Diet of the horse mackerel (*Trachurus trachurus*) in the North Atlantic of Morocco

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Abstract. The present study focused on the study of the diet biology of the horse mackerel (*Trachurus trachurus*) in the northern area of the Moroccan Atlantic between December 2015 and November 2016, with the aim of providing the biological elements for a good analysis of population dynamics and for stock management. This species has a diet composed of crustaceans as preferential prey, Teleostei classified as complementary prey. The mollusca, foraminifera and annelida considered as occasional or accidental prey. Thus, 21 categories of prey were identified in their stomach contents. The combination of the frequency of occurrence (frequency of presence and abundance in number and weight) and their evolution by size showed qualitative and quantitative changes in the feeding habits of horse mackerel during its ontogeny development. The feeding intensity is greater in adult individuals (Lt>22.5 cm) and the main species of prey consumed are: Euphausiacea and Copepoda (Calanidae).
Key Words: emptiness coefficient, Moroccan North Atlantic, relative importance index, total fullness index, *Trachurus trachurus*.

Introduction. Small pelagic fishing occupies an important place in the Moroccan fisheries sector. It covers the entire Moroccan continental shelf, Atlantic and Mediterranean and targets the main resources composed of European pilchard (*Sardina pilchardus*), Atlantic chub mackerel (*Scomber colias*), European anchovy (*Engraulis encrasicolus*), round sardinella (*Sardinella aurita*), and Atlantic horse mackerel (*Trachurus trachurus*). In 2017, 1.46 million tons of small pelagic fish were captured. Catches are mainly composed of sardines (73%), followed by mackerel (17%) and horse mackerel (7%) (INRH 2017).

Horse mackerel is very common throughout the Mediterranean Sea, in the waters of countries such as Morocco, Algeria and Tunisia (Fezzani et al 2006). It lives in waters generally less than 200 m deep, with sandy bottoms and it feeds mainly on crustaceans and fish such as anchovies (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*), pilchard (*Sardina pilchardus*), herring (*Clupea harengus*) (Quéro & Vayne 1997).

Feeding trends of fish species are crucial in classical ecological theory, mainly in the identification of food competition (Bacheler et al 2004), structure and stability of food chain (Post et al 2000) and evaluation of the functional responses of prey and predators (Dörner & Wagner 2003). The key role of diet studies for fisheries biology and ecology is important for fisheries management, and it was only discovered in the last decade with the use of trophic level to predict the effects of fishing on the balance of marine food chain (Pauly et al 1998).

In order to provide more reliable information for the good management of the horse mackerel (*Trachurus trachurus*) fishery, this work aims to study its diet in the North Moroccan Atlantic by determining the dietary composition as well as preferential and accidental preys.

Material and Method

Sampling. Sampling was done on a regular basis (once a month), with samples of about 20 kg, over the period between December 2015 and November 2016, in the North Moroccan Atlantic area (33°15 N and 35°00 N) (Figure 1, generated using ArcGIS software). For each sampling, the species is first identified in the commercial fishing catches landed at the Casablanca fishing port by coastal trawlers. The fishing gear used is a two-sided bottom trawl, classic type, used at depths ranging from 30 to 200 m. The sample unit consists of a standardized plastic case (56x37x16 cm).

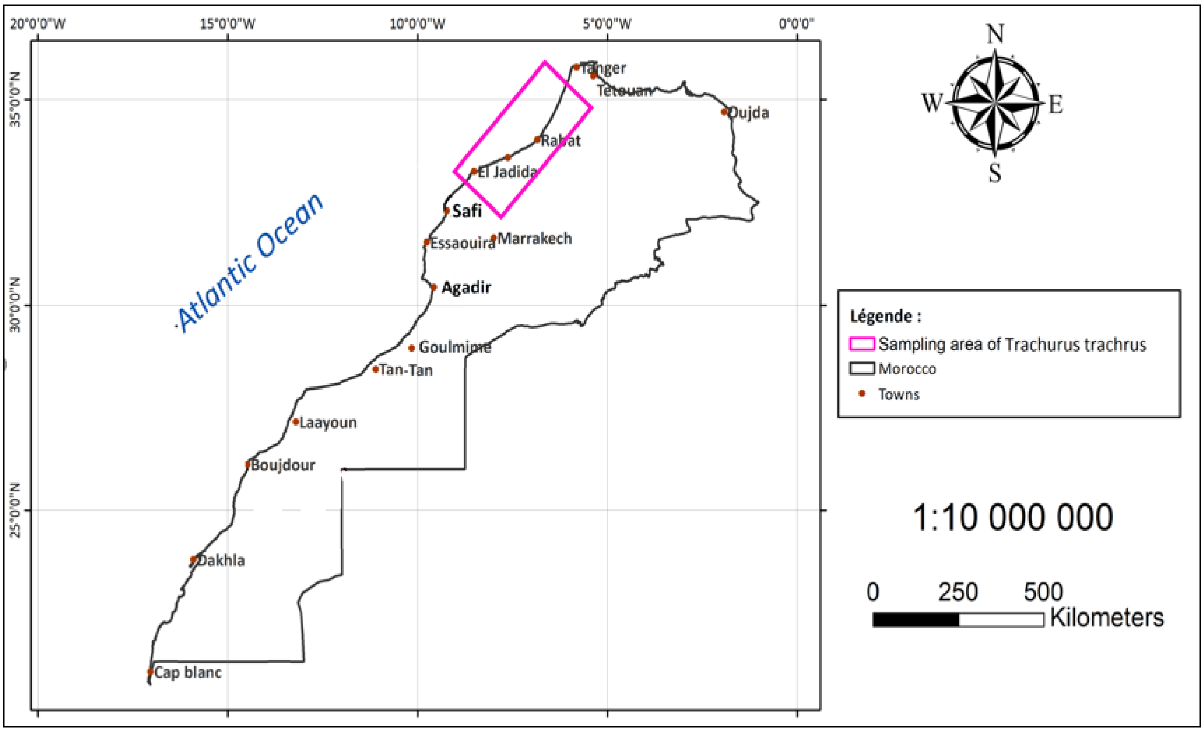

Figure 1. Sampling area for horse mackerel (*Trachurus trachurus*) (www.arcgis.com).

