time. They tend to rely mainly on the abundant fish as prey, although they will occasionally exploit crustaceans molluscs to enhance their diet.

In this study, the obtained results show that food habits considerably change as fish grow. Larger specimens tended to consume biggest range of prey species comprising mostly teleosts. While the juveniles had a higher proportion of crustaceans in their diet and preferred small pelagic fish and fish larvae. The proportion of crustaceans was decreased as body size increased, whereas the consumption of fishes increased gradually. This supports the findings of Whitley (1964) who observed that *A. rochei* fed on small sized fish (juveniles and larvae of anchovies, mullets, silver sides and other small fish). Moreover, Yang and Sun (1977) who observed that *A. rochei* of fork length between 24 and 35 cm in the in Taiwan waters, fed on euphausiaceans, followed by

mollusc pteropods and unidentified fish larvae. Overall, small schooling pelagic clupeoids dominated the diet in terms of %N and %W. However, the species also consumed demersal prey, demonstrating that it may feed opportunistically during periods when epipelagic prey are less abundant.

In summary, bullet tuna is an opportunistic predator whose diet in the Tunisian waters, comprises mainly teleosts. In its first years of life, the feeding ecology of *A. rochei* is fragmentary. They tend to rely mainly on the abundant fish as prey, although they will occasionally exploit crustaceans and molluscs to their diet. The importance of fish and crustaceans differed significantly with seasons as well as in small and larger size-classes. Our paper brings new data about important aspects of the life cycle of this fishing resource and represents a first step toward an ecosystem-oriented approach to fishing management of this species.

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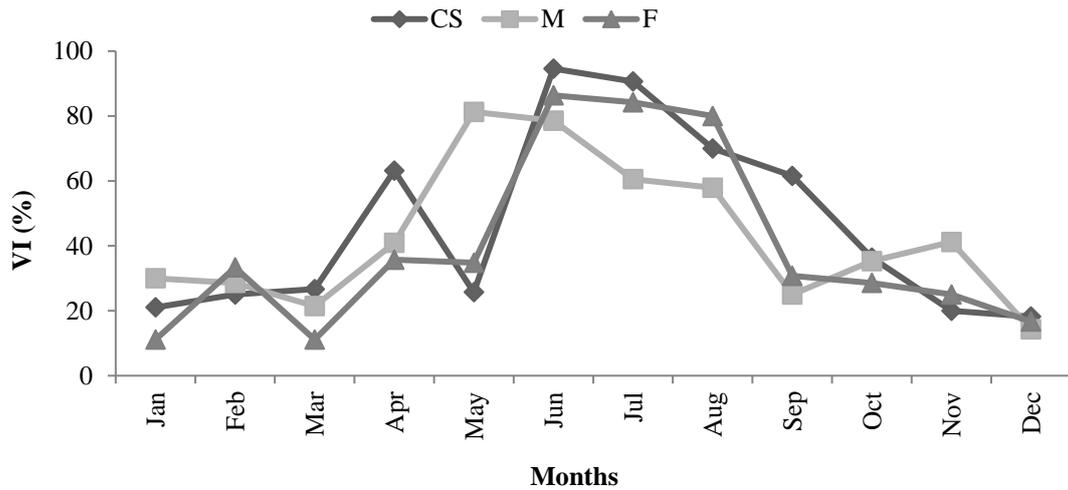
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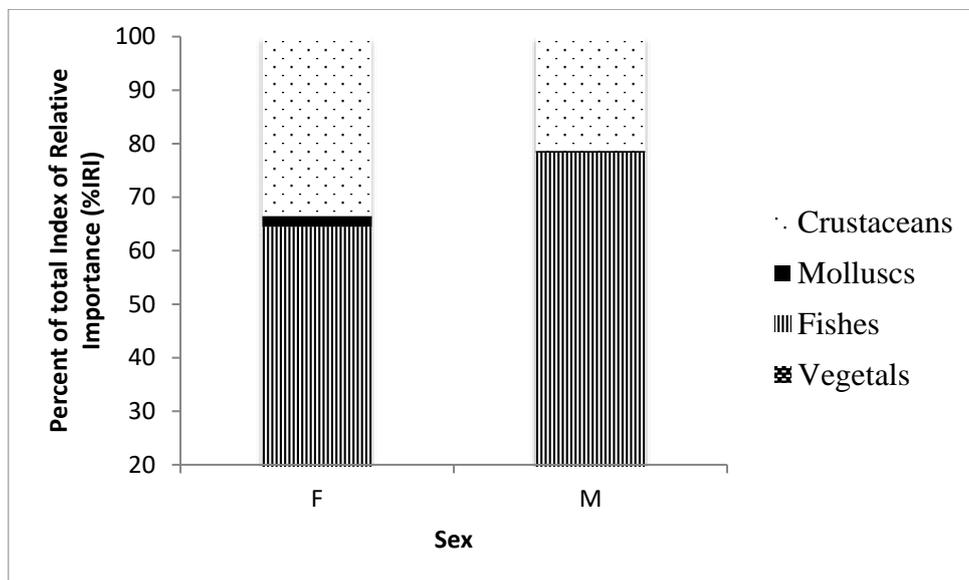
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**Table 1.** Diet composition of *Auxis rochei* of Tunisian waters.

