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Diet composition of round sardinella (*Sardinella aurita*) and flat sardinella (*Sardinella maderensis*) in the south of Atlantic Moroccan coast

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ABSTRACT

The feeding of round sardinella (*Sardinella aurita* Valenciennes, 1847) and flat sardinella (*Sardinella maderensis* Lowe, 1938) was investigated in the south of the Moroccan Atlantic coast from February 2015 to January 2016. Several indices were estimated to figure out the diet composition of *Sardinella* spp. Thusly; the vacuity index was low for both species, which indicates a high availability of food in the study area. The crustaceans were the main prey headed by the copepods which were the most abundant prey item throughout the year whereas the detritus was mainly present in winter and spring. The variation of the index of relative importance (IRI) depending on the size of *Sardinella* spp. has shown that the small individuals have a different dietary preference than large individuals. The results provide a baseline for resource managers to evaluate and predict differences in feeding ecology, which could be useful in the management of the fishery of these species.

INTRODUCTION

The biological interactions between species are not limited only to trophic relationships; parasitism and diseases also occur. However, predator-prey relationships have a dominant role. In fact, natural mortality can vary considerably with predation, famine, and disease, but predation seems to be the dominant factor **(Daan, 1989)**. Studies on diet composition are crucial in community ecology considering that the use of resources by organisms has a major influence among population interactions within a community **(Mequilla and Campos, 2007)**. Analysis of stomach contents could provide helpful information concerning the position of the fishes in the food web of their environment and estimation of trophic levels **(Pauly and Christensen, 2000; Post *et al.*, 2000)**. In addition, the quality and quantity of food are among primordial factors that directly impacting the growth, and indirectly, the maturation and the mortality of fish, thus being ultimately related to fitness **(Wootton, 1990)**.

The *Sardinella* spp. are marine pelagic fish that widely distributed throughout the tropical and subtropical seas of the world, including the Mediterranean and the Black Sea **(Froese and Pauly, 2018)**. They are a key species in the ecosystem of the northwest African upwelling region **(Bard and Koranteng, 1995)**. For some years now, the biomass of *Sardinella* spp. has been fluctuating. For instance, the average catch of *Sardinella* spp. in the Moroccan cost was increased from 11 283 tons in 2016 to 32 404 in 2017, knowing that the south of Cape Boujdor (26°N) area represents 90% of the average catch **(INRH, 2017)**. The *Sardinella* spp. represent the second pelagic species caught in this area after the sardine (*Sardina pilchardus* Walbaum, 1792), where *Sardinella aurita* represents the most dominant species **(Baali et *al.*, 2017**).

No study of *Sardinella* spp. feeding has been conducted in the South of Atlantic Moroccan coast despite it is subject to the influence of coastal upwelling towards the surface of the ocean. This area is very disturbed; it is the seat of the meeting of North Atlantic Central Waters and South Atlantic Central Waters. The upwelling index in this region is the most unstable and the highest of all Moroccan zones. It has a bimodal distribution with a secondary peak in May-June and a principal one in September-October **(INRH, 2018)**. However, many studies have been developed on dietary habits of *S. aurita* from neighbouring areas, such as the north-west African coast **(Pham-Thuoc and Szypula, 1973)**, the Senegal waters **(Nieland, 1982)**, and the Mauritania coast **(Gushchin and Corten, 2015)**, as well as from the Caribbean Sea **(Gómez-Canchong, 2004)** and the Northwest Atlantic **(Bowman, 2000)**. In the Mediterranean, the first work was done by **Ananiades (1952)** in Greece, then followed by several works such as in the Aegean Sea **(Tsikliras *et al*., 2005)**, in the center of the Mediterranean Sea **(Lomiri, 2008)**, in the northwest of the Mediterranean Sea **(Morote, 2008)**, in egyptian coast **(Abdel Aziz and Gharib, 2007; Madkour, 2012)**, in the north of the Aegean Sea **(Karachle and Stergiou, 2014)** and in turkish coasts **(Bayhan and Sever, 2015)**. Contrariwise, little is known about feeding of *S. maderensis*, because few studies have dealt with, such as **Bowman (2000)** in the Northwest Atlantic and **Gushchin and Corten (2015)** in the Mauritania coast.

The purpose of our work is to study the feeding habits of *S. aurita* and *S. maderensis* in the south of Atlantic Moroccan coast, by body size class and season, as well as to identify which the most important food groups of *Sardinella* spp. and to investigate if their diet in our study area will be as of other populations throughout their distribution.

MATERIALS AND METHODS

Samples were collected from local commercial fishermen in Dakhla port who use purse seine and pelagic trawl as fishing gear along the area between Cape Boujdour (26°N) and Cape Blanc (21°N) in the south of the Moroccan Atlantic coast (Fig. 1). The care and use of experimental animals complied with the Moroccan Legislation Article 14, Section 3, Bill 122.22 and the Cartagena Protocol on Biosafety to the Convention on Biological Diversity promulgated by the royal decree "1.09.123".