The stomach contents of the fish were examined monthly during the period from December 2015 to November 2016. A total of 582 individuals of horse mackerel ranging in size from 12 to 35.5 cm in total length (Lt) were collected. The stomachs were immediately fixed with a 70% ethanol solution, their contents poured into a Petri dish, and the inner surfaces of the stomachs were rinsed with water to loosen any components that might get stuck. The prey was then identified, counted, and weighed. The system has been pushed to the most precise taxonomic level possible, after observation under a binocular microscope and using various identification works (Chevreux & Fage 1925; Rose 1933; Richardson et al 2013). Preys in an advanced state of digestion were recognized by their undigested remains, such as the appendages of crustaceans.

In addition, empty stomachs were counted during the identification process. Several indices have been used in the analysis of stomach contents. The following indices were used to quantify the importance of different prey in the diet of the horse mackerel.

Vacuity index. The vacuity index (Vi %) expresses the percentage of empty stomachs (Nev) in relation to the total number of stomachs studied (Ne) (Hureau 1970; Geistdörfer 1975). This coefficient, inversely proportional to the power supply intensity, is calculated according to the following equation: Vi = Nev / Ne x 100.

Frequency of occurrence. The frequency of occurrence (Fo %) represents the ratio between the number of stomachs containing one or more individuals of a prey category (Nei) and the total number of non-empty stomachs (Nep). Thus, Fo is calculated by the following equation (Hureau 1970; Labourg et al 1973): Fo = Nei / Nep x 100.

This index indicates the importance of a given prey in relation to the stomachs examined and makes it possible to know the dietary differences of the species studied according to the following scale: Fo>50% identifies as preferential prey; 10<Fo<50% identifies as secondary prey; Fo<10% identifies as occasional prey.

Total fullness index. The total stomach fullness index (TFI) is calculated for each individual stomach containing prey (Bowering & Lilly 1992). This index, used to assess stomach filling from a quantitative point of view, is modified by Bozzano et al (1997), as follows: TFI = Ws x 10^4 / Tw; where: Ws is the weight of stomach contents and Tw is the total weight of the individual.

Index of relative importance. The contribution of each type of prey in the diet is described in percentage of frequency of occurrence (Fo), in percentage of abundance in number (N) and in percentage of abundance by weight (P) (Hyslop 1980). According to Bozzano et al (1997), a modification of the version of IRI described by Pinkas et al (1971) was used. Hence the following equation is used to determine the index of relative importance (IRI): IRI = Fo x (N + P), where: IRI>50% = preferential prey; 10<IRI<50% = secondary prey; 1<IRI<10% = complementary prey and IRI<1% = accidental prey.

Statistical analysis. To calculate the degree of similarity of food preferences in different seasons as well as between different size groups of horse mackerel, we used the Ascending Hierarchical Classification (AHC) using the STATISTICA 6 software, using the Jump Minimum as an aggregation method and Euclidean distance for distance measurement, these two methods being the most used for this type of analysis. The dendrograms obtained give us the composition of the different classes and seasons, as well as the order in which they were formed. It also tells us, on the horizontal axis, what was the value of the index between the two classes that were aggregated at a given stage or both seasons.

Results. Observations have shown that the diet of this species is based on four large groups of prey that constitute its exclusively carnivorous diet: crustaceans, mollusca (Gastropoda and Cephalopoda), annelida and teleostei. Completely undigested prey were identified at the genus and family taxonomic level. Some prey has been recognized only by appendages remnants for crustaceans and skeletal structures (otolith, scales, and vertebra) for fish. Cephalopoda are spotted by the remains of tentacles and beaks. Based on identification keys (Rose 1933; Richardson et al 2013; Chevreux & Fage 1925; Kélig et al 2006), below, Table 1 shows the faunal list of all the prey ingested and identified.

Table 1

List of prey identified in the stomach contents of *Trachurus trachurus*

Prey		*Taxonomic group*
Crustacean	Copepoda	Calanidae
		Euterpinidae
		Centropagidae
		Not identified
	Cladocera	Not identified
	Cladocera	Caprellidae
		Gammaridae
	Euphausiacea	*Euphausia* sp.
	Isopoda	Not identified
	Ostracoda	Not identified
	Zoea	*Zoea*
	Decapoda	Penaeidae
	Mysidacae	Not identified
	Nephrops	*Nephrops norvegicus*
Mollusca	Cephalopoda	*Sepia officinalis*
	Gastropoda	Pteropoda

	Bivalve larvae	Not identified
Teleostei	Anchovy	*Engraulis encrasicolus*
	Fish scales	Not identified
	Fish vertebra	Not identified
Protozoa	Foraminifera	Not identified
Worms	Annelida	Polychaeta

The vacuity index (Vi) of horse mackerel changes over the months in the same direction in both sexes with a substantially identical rate. As a result, both sexes of horse mackerel have the same feeding intensity throughout the year (Figure 2).