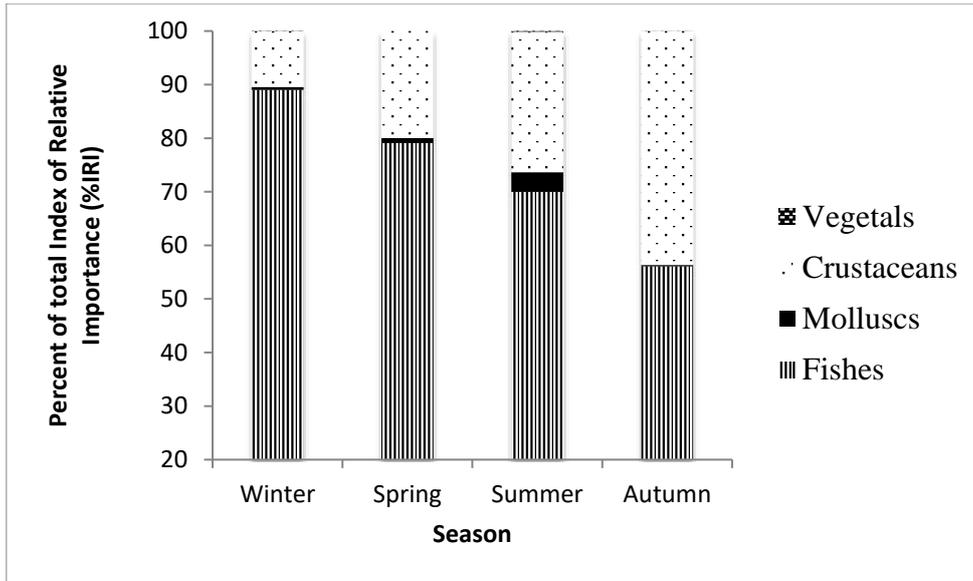
<b>Group</b>	<b>Family</b>	<b>Item (species)</b>	<b>O%</b>	<b>N%</b>	<b>W%</b>	<b>IRI</b>	<b>IRI%</b>
Teleosts	Clupeidae	<i>Sardinella aurita</i>	36,11	30,06	55,63	3094,28	74,17
		<i>Sardina pilchardus</i>	12,04	6,11	3,42	114,70	2,75
	Sparidae	<i>Boops boops</i>	4,63	3,11	1,58	21,75	0,52
		<i>Diplodus sp</i>	5,56	2,99	1,11	22,80	0,55
		<i>Pagellus sp</i>	1,85	0,72	0,47	2,19	0,05
	Belonidae	<i>Belone belone</i>	5,56	5,03	1,36	35,50	0,85
	Scombridae	<i>Scomber sp</i>	2,78	4,31	1,41	15,90	0,38
	Engraulidae	<i>Engraulis encrasicolus</i>	6,48	2,51	1,59	26,60	0,64
	Atherinidae	<i>Atherina sp</i>	1,85	5,03	0,47	10,18	0,24
		Non-identified Teleosts	3,70	4,67	0,99	20,97	0,50
		<b>Total teleosts</b>	<b>77,56</b>	<b>63,55</b>	<b>65,51</b>	<b>3364,88</b>	<b>80,65</b>
Molluscs	Sepiidae	<i>Sepia officinalis</i>	6,48	1,92	1,48	22,00	0,53
	Loliginidae	<i>Loligo sp</i>	3,70	0,48	0,63	4,10	0,10
		Non-identified Gastropoda	10,19	1,44	1,36	28,50	0,68
	<b>Total molluscs</b>	<b>13,01</b>	<b>3,74</b>	<b>3,33</b>	<b>54,59</b>	<b>1,31</b>	
Crustaceans	Penaeidae	<i>Penaeus kerathurus</i>	12,04	4,55	8,87	161,60	3,87
		<i>Metapenaeus monoceros</i>	12,96	7,43	10,87	237,12	5,68
		<i>Squilla mantis</i>	7,41	3,47	3,40	50,93	1,22
	Gammaridae	Non-identified Gammaridae	11,11	1,68	0,71	26,54	0,64
	Isopoda	Non-identified Isopoda	10,19	4,43	1,58	61,20	1,47
		Non-identified Crustaceans	16,67	9,82	2,95	212,92	5,10
	<b>Total crustaceans</b>	<b>61,37</b>	<b>29,62</b>	<b>26,34</b>	<b>750,30</b>	<b>17,98</b>	
Vegetals		Non-identified Vegetals	3,70	0,48	0,12	2,21	0,05
	<b>Total Vegetals</b>	<b>3,70</b>	<b>0,48</b>	<b>0,12</b>	<b>2,21</b>	<b>0,05</b>	