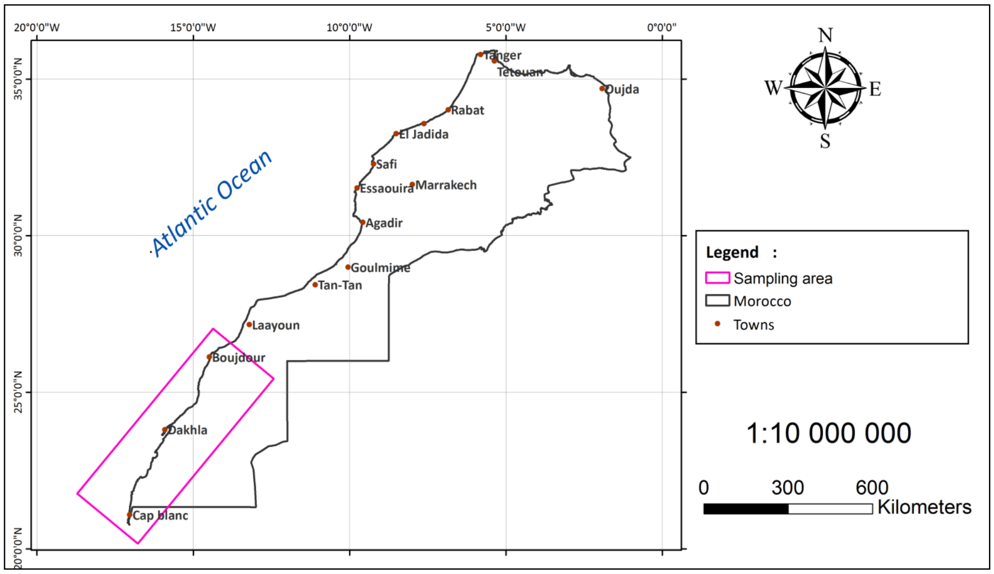

Fig. 1. Sampling area of *Sardinella aurita* and *Sardinella maderensis*

Stomach contents of dead fish were examined monthly during the period of February 2015 - January 2016. A total of 216 *Sardinella aurita* and 84 *Sardinella maderensis* were collected during the sampling period, with the total length ranging between 13.5 and 35.5 cm for *S. aurita* and between 22.5 and 33.5 cm for *S. maderensis*. The stomachs were immediately fixed with 70% Ethanol solution. Their contents were poured into a petri dish and the internal faces of the stomachs were rinsed with water to detach any debris that may remain associated. Preys were then identified, counted and weighed. Each prey was determined to the lower possible taxonomic level, using a binocular microscope and different identification keys **(Chevreux and Fage, 1925; Rose, 1933; Richardson *et al.*, 2013)**. Preys in a state of advanced digestion were recognized by their undigested remains, such as appendages of crustaceans. Furthermore, empty stomachs were counted during identification processing. Ontogenetic shifts in the diet of *Sardinella* spp. were examined by grouping the fish according to Sturge's rule **(Sturge, 1929)**; a rule for determining number of classes to use in a histogram or frequency distribution table. Where: $k = 1 + 3.322(\log_{10} n)$, k is the number of classes, n is the size of the data. The interval between each class is then obtained as follows: Class interval = $(X_{max} - X_{min}) / k$. With X_{max} and X_{min} are respectively the largest and the smallest sizes.

Several indices were used in the analysis of the stomach contents. The following indices were used to quantify the importance of different prey items in the diets of *S. aurita* and *S. maderensis*:

- Vacuity index (%VI): it allows to report the proportion of empty stomachs and corresponds to the ratio in percentage between the number of empty stomachs (ES) and the total number (TN) of stomachs analyzed **(Geistdoerfer, 1975)**.

$$\%VI = \frac{ES}{TN} \times 100$$

- The frequency of occurrence (% FO): it represents the number of stomachs containing at least one individual of prey (ni) divided by the total number of non-empty stomachs (N), expressed as a percentage **(Hureau, 1970)**.

$$\%FO = \frac{ni}{N} \times 100$$

This index makes it possible to know the food preferences of the predatory species then the prey is classified in three categories:

%FO ≥ 50%: preferential preys.
10% <%FO< 50%: secondary preys.
%FO ≤ 10%: occasional preys.

- The numerical abundance (%N): provides information on the feeding behaviour of the predator. It is the ratio between the number of individuals of a given prey (Np), and the total number of prey items (Npt), expressed as a percentage.

$$\%N = \frac{Np}{Npt} \times 100$$

- The gravimetric composition (%W): It is the ratio between the fresh weight of a given prey (Wp) and the total weight of all prey ingested (Wpt), expressed as a percentage.

$$\%W = \frac{Wp}{Wpt} \times 100$$

- The total fullness index (TFI) of the stomach is calculated for each individual containing prey **(Bowering and Lilly, 1992)**. This index which is used to evaluate the filling of the stomach was modified by **Bozzano *et al.* (1997)** as follows:

$$TFI = \frac{Ws \times 10^4}{Tw}$$

Where Ws is the weight of stomach contents, and Tw is the total body weight of each individual (g).

- Index of relative importance (%IRI): The combination of measurements of %FO, %N and %W gives more accurate information by reducing the bias in descriptions of animal dietary data **(Pinkas *et al*., 1971)**. Thus, these variables are combined in composite indexes, like the Index of Relative Importance, IRI:

$$\%IRI = \%FO \times (\%N + \%W)$$

To reveal the relationships between and within season and preys, the Correspondence Analysis (CA) was used as a graphic method via the package FactoMineR **(Lê *et al*., 2008)** implemented in R software, version 3.6.1 (R Core Team

2019) based on data given in a contingency table. The package performs the Chi-Square test of Independence to determine the signification of relationship between the two variables. In order to evaluate relative similarity in the food preferences of different *Sardinella* spp. size groups, the principal component analysis (PCA) of the IRI and the numerical abundance (N) of each prey carried out using also the package FactoMineR.

RESULTS

Of the 216 specimens of *Sardinella aurita* examined, 11 (5.09%) had empty stomachs most of them were encountered during winter (8.51%), followed by autumn (6.06%), summer (5.80%) and spring (2.99%) (Table 1). While for *Sardinella maderensis*, it was in summer that we found two empty stomachs out of 84 examined (2%) (Table 1). Furthermore, the results of the variance analysis of the Total Fullness Index (TFI) by season showed that the season has a significant effect for the both species ($p < 0.05$) (Table 1). For *S. aurita* the highest values of TFI were observed in autumn and summer. Concerning the *S. maderensis*, the highest values of TFI were perceived in winter and spring.

Table 1. Seasonal variation of the vacuity index (VI) and the total fullness index (TFI) of *S. aurita* and *S. maderensis* in the south of Atlantic Moroccan coast, 2015-2016.

		Sardinella aurita			***Sardinella maderensis***	
Index	VI (%)	TFI	Number of stomachs	VI (%)	TFI	Number of stomachs
Autumn	6.06	17.55	33	0	15.64	23
Winter	8.51	5.14	47	0	42.85	30
Spring	2.99	9.98	67	0	39.37	12
Summer	5.80	13.63	69	8.69	7.56	19
Total	5.09	10.52	216	2	26.35	84

Prey items were grouped in five different taxa for *S. aurita* and four groups for *S. maderensis*. Crustaceans were the main prey, followed by fish (eggs, larvae and scales) and detritus (Figs. 2 and 3). The seasonal variation of the percentage of occurrence shows that crustaceans represent the preferential prey for *S. aurita* during the four seasons (FO > 50%). Fish and detritus constitute secondary preys during winter and spring (FO > 10%) (Fig. 2). For *S. maderensis*, crustaceans represent the preferential prey and fish (eggs, larvae and scales) serve as secondary preys during the whole year. As for *S. aurita* there is a high percentage of detritus during spring and winter (Fig. 3). The rest of preys constituted occasional prey for both species (Figs. 2 and 3).