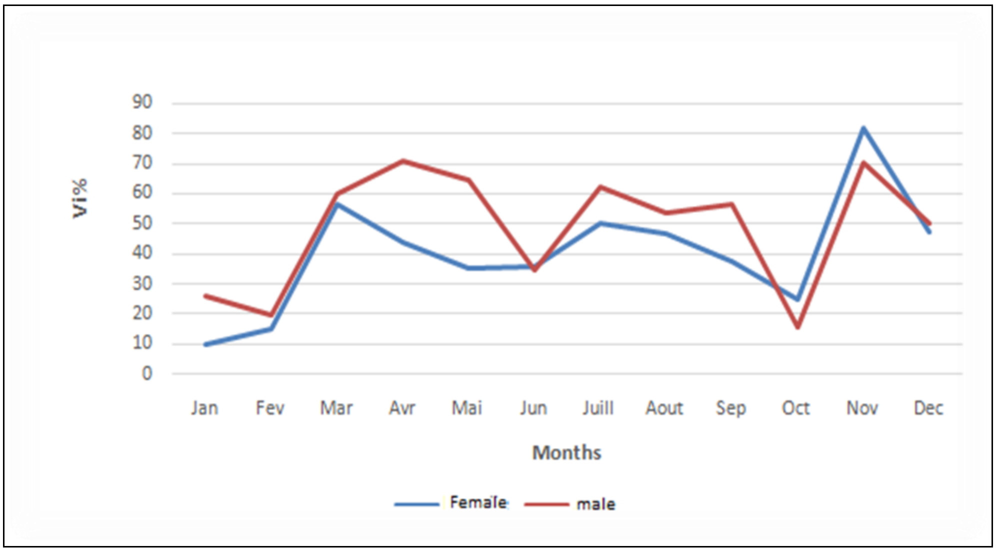

Figure 2. Monthly evolution of the Vi of *Trachurus trachurus* by sex.

The seasonal evolution of the vacuity index of the horse mackerel by sex shows that there is not a great variation for the two sexes except in spring when the Vi of the males is higher than that of the females with 65.57% and 43.75% respectively. Indeed, winter marked the lowest rate of the vacuity index for both sexes, which is around 25.95% for females and 28.57% for males (Figure 3).

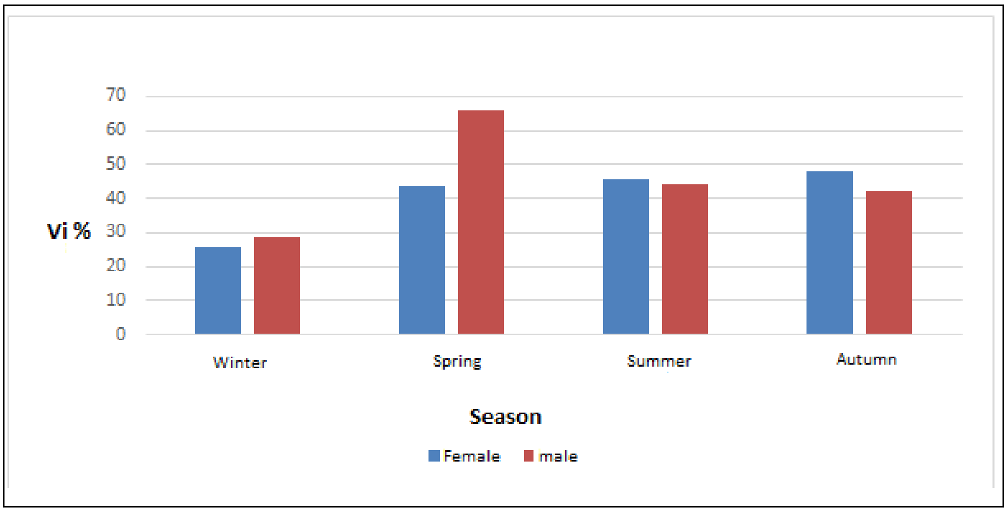

Figure 3. Seasonal evolution of the vacuity index of *Trachurus trachurus* by sex.

Analysis by size class (Figure 4), based on total length, indicates that for individuals in groups 12-14.5 cm, 15-17.5 cm, 21-23.5 cm, and 24-26.5 cm, the Vi is relatively the same (average of 40%) while the size group 18-20.5 cm shows the greatest value (54.54%). For groups 27–29.5 cm and 30–35.5 cm which include adult individuals, the Vi is relatively low (29.41% and 7.14%). As a result, a high feeding intensity is observed in large adult individuals.

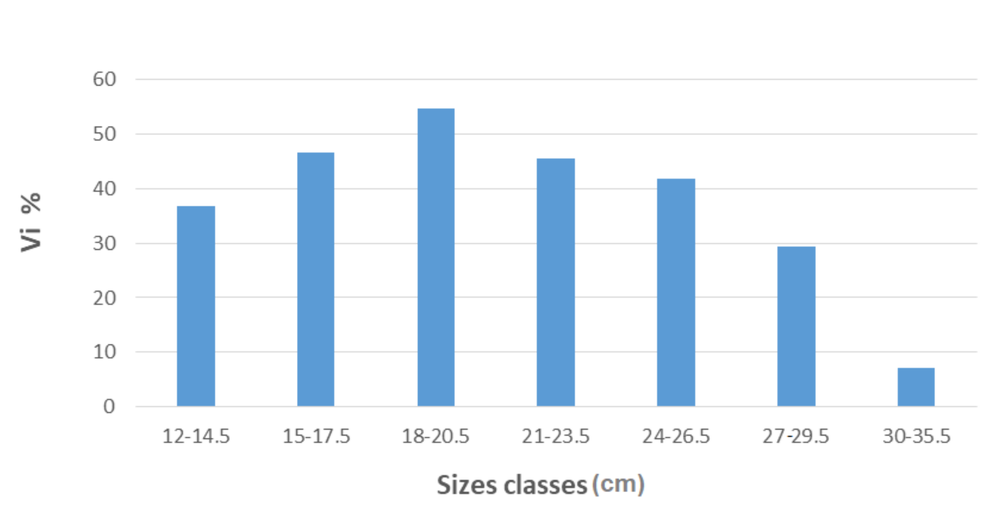

Figure 4. Evolution of the vacuity index of *Trachurus trachurus* by size class.

The evolution of the vacuity index of *Trachurus trachurus* by size class and by sex (figure 5) shows that the Vi of the males is appreciably equal to that of the females for the group 18-23.5 cm, whereas it is slightly in favor of males for group 24-29.5 cm and in favor of females for group 12–17.5 cm. For the size group 30-35.5 cm, the Vi is quite low compared to that calculated for the first groups. As a result, large individuals of horse mackerel feed more than individuals of small and medium sizes (Figure 5).