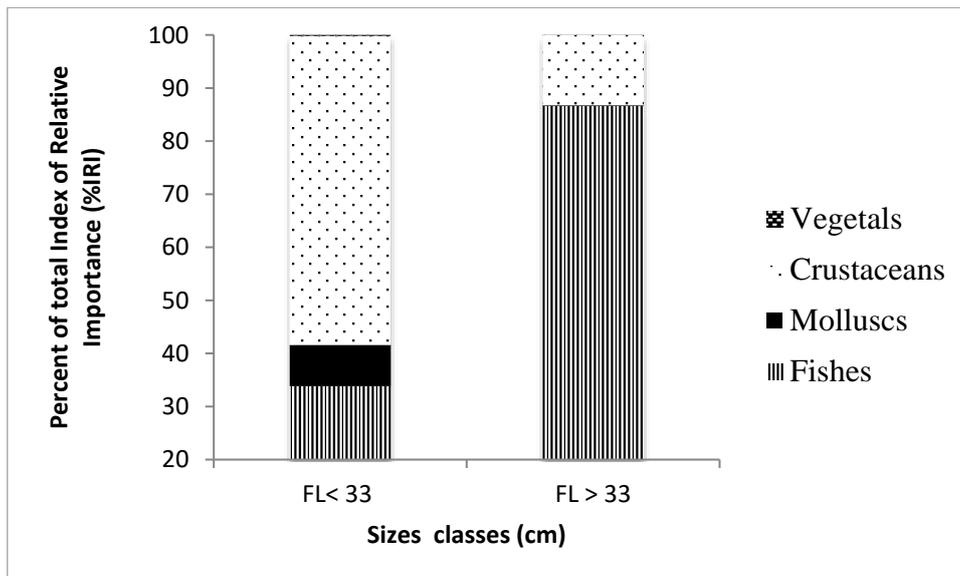
**Figure 1.** Variation in percentage of empty stomachs of *Auxis rochei* throughout the year. CS, combined sex; F, female; M, male.



**Figure 2.** Diet composition for males and females of *Auxis rochei* in the Tunisian waters, based on the percentage index of relative importance values (IRI%) of the major prey groups. (Vegetals and Molluscs are not always noticeable in the figure because of their minimum values).



**Figure 3.** Diet composition of *Auxis rochei* in the Tunisian waters throughout the year, based on the percentage index of relative importance values (IRI%) of the major prey groups. (Vegetals and Molluscs are not always noticeable in the figure because of their minimum values).



**Figure 4.** Diet composition of *Auxis rochei* in the Tunisian waters among size-classes, based on the percentage index of relative importance values (IRI%) of the major prey groups. (Vegetals and Molluscs are not always noticeable in the figure because of their minimum values).