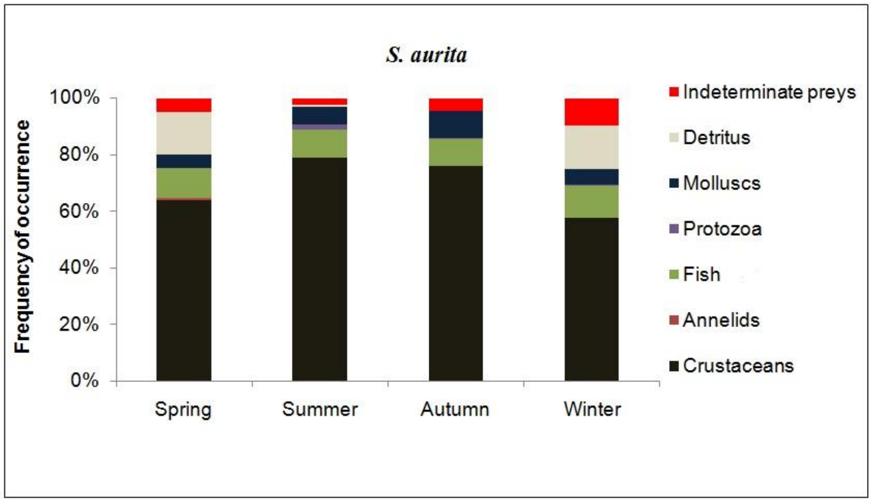

Fig. 2. Round sardinella, southern Moroccan coast, 2015-2016. Seasonal variation in diet based on percentage of frequency of occurrence (%FO)

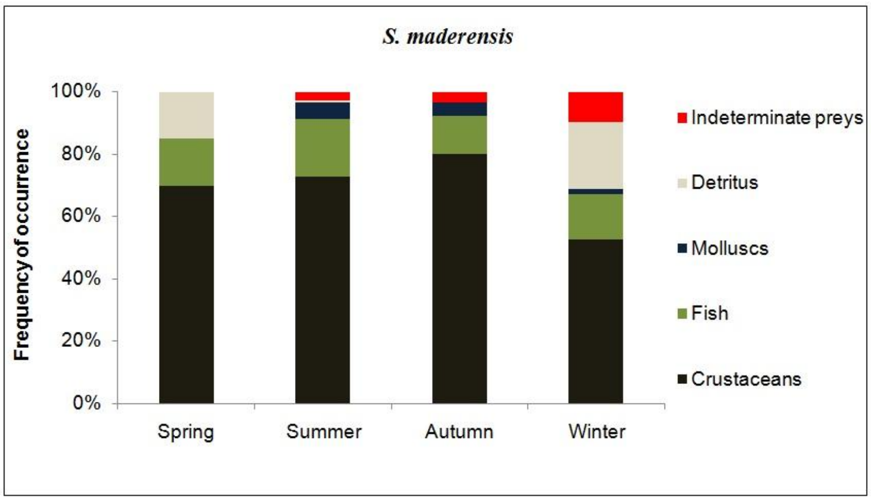

Fig. 3. Flat sardinella, southern Moroccan coast, 2015-2016. Seasonal variation in diet based on percentage of frequency of occurrence (%FO)

The percentage of frequency of occurrence varied according to *Sardinella* spp. size classes (Figs. 4 and 5). For the whole size classes, *S. aurita* feeds on crustaceans as preferential preys. We noticed also the presence of fish and molluscs for all size classes. For the most individuals, we observed that the percentage of crustaceans decreases with the appearance of detritus, which has served as secondary prey for specimens with sizes between (28.5 and 35.5 cm) (Fig. 4). For *S. maderensis*, crustaceans represent also the preferential prey for the whole sizes followed by fish, which has served as secondary prey for all sizes. The detritus were present with high percentage (14.3-22.5%) for small and large individuals (Fig. 5).

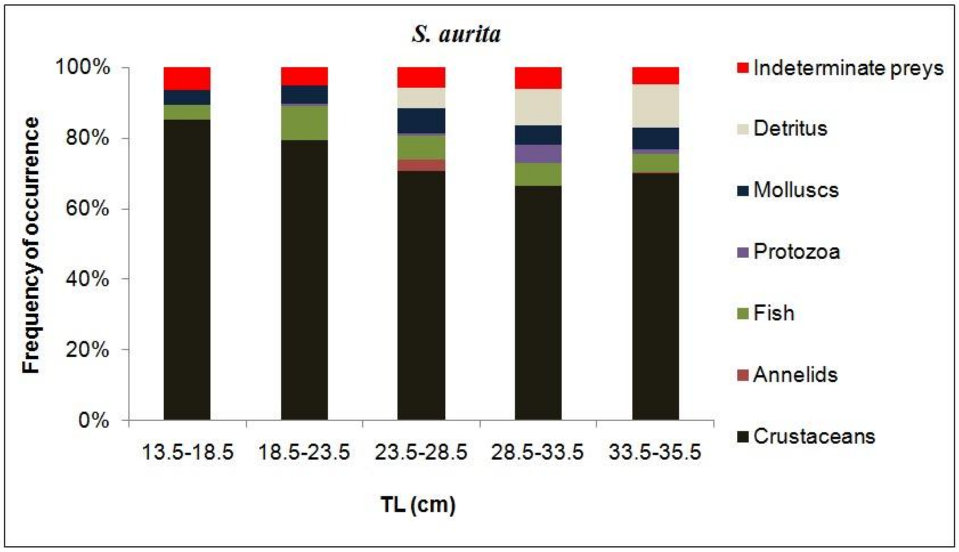

Fig. 4. Round sardinella, southern Moroccan coast, 2015-2016. Variation in diet based on percentage of frequency of occurrence (%FO) as a function of total length (TL, cm)