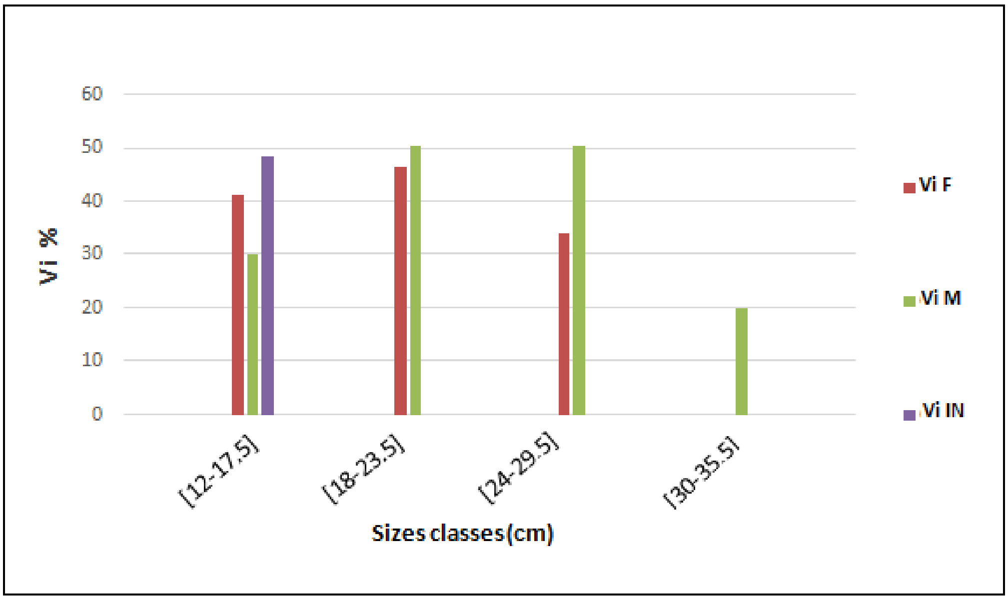

Figure 5. Evolution of the vacuity index of *Trachurus trachurus* by size class and by sex.

The evolution of the frequency of occurrence (Fo) by prey group and by sex has made it possible to define the importance of the different prey in the diet of horse mackerel. In fact, crustaceans (Euphausiacea, Copepoda, Penaeidae and Nephrops) constitute preferential prey for both sexes, teleostei (anchovies, fish scales, fish vertebra) have a rate of 21%, and Mollusca (Cephalopoda, Gastropoda) have a rate of 11% and constitute secondary prey, while the other prey encountered in their stomachs are qualified as occasional prey with a very low rate, not exceeding 3% (Table 2).

Table 2
Evolution of the frequency of occurrence (Fo) by prey group and by sex of *Trachurus trachurus*

Group	*Female %*	*Male %*	*Total %*
Crustacean	64.14	66.42	64.93
Teleostei	21.22	21.53	20.53
Mollusca	10.28	11.12	10.85
Annelida	3.13	0.51	2.64
Protozoa	0.49	0.12	0.39
Other	0.74	0.16	0.42

The seasonal evolution of the frequency of occurrence of horse mackerel during the study period (Table 3) shows that crustaceans (Euphausiacea, Copepoda, Penaeidae, Nephrops) represent the preferred prey during the four seasons. For secondary prey, they consist only of teleostei in winter and spring, while in summer and autumn, Mollusca (Cephalopoda, Gastropoda) are added to this category. For other prey, they are qualified as occasional prey during the four seasons.

Table 3
Evolution of the frequency of occurrence (Fo) by prey group and by season of *Trachurus trachurus*

Group	*Winter %*	*Spring %*	*Summer %*	*Autumn %*
Crustacean	7.47	53.19	63.61	71.24
Teleostei	18.11	41.17	20.46	14.21
Mollusca	3.94	4.23	13.31	13.11
Annelida	6.29	0.12	0.14	0.12
Protozoa	0.42	0.07	0.81	1.23
Other	0.77	1.22	1.67	0.19

According to our study (Figure 6.1 for winter, Figure 6.2 for spring, Figure 6.3 for summer, Figure 6.4 for autumn), crustaceans are consumed throughout the year by horse mackerel and by all size classes. The Euphausiacea and Copepoda, which are the main prey of *T. trachurus*, are found in the stomachs analyzed during the four seasons both in young and in adults. Teleostei which are represented by anchovies, fish vertebra, and fish scales are also present throughout the year and in all size classes.

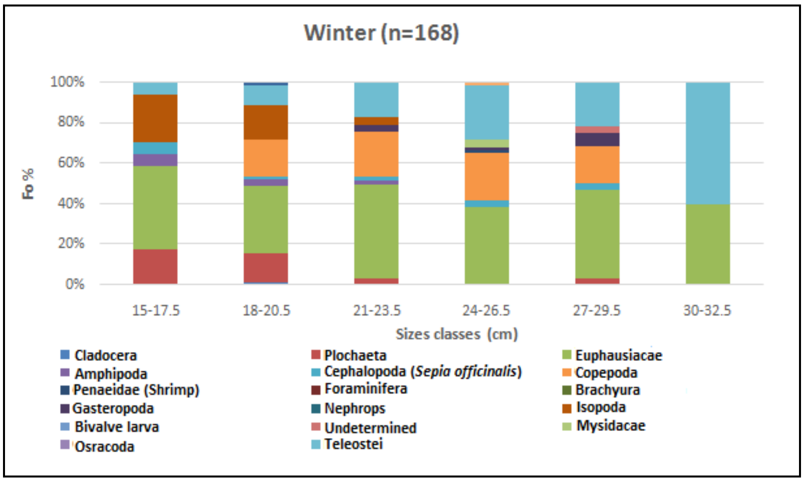

Figure 6.1. Main prey of horse mackerel by size class in winter.