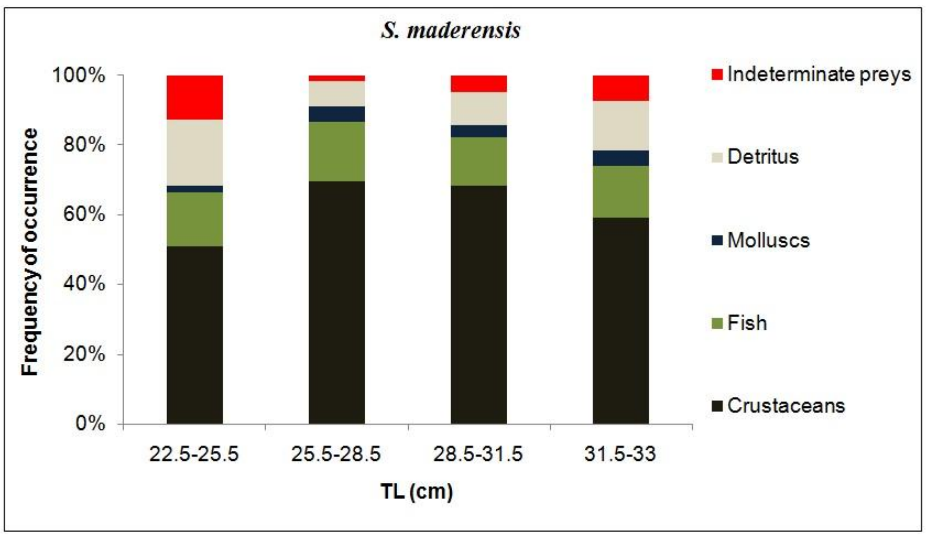

Fig. 5. Flat sardinella, southern Moroccan coast, 2015-2016. Variation in diet based on percentage of frequency of occurrence (%FO) as a function of total length (TL, cm)

For *S. aurita*, 10140 prey items were observed, but on the other hand, for *S. maderensis* it's only 4173 prey items. Frequency of occurrence, numerical abundance, gravimetric composition and index of relative importance values were assessed in the study, which allowed us to identify five food groups for *S. aurita* and three taxa for *S. maderensis* including Crustacea, Mollusca, Teleostei, Protozoa and Annelida (Tables 2 and 3).

Table 2. Feeding of round sardinella *S. aurita* (N%: percentage numerical abundance, FO%: frequency of occurrence, W%: percentage gravimetric composition, IRI%: percentage index of relative importance)

Subclass	Prey groups	N (%)	FO (%)	W (%)	IRI (%)
Crustacean	Copepoda (Calanidae)	14.85	11.69	9.39	19.1
	Copepoda (Candaciidae)	1.81	0.98	1.84	0.24
	Copepoda (Centropagidae)	2.78	2.62	8.36	1.97
	Copepoda (Corycaeidae)	1.22	2.7	0.32	0.28
	Copepoda (Ectinosomatidae)	0.69	2.45	0.19	0.15
	Copepoda (Euchaetidae)	0.02	0.08	0.00	0.01
	Copepoda (Euterpinidae)	23.23	13.25	5.03	25.23
	Copepoda (Metridinidae)	0.33	0.25	0.68	0.02
	Copepoda (Oithonidae)	0.1	0.25	0.02	0.01
	Copepoda (Oncaeidae)	18.52	8.91	4.2	13.64
	Copepoda (Paracalanidae)	0.06	0.41	0.17	0.01
	Copepoda (Pontellidae)	0.03	0.16	0.07	0.01
	Copepoda (Sapphirinidae)	0.06	0.25	0.11	0.01
	Copepoda (Temoridae)	0.09	0.65	0.08	0.01
	Copepoda (non identified)	13.1	8.34	18.8	17.93
	Cladocera (Podonidae)	4.76	3.35	2.31	1.6
	Amphipoda (non identified)	0.78	2.7	0.12	0.16
	Euphausiacea (non identified)	0.1	0.57	0.1	0.01
	Isopoda (Tylidae)	0.02	0.16	1.04	0.01
	Ostracoda (non identified)	0.06	0.41	0.02	0.01
	Zoea (non identified)	1.02	4.42	7.22	2.46
	Cirripedia (Cypris larvae)	1.6	3.11	0.68	0.48
	Decapoda (non identified)	0.28	1.55	0.08	0.04
	Mysidacea (non identified)	0.03	0.25	0.12	0.01
	Crustacean eggs	0.61	1.71	0.01	0.07
	Nauplius	0.04	0.33	0.00	0.01
	Total	**86.17**	**71.55**	**60.98**	**83.48**
Mollusca	Bivalvia	4.42	5.47	4.55	3.31
	Pteropoda	0.15	0.9	3.52	0.22
	Total	**4.57**	**6.37**	**8.07**	**3.53**
Teleostei	Anchovy eggs	4.3	5.63	16.46	7.9
	Fish scales	3.4	4.08	12.47	4.38
	Fish larvae	0.04	0.25	0.04	0.01
	Fish eggs	0.34	0.25	0.09	0.01
	Total	**8.08**	**10.21**	**29.06**	**12.30**
Protozoa	Pelagic foraminifera	0.18	1.07	0.3	0.02
Annelida	Annelida	0.18	1.07	0.3	0.02
Detritus	Detritus	n.i.d	6.69	n.i.d	n.i.d
Undetermined	Undetermined	0.97	3.86	1.59	0.66

Table 3. Feeding of flat sardinella *S. maderensis* (N%: percentage numerical abundance, FO%: frequency of occurrence, W%: percentage gravimetric composition, IRI%: percentage index of relative importance)

Subclass	Prey groups	N (%)	FO (%)	W (%)	IRI (%)
Crustacean	Copepoda (Acartiidae)	0.22	0.21	0.11	0.01
	Copepoda (Calanidae)	15.36	12.47	3.50	14.91
	Copepoda (Candaciidae)	0.12	1.04	0.26	0.03
	Copepoda (Centropagidae)	0.36	1.87	0.93	0.15
	Copepoda (Corycaeidae)	1.29	3.74	0.47	0.42
	Copepoda (Ectinosomatidae)	0.05	0.42	0.01	0.01
	Copepoda (Euterpinidae)	24.61	12.06	2.78	20.93
	Copepoda (non identified)	7.19	12.06	1.30	6.49
	Copepoda (Lucicutiidae)	0.07	0.21	0.04	0.01
	Copepoda (Oithonidae)	1.01	1.46	0.17	0.11
	Copepoda (Oncaeidae)	12.22	5.41	1.27	4.62
	Copepoda (Paracalanidae)	0.02	0.21	0.01	0.01
	Copepoda (Temoridae)	0.07	0.62	0.12	0.01
	Cladocera (Podonidae)	5.54	6.03	2.44	3.05
	Amphipoda (non identified)	0.78	2.7	0.12	0.16
	Amphipoda (Leucothoe)	0.05	0.21	1.17	0.02
	Isopoda (Tylidae)	0.36	1.25	0.20	0.04
	Ostracoda (non identified)	0.05	0.42	0.22	0.01
	Zoea (non identified)	0.46	3.12	0.21	0.13
	Decapoda (non identified)	0.36	1.66	3.11	0.37
	Crustacean eggs	0.05	0.42	0.00	0.01
	Nauplius	0.07	0.62	0.01	0.01
	Crab megalope	0.55	1.66	2.60	0.33
	Total	**70.43**	**69.44**	**21.42**	**51.75**
Mollusca	Bivalvia	0.5	3.12	0.15	0.13
	Pteropoda	0.05	0.42	0.01	0.01
	Total	**0.55**	**3.54**	**0.16**	**0.13**
Teleostei	Fish larvae	0.14	0.83	0.01	0.01
	Fish eggs	25.33	7.28	75.77	46.64
	Anchovy eggs	1.29	2.08	0.98	0.30
	Fish scales	1.49	5.41	1.12	0.89
	Total	**28.25**	**15.6**	**77.88**	**47.84**
Detritus	Detritus	n.i.d	7.28	n.i.d	n.i.d
Undetermined	Undetermined	0.77	4.14	0.54	0.28

Considering all indices for *S. aurita* there was a clear dominance of crustaceans and they were the most important prey group while other taxa, i.e. teleostei, mollusca, protozoa and annelida, were less importance in the diet. Among the crustaceans, copepods especially Euterpinidae and Calanidae made the most important contribution to diet (IRI% = 25.23 and 19.1 respectively). Thus, copepods were the primary food item in the diet, varying quantities between 0.01 and 25.23 of IRI% (Table 2). The crustaceans was followed by teleostei (IRI% = 12.3), mollusca (IRI% = 3.53), protozoa (IRI% = 0.02) and annelida (IRI% = 0.01). For *S. maderensis*, the values obtained from the three indices (N, FO and IRI) show the dominance of crustaceans in the diet of this species. As for *S.*

aurita, copepods belonging to Euterpinidae and Calanidae families made the most important contribution to diet of this species (IRI% = 20.93 and 14.91 respectively). However, in terms of weight, teleostei represent the highest value (W% = 77.88), and it were dominated by fish eggs (W% = 75.77) (Table 3).

The symmetric plot of season and preys displayed by the Correspondence Analysis (CA) (Figs. 6 and 7) showed that for the two species, crustaceans is close to the center of gravity of the cloud; corresponding to the mean profile, which confirm that crustaceans are the main prey all year-round. However, the food preferences between the four seasons revealed the presence of three groups for *Sardinella* spp. (Figs. 6 and 7). For *S. aurita*, the first group is composed from individuals sampled during autumn and spring seasons. They stomachs are characterized by Mollusca and Annelida. The two other groups consist of specimens sampled in summer and winter, which their preys are described by the presence of Protozoa and undetermined preys respectively (Fig. 6). The stomach content for *S. maderensis* was almost similar between autumn and spring (group 1) where the crustaceans consist the main prey. In addition to the crustaceans, in the summer the stomach content is constituted by Mollusca and Teleostei (group 2) variously to the winter which is marked by the presence of Protozoa, Teleostei and undetermined preys (group 3) (Fig. 7). For the two species, the chi square of independence between season and preys was important and very highly significant (p-value < 0.001) that means taking a risk of 0.1%, the season and the type of prey cannot be considered as independent.

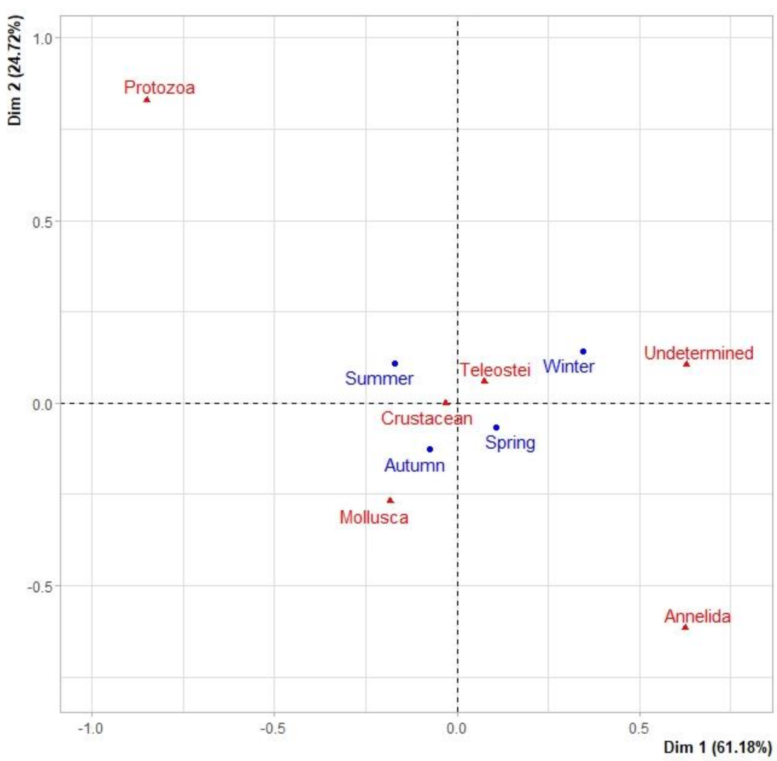

Fig. 6. Detrended correspondence analyses of seasonal similarities in stomach contents derived from analyses of dietary data for *Sardinella aurita* based on %IRI