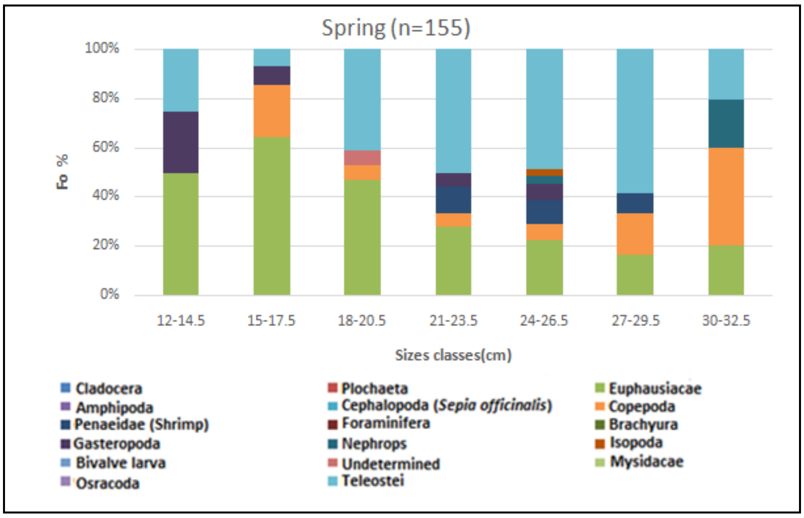

Figure 6.2. Main prey of horse mackerel by size class in spring.

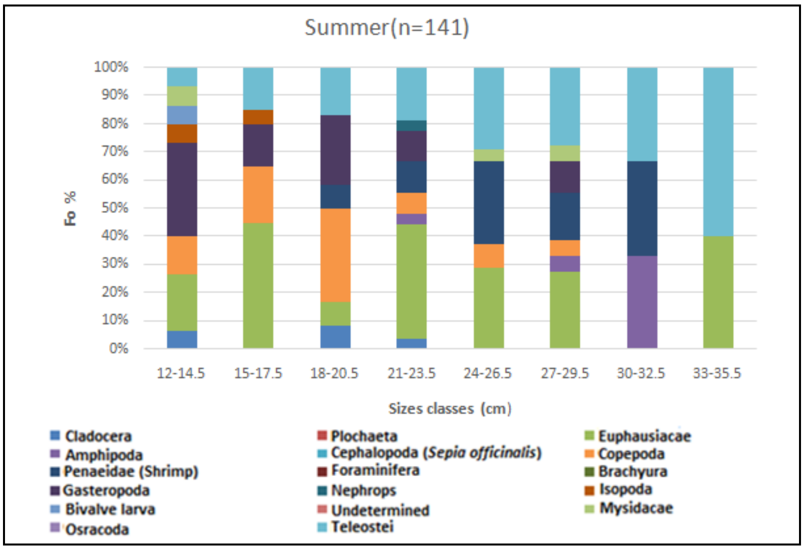

Figure 6.3. Main prey of horse mackerel by size class in summer.

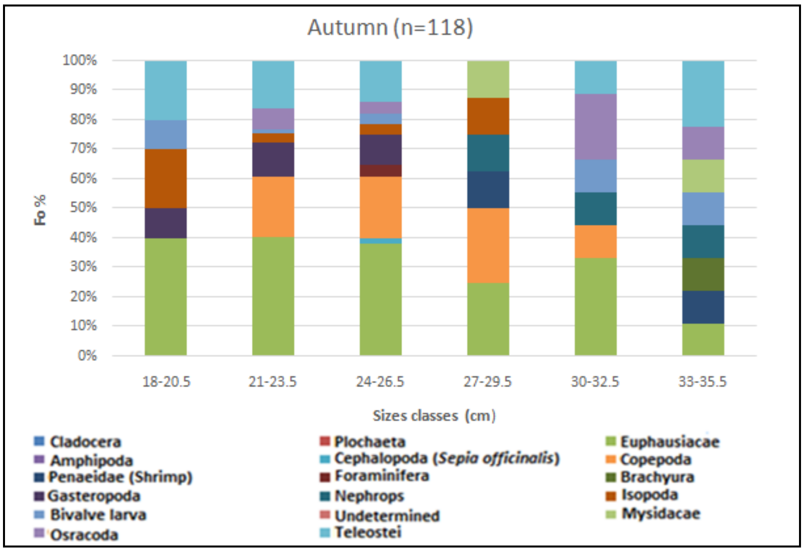

Figure 6.4. Main prey of horse mackerel by size class in autumn.

To test the significance of the change regarding the total fullness index (TFI) by season, by sex and by size, we adopted the MANOVA multi-factor analysis of variance. The size classes are divided into eight groups with a gap of 2.5 cm which correspond to immature individuals and mature adults. The results of the analysis of variance showed that the season and the size have a significant effect on the TFI index (p=0.00), while the sex does not have a significant effect on the TFI index with p=0.09. The values of TFI of immature individuals are slightly higher than those of mature individuals except for the youngest individuals (12-14.5 cm) where the TFI is very minimal (35.48). Analyzed by season, high TFI values are observed in winter. For both sexes, we found an identical TFI index (Table 4).

Table 4
Evolution of the total full index (TFI) by size, sex, and season of *Trachurus trachurus*

		Average of TFI	*Number of stomachs*	*Standard deviation*
Size (cm)	12 – 14.5	35.48	13	19.80
	15 – 17.5	64.68	33	83.04
	18 – 20.5	66.13	57	65.47
	21 – 23.5	51.29	91	54.17
	24 – 26.5	45.46	93	45.45
	27 -29.5	50.12	36	76.71
	30 – 32.5	49.86	10	55.19
	33 – 35.5	55.32	3	44.85
Sex	Females	51.59	217	53.50
	Males	53.74	98	57.62
Seasons	Winter	80.21	121	60.68
	Spring	33.15	60	46.05
	Summer	33.27	71	56.57
	Autumn	30.31	84	43.68

The diet of horse mackerel consisted mainly of crustaceans as preferred prey, followed by teleostei and other prey with very low IRI indices. Crustaceans account for 95.36% of the total IRI and 70.07% of the frequency of occurrence (Fo) and they are dominated by Copepoda, notably the family Calanidae. The teleostei (complementary prey) which represent 4.01% of the total IRI and 20.86% of Fo are mainly composed of anchovies (*Engraulis encrasicolus*), fish vertebra and fish scales. Mollusca (accidental prey) which represent only 0.27% of IRI and 6.78% of total Fo are composed only of Gastropoda, bivalve larvae, and Cephalopoda (*Sepia officinalis*).

Protozoa, worms, and undetermined prey are represented in very small proportions, and they consist of Annelida, Foraminifera, and unidentified species, respectively (Table 5).

Table 5
Importance of the different preys of *Trachurus trachurus* expressed in: Fo %, frequency of occurrence; N %, abundance; P %, biomass and IRI %

Prey		*Taxonomic groups*	*Fo (%)*	*N (%)*	*P (%)*	*IRI (%)*
Crustacean	Copepoda	Calanidae	15.97	26.49	21.49	18.39
		Euterpinidae	0.15	0.01	0.00	0.00
		Centropagidae	0.45	0.05	0.00	0.00
		Not identified	3.71	16.26	2.10	1.41
	Cladocera	Not identified	0.61	0.06	0.00	0.00
	Amphipoda	Caprellidae	0.64	0.04	0.01	0.00
		Gammaridae	0.45	0.11	5.51	0.08
	Euphausiacae	*Euphausia* sp.	36.84	42.39	28.60	73.93
	Isopoda	Not identified	4.27	5.14	2.29	0.84
	Ostracoda	Ostracoda	1.71	0.10	0.01	0.00

	Zoea	*Zoea*	0.11	0.01	0.00	0.00
	Decapoda	Penaeidae	2.60	0.23	5.43	0.59
		Nephrops norvegicus	0.91	0.12	2.50	0.07
	Mysidacea	Not identified	1.35	0.90	0.42	0.05
		Total	70.07	91.91	68.35	95.36
Mollusca	Cephalopoda	*Sepia officinalis*	0.91	0.04	1.76	0.05
	Gastropoda	Pteropoda	4.82	1.34	0.14	0.21
	Bivalve larvae	Not identified	1.05	0.07	0.04	0.00
		Total	6.78	1.45	1.94	0.27
Teleostei	Anchovies	*Engraulis encrasicolus*	10.50	0.40	27.07	3.96
	Fish vertebra	Not identified	5.60	0.23	0.05	0.05
	Fish scales	Not identified	4.31	0.06	0.05	0.01
		Total	20.41	0.69	27.17	4.01
Protozoa	Foraminifera	Not identified	0.32	0.01	0.05	0.00
		Total	0.32	0.01	0.05	0.00
Worms	Annelida	Polychaeta	2.26	5.93	2.46	0.36
		Total	2.26	5.93	2.46	0.36
Undetermined	Not identified		00.16	0.01	0.03	0.00
		Total	0.16	0.01	0.03	0.00

The variation in the IRI index of the 21 types of prey by size shows that crustaceans are present in all size classes of horse mackerel. Their percentage of IRI is almost similar for all classes. Their contribution to the diet of horse mackerel is significantly important compared to the rest of the prey for all sizes, except for the class (12-14.5 cm) where Gastropoda occupy a significant rank in the diet (preferential prey). In addition, we noted that among the crustaceans consumed, Euphausiacea present the most important IRI, the latter is high in individuals of medium and large sizes (21-35.5 cm) compared to other small groups (12-14.5 cm). Teleostei are considered secondary prey for large individuals (33-35.5 cm) (Table 6).

Table 6

Evolution of the percentage of index of relative importance (IRI) of the *Trachurus trachurus* prey groups calculated by size classes

Preys		*Taxonomic groups*	*Size classes (cm)* 12-14.5	15-17.5	18-20.5	21-23.5	24-26.5	27-29.5	30-32.5	33-35.5
Crustacean	Copepods	Calanidae	0.00	1.87	69.90	3.06	7.18	2.03	18.38	0.00
		Euterpinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Centropagidae	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
		Not identified	5.75	0.00	1.96	0.85	0.00	0.32	1.41	0.00
	Cladocera	Not identified	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	Amphipoda	Caprellidae	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
		Gammaridae	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00
	Euphausiacae	Euphausiacae (*Euphausia* sp.)	44.72	85.05	18.26	93.54	84.94	78.92	73.93	62.88
	Isopoda	Not identified	0.53	9.15	5.11	0.07	0.06	0.00	0.83	0.00
	Ostracoda	Ostracoda	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00
	Zoea	*Zoea*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Decapoda	Penaeidae	0.00	0.00	0.02	0.30	0.75	2.73	0.28	6.51
		Nephrops	0.00	0.00	0.00	0.01	0.00	0.81	0.07	5.98

		norvegicus								
	Mysidacae	Not identified	0.21	0.00	0.00	0.00	0.33	0.18	0.05	0.56
	Total		51.27	51.27	96.08	95.27	97.85	93.32	85.00	95.02
Mollusca	Cephalopoda	*Sepia officinalis*	0.00	0.13	0.00	0.01	0.22	0.01	0.05	0.00
	Gastropoda	Pteropoda	44.80	0.30	0.19	0.13	0.03	0.08	0.22	0.00
	Bivalve larvae	Not identified	0.12	0.00	0.00	0.00	0.00	0.00	0.00	1.79
	Total		44.92	44.92	0.43	0.19	0.14	0.25	0.09	0.27
Teleostei	Anchovies	*Engraulis encrasicolus*	3.81	0.05	0.29	1.94	6.24	14.71	4.16	21.98
	Fish vertebra	Not identified	0.00	0.01	0.03	0.03	0.07	0.06	0.09	0.00
	Fish scales	Not identified	0.00	0.00	0.01	0.01	0.01	0.04	0.00	0.30
	Total		3.81	3.81	0.06	0.33	1.98	6.32	14.83	4.25
Protozoa	Foraminifera	Not identified	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	Total		0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Worms	Annelida	Polychaeta	0.00	3.43	4.20	0.03	0.00	0.00	0.46	0.00
	Total		0.00	0.00	3.43	4.20	0.03	0.00	0.00	0.46
Undetermined	Undetermined	Not identified	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
	Total		0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00

The estimation of the degree of similarity of food preferences between the different size groups of *Trachurus trachurus* using AHC shows that the population of this species can be divided into two groups with a degree of similarity of 54.85%:

The first group is made up of individuals belonging to the 18-20.5 cm size range and which feed mainly on the copepoda of the Calanidae family.