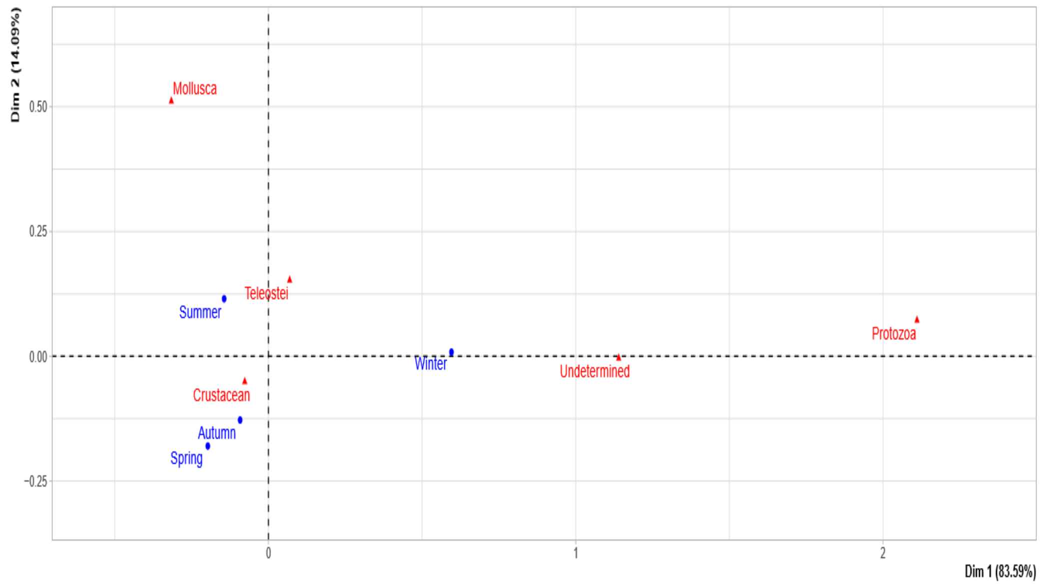

Fig. 7. Detrended correspondence analyses of seasonal similarities in stomach contents derived from analyses of dietary data for *Sardinella maderensis* based on %IRI

The estimation of the degree of similarity of food preferences between the different size groups of *Sardinella* spp. using the Principal Component Analysis (PCA) based on %IRI values showed that the population of *Sardinella* spp. is divided into three groups with different dietary preferences (Figs. 8 and 9); small, medium and large. For *S. aurita*, the first group composed of the small individuals whose sizes are between 13.5 and 23.5 cm and feeds essentially on; Zoea, Metridinidae, Copepoda, Ectinosomatidae, Emphipoda, while, the second group whose sizes are from 23.5 cm to 33.5 cm would rather feed on; Temoridae, annelida, fish scales, bivalvia. The third group constituted by individuals between 33.5 cm and 35.5 cm that feed on; Centropagidae, Oncaedae, fish larvae, Pteropoda, Candaciidae, Centropagidae (Fig. 8). The first two components explained 67.08% of the variance. Similar clustering were obtained with dimension 1 and dimension 3. The PCA performed using prey's data of *S. maderensis* showed clear separation of the three groups (Fig. 8a). Thus, the group composed of the small individuals from 22.5 cm to 25.5 cm devour the Centropagidae, Podonidae, Copepoda and Calanidae, whereas, the second group whose sizes between 25.5 cm and 31.5 cm feed on Candaciidae, Oithonidae, fish eggs and fish scale. the largest group, which size from 31.5 cm to 33 cm, would prefer to eat bivalvia, cirripedia, decapoda, fish larvae, Engraulidae, crab megalope, Corycaedae, Ectinosomatidae, Nauplius, Lucicutiidae, Temoridae, etc. (Fig. 9). The first two axes convey most of the information with 87.41% of total inertia.

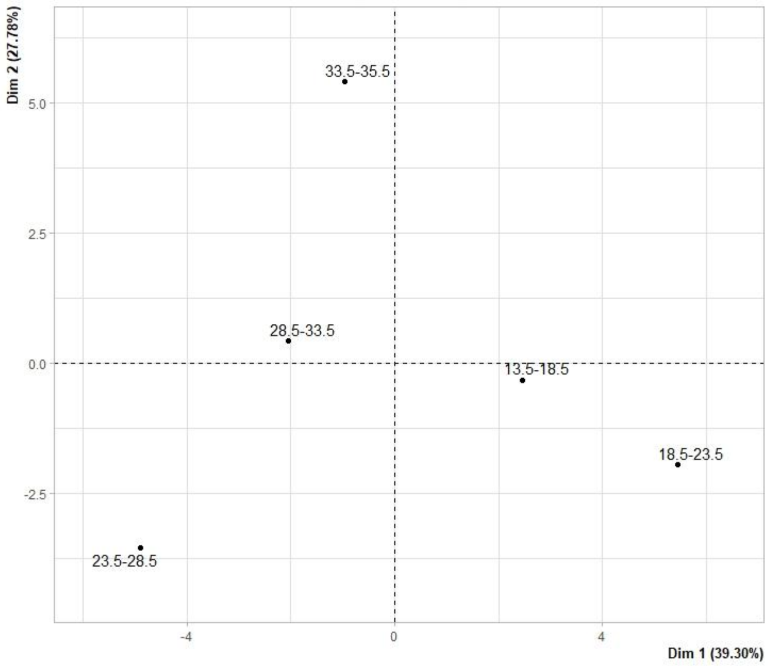

Fig. 8a. Graphical depictions of stomach contents of *Sardinella aurita* based on %IRI (a) Principal Component Analysis (PCA) diagram showing the size groups similarities

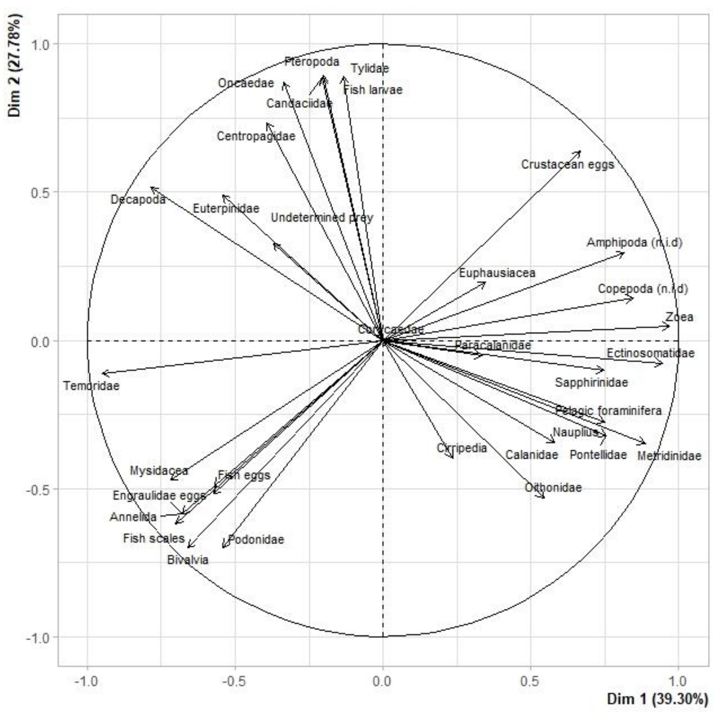

Fig. 8b. Graphical depictions of stomach contents of *Sardinella aurita* based on %IRI (b) Factor dietary preferences in the above PCA analysis

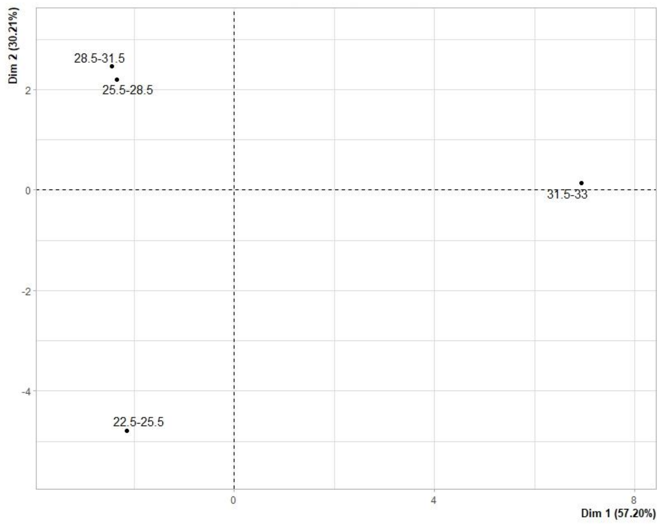

Fig. 9a. Graphical depictions of stomach contents of *Sardinella maderensis* based on %IRI (a) Principal Component Analysis (PCA) diagram showing the size groups similarities

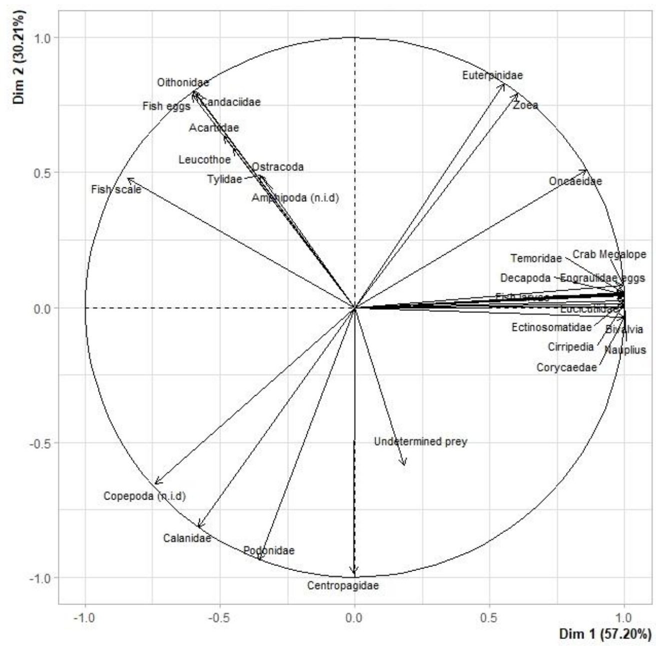

Fig. 9b. Graphical depictions of stomach contents of *Sardinella maderensis* based on %IRI (b) Factor dietary preferences in the above PCA analysis

DISCUSSION

Sardinella aurita

The results of this study showed that the list of preys is composed of 17 families with other unidentified preys due to their advanced digestion. As mentioned above, the analysis of the stomach contents of *S. aurita* revealed that the copepods were the main part of their diet where the euterpinidae, the calanidae and the oncaeidae constitute the major families. Indeed, our study has shown that *S. aurita* can be characterized as a mainly zooplankton fish. These results are in agreement with several previous studies in other areas **(Bayhan and Sever, 2015)**. Otherwise, other studies have described *S. aurita* as an omnivorous fish **(Nieland, 1982; Tsikliras *et al*., 2005; Madkour, 2012)**.

Feeding intensity was strongly seasonal. In fact, *S. aurita* feed actively throughout the year which indicates the favorable trophic conditions in the study area. Most empty stomachs were encountered in winter, followed by autumn, summer and spring. The pelagic ecosystem of this area is influenced by a varied upwelling index. In fact, the area between 25.5°N and 28°N is characterized by an upwelling index that shows a tendency to increase from April until September, while the area between 21.3°N and 25.5°N has a bimodal distribution of upwelling index; a secondary peak in May - June and a main peak in September - October **(Berrada *et al.*, 2017)**. This shows that the low upwelling index appears (October - March) in accordance with the presence of highest percentage of empty stomachs, which allows us suggesting that the hypothesis of relationship between the availability of food material and the percentage of empty stomachs could be adopted. **Tsikliras *et al.* (2005)** reveal a high VI in the Aegean Sea of northern Greece; 36.6% in autumn, 30.0% in winter, 26.6% in spring and 16.6% in summer. Similar results, conducted by **Bayhan and Sever (2015)** in the Turkish's Aegean Sea, showed that the most value of empty stomachs was mentioned in autumn (19.1%) and the lowest was noted in spring (2.00%). **Tsikliras *et al*. (2005)** propose that low VI in summer and spring was associated with spawning period that need more energy input to meet the requirements of reproduction. In contrast, in the Port Said coastline on the Mediterranean shores of Egypt, **Madkour (2012)** has reported a higher VI during summer (more than 60%) and a lower one during the spring months, which were explained by the ripe gonads that occupied abdominal cavity during the spawning season **(Madkour, 2012)**. Nevertheless, it seems that *S. aurita* displayed low vacuity index values during spring, which is the beginning of the breeding season.