The second group is composed of individuals of sizes between 12-17.5 and 21-35.5 cm whose consumption of Euphausiacea is preferred. This group consists of two subgroups, the first (12-14.5 cm), which feeds on Gastropoda of the Pteropoda family and the second (31.5-33 cm) has a certain preference for teleostei mainly anchovies (Figure 7).

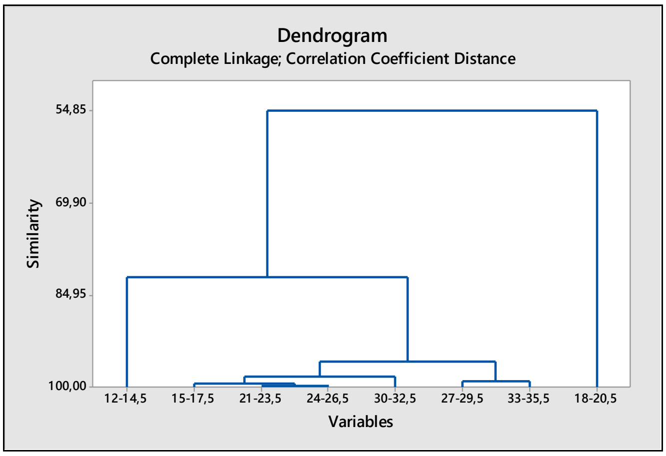

Figure 7. Dendrogram based on % IRI and showing the food similarity of size classes of horse mackerel.

The seasonal evolution of the IRI index of the 21 types of prey that make up the diet of horse mackerel indicates that crustaceans are found during all seasons. Their percentage of IRI is almost the same for all four seasons, and therefore a significant contribution in the diet of horse mackerel compared to the rest of the prey (preferential prey). We also noticed that among the crustaceans consumed, Euphausiacea represent the most important IRI in autumn and spring, while in winter they share their dominance with Calanidae with IRI of 52.55% and 38.88% respectively. In summer, Copepoda are the most dominant with an IRI of 59.35% followed by Euphausiacae with 16.38% (secondary prey) and Penaeidae (shrimp) with an IRI of 9.82% (complementary prey). For Teleostei they have a similar contribution for all seasons with a low IRI not exceeding 6%, and they are considered accidental prey (Table 7).

Table 7

Seasonal evolution of index of the relative importance (IRI) groups prey of *Trachurus trachurus*

Prey		*Taxonomic groups*	*Seasons*			
			Autumn	*Winter*	*Spring*	*Summer*
Crustacean	Copepoda	Calanidae	1.00	38.88	1.33	0.02
		Euterpinidae	0.00	0.00	0.00	0.00
		Centropagidae	0.00	0.00	0.00	0.00
		Not identified	0.00	0.00	0.44	59.32
	Cladocera	Not identified	0.00	0.00	0.00	0.04
	Amphipoda	Caprellidae	0.00	0.01	0.00	0.00
		Gammaridae	0.00	0.00	0.00	4.03
	Euphausiacea	Euphausiacea (*Euphausia* sp.)	97.91	52.55	88.89	16.38
	Isopoda	Not identified	0.03	2.04	0.00	0.02
	Ostracoda	Ostracoda	0.05	0.00	0.00	0.00
	Zoea	*Zoea*	0.00	0.00	0.00	0.00
	Decapoda	Penaeidae	0.09	0.01	3.72	9.82
		Nephrops norvegicus	0.14	0.00	1.53	0.01
	Mysidacea	Not identified	0.01	0.07	0.00	0.15
	Total		99.23	99.23	93.56	95.91
Mollusca	Cephalopoda	*Sepia officinalis*	0.01	0.13	0.00	0.00
	Gastropoda	Pteropoda	0.30	0.01	0.13	4.27
	Bivalve larvae	Not identified	0.03	0.00	0.00	0.00
	Total		0.34	0.34	0.14	0.13
Teleostei	Anchovies	*Engraulis encrasicolus*	0.41	4.51	3.62	5.87
	Fish vertebra	Not identified	0.01	0.05	0.13	0.04

	Fish scales	Not identified	0.01	0.03	0.20	0.03
	Total		0.43	0.43	4.59	3.95
Protozoa	Foraminifera	Not identified	0.00	0.00	0.00	0.00
	Total		0.00	0.00	0.00	0.00
Worms	Annelida	Polychaeta	0.00	1.71	0.00	0.00
	Total		0.00	0.00	1.71	0.00
Undetermined	Undetermined	Not identified	0.00	0.00	0.01	0.00
	Total		0.00	0.00	0.00	0.01

The estimation of the degree of similarity of the food preferences of horse mackerel during the four seasons shows that the study period can be divided into two groups with a degree of similarity of 56.15%:

During the summer, *Trachurus trachurus* feeds mainly on Copepoda, Euphausiacea as secondary prey and Teleostei (anchovies) as complementary prey.

The second period includes autumn, spring, and winter when the horse mackerel feeds mainly on Euphausiacea. This period consists of two sub-periods: the first is winter when individuals of *Trachurus trachurus* feed on Euphausiacea and Copepoda of the Calanidae family: the second, spring and autumn, shows a certain preference for Euphausiacea (Figure 8).