According to the IRI, crustaceans were the most important prey group while other taxa such as fish (larvae, scales and eggs) or molluscs were less important in the diet of *S. aurita*. Among crustaceans, copepods contributed the most in the diet of this species. This dominance has been observed for individuals of all size classes and during the four seasons. Our results are in agreement with those of **Bayhan and Sever (2015)** in the Turkish Aegean Sea, who found that crustaceans especially copepods (calanoids) are the most important prey in the dietary of *S. aurita* with an IRI of 42.16%. On a study conducted in the Cape Hatteras area of the United States, **Bowman *et al*. (2000)** found that *S. aurita* feeds on zooplankton, especially planktonic copepods (calanoids) which were chosen as the preferred diet **(Bowman *et al*., 2000)**. Analysis of the stomach contents of *S. aurita* individuals examined in the Aegean Sea of northern Greece shows that crustaceans (copepods, amphipods, mysids, decapods larvae and others) were the main food group **(Tsikliras *et al*., 2005)**. Copepods were the most abundant prey group in winter and spring, while decapod larvae and amphipods replaced copepods in summer and autumn **(Tsikliras *et al*., 2005)**. **Lomiri *et al*. (2008)** studied the contents of the digestive system of this species in the coast of Sicily in the middle of the Mediterranean and revealed that it fed mainly on crustaceans, especially copepods. In Egypt, in the coast of Port Said, zooplankton constitutes 50.1% of the prey ingested by the species **(Madkour, 2012)**. The dominance of copepods in the diet of *S. aurita* has been reported by several authors in different study areas, in United States **(Bowman *et al*., 2000)**, Columbia (La Guajira) **(Gómez-Canchong *et al*., 2004)**, the Greek coast of the Aegean Sea **(Tsikliras *et al*., 2004, Karachle and Stergiou, 2014)**, the Sicilian coast of the Mediterranean **(Lomiri *et al*., 2008)** and the Mediterranean north-west **(Morote *et al*., 2008)**. About the detritus, which are composed of sand and degraded plant material, they were also found in Egypt **(Madkour, 2012)** and in Mauritanian waters where **Gushchin and Corten (2015)** mentioned the presence of detritus-algae.

Sardinella maderensis

For *S. maderensis*, previous studies on the dietary are scarce. In this study, the results of the stomach contents analysis showed that the diet of this species is composed of four groups of prey: crustaceans, molluscs, fish and detritus. The list of prey is composed of 16 families. The food composition of *S. maderensis* consists mainly of fish eggs and copepods (euterpinidae and calanidae). Analyzed stomachs showed that *S. maderensis* in the south of Morocco is zooplanktivorous, but we also note the presence of detritus in the stomach contents of this species for all size classes. In different parts of its distribution area, *S. maderensis* feed on detritus **(Diouf, 1996)**, phytoplankton **(Whitehead, 1985)** and zooplankton **(Da Silva Monteiro and Marques, 1998)**; cases of feeding on eggs and fish larvae are observed **(Whitehead, 1985)**. However, it should be noted that in the Mauritanian zone the amount of detritus reaches 40% of the food mass for young *S. maderensis* with TL < 100 mm **(Gushchin, 2013)**. A recent study by **Gushchin and Corten (2015)** showed that *Sardinella maderensis* is an omnivorous species with the presence of detritus in the stomach of small individuals.

Of the 84 stomachs analyzed for *S. maderensis*, two stomachs were empty representing a vacuity index (VI) of 2%. This very low value could be explained by the high availability of food in our study area as an upwelling area. In the Gulf of Arguin, **Gushchin (2013)** found that in 31 stomachs analyzed juveniles of *S. maderensis*, 13 stomachs were empty representing a VI of 42%.

The use of the gravimetric composition index showed the dominance of fish eggs in the diet of *S. maderensis* (W = 75.77%). According to the IRI, crustaceans and fish (larvae, scales and eggs) were the dominant prey groups, while, other preys such as molluscs or detritus are less important in the diet of this species the IRI index reveals that the Euterpinidae family was the most dominant prey within the copepods, followed by the Calanidae family. These results are similar to that we found for *S. aurita* which gives us an idea of the availability of these two groups of prey during this year. In addition, the value of the IRI of fish eggs observed for *S. maderensis* (46.64%) was higher than that found for *S. aurita* (< 8%), which shows that the flat sardinella have a preference towards large prey.

For the both species the presence of scales in the stomach contents, are probably due to the sampling strategy. E.g. during purse-seining/trawling, as the fish come very closely, the scales are detached from the body. In their gasping efforts, fish swallow scales.

The variation of the relative importance index depending on the size of *Sardinella* spp. has shown that small individuals have a different dietary preference than large individuals. The difference observed between size groups and seasons shows that the feeding habits of *sardinella* spp. depend mainly on the season, as well as the availability and constituents of their food supply **(Komarovsky, 1959)**. Differences in diet between size groups are likely due to energy needs, which vary by stage of development **(Tsikliras *et al*., 2005)**, allowing them to sequentially exploit a range of prey sizes ranging from small zooplankton to much larger prey **(Wootton, 1998)**.

In summary, the feeding preferences of fish species are important in classic ecological theory, mainly in the identification of food competition, the structure and stability of food webs and the evaluation of functional responses of prey-predators. The key role of feeding studies for biology and ecology of fisheries has been discovered only in the last decade with the use of the trophic level to predict the effects of fishing on the balance of marine food webs **(Pauly *et al*., 1998)**. There are no studies on the diet composition of the *Sardinella aurita* and *Sardinella maderensis* from Moroccan coast. In this study, feeding habits of the *Sardinella* spp*.* were observed. The present work indicates that crustaceans were the main prey for *Sardinella* spp. with the dominance of copepods throughout the year. We also remarked the presence of detritus in the stomach contents of the two species. The variation of the relative importance index depending on the size of *Sardinella* spp. indicates that small specimens had a different dietary preference than large ones. We hope that these findings of study will contribute to the development of management strategies of these species that has a great economic value for the region of northwest Africa.

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