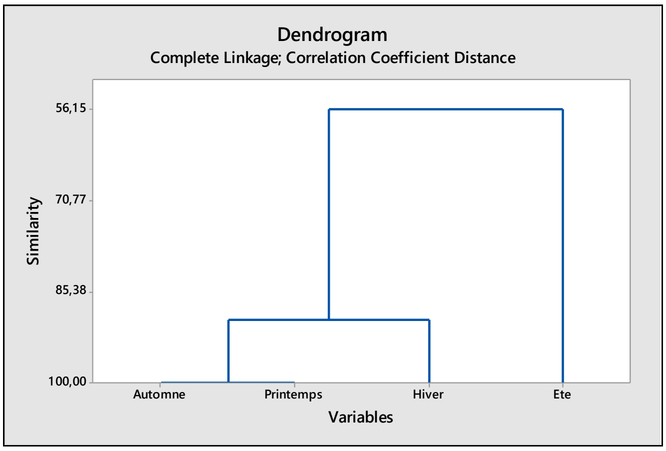

Figure 8. Dendrogram based on IRI & and showing dietary similarity of horse mackerel from all four seasons.

Discussion. The feeding preferences of fish species are important in classic ecological theory, mainly in the identification of food competition, the structure and stability of the food chain and the evaluation of functional responses of prey and predators (Post et al 2000; Bacheler et al 2004).

Horse mackerel *Trachurus trachurus* is an active demersal predator throughout its life cycle. Due to its wide bathymetric distributions and abundance, this species plays an important role in species communities in the fishery.

The results of this study showed that the diet of the horse mackerel *Trachurus trachurus* is made up of four main groups of prey: Crustaceans, Teleostei, Mollusca (Cephalopoda and Gastropoda) and a final group which includes Annelida, and undetermined prey. The faunal list is made up of 21 taxonomic identified groups, and others were not identified due to their advanced digestion. These results turn out to be identical to those obtained by studies carried out on the same species from the Adriatic Sea (Santic et al 2005) concluding that the diet of this species is based mainly on crustaceans, composed of Euphausiacea, Mysidacea and Decapoda, which have been qualified as preferential prey. These results also agree with studies carried out in the Atlantic and the Mediterranean, mainly in Portugal and Spain, which also showed that the diet of *Trachurus trachurus* is made up of crustaceans, mainly Euphausiacea, Mysidacea and Decapoda, but Euphausiacea remain by far the dominant prey (Ben Salem 1988; Olaso et al 1999; Cabral & Murta 2002; Jardas et al 2004; Garrido et al 2008; Garrido & Murta 2011). In the Aegean Sea, in addition to Euphausiacea, Copepoda and Mysidacea represent the prey most consumed by small size classes, while Teleostei constitute the main food for large sizes (Bayhan & Sever 2009). This diet is like that of other species of the genus *Trachurus* such as *T. mediterraneus* (Steindachner 1868) in the Central Aegean Sea, the Black Sea, and the Central Adriatic Sea where this species feeds mainly on crustaceans (Copepoda, Mysidacea and Euphausiacea), Teleostei and Cephalopoda being classified as accidental prey (Kyrtatos 1998; Santic et al 2003; Yankova et al 2008).

Food intensity is inversely related to the percentage of empty stomachs (Bowman & Bowman 1980). It increases as the size of individuals increases, so that the highest values are recorded in individuals of small size. It seems that this is believed to be related to the smaller prey sizes (Euphausiacea and Copepoda) targeted by young individuals, and that these preys are digested more quickly compared to those consumed by large individuals (Growe & Grawford 1980; Chapman et al 1988 cited by Jardas 1996).

As the size increases, *Trachurus trachurus* gains the power to access new feeding grounds, accumulate skills to seek and capture prey, and it can move faster on long search routes. As a result, the range of prey likely to be caught is wider, which explains the diversity of species found in the stomachs analyzed.

The frequency of occurrence index shows that crustaceans, mainly Euphausiacea and Copepoda, make up the bulk of the horse mackerel's diet, followed by Teleostei. Mollusca and others being referred to as occasional prey. Both Euphausiacea and Copepoda are consumed throughout the sampling period and by all size classes. These results agree with those found by Aloncle in 1964.

The total fullness index (TFI) reveals the energy requirements of horse mackerel per unit of body weight. The highest values of this index were recorded in young individuals. The variations in TFI encountered during the four seasons appear to be related to the change in the quality of the diet. Indeed, the maximum value of the TFI was recorded in winter when the Euphausiacea represent more than 80% of the prey consumed by the horse mackerel.

A temporal variation in the diet of *Trachurus trachurus* with a difference between the sampling periods, is well-marked despite the existence of common prey, and seems to be linked to the difference in the duration of fishing carried out by the fishing boats, unlike the time of fishing launches or the variation in depth along the fishing target.

The feeding rate of *Trachurus trachurus* varies depending on the period of sampling. It is important in winter, when the vacuity index is at its minimum, which corresponds to a high trophic activity of the species, while in other seasons, the overall vacuity rate reaches 40% (spring). These variations are related to the biological and migratory cycle of the species according to Joyeux et al (1991) and Layachi et al (2007) in the Mediterranean Sea, Mouny (1998) at the Seine estuary and Gandega et al (2011) in Mauritania (Atlantic). Decreased food intake in most fish species is related to reproductive activity. Mature ovaries compress the species digestive tract, reducing trophic activity. Analysis of stomach contents showed that the diet of *Trachurus trachurus* is mainly planktonophagous.

Pelagic crustaceans, especially Euphausiacea and Copepoda, constitute the bulk of the prey ingested. The composition of the diet of *Trachurus trachurus* varies between the four seasons that make up the study period. This variation is related to the spatio-temporal variability of the composition, abundance, and structure of phytoplankton and zooplankton communities, which is closely related to variations in biotic and abiotic factors in the ecosystem. The qualitative composition of stomach contents depends not only on food preference, but also on the abundance of prey. In fact, we have observed that individuals from the same landing lot often have identical stomach contents in qualitative terms.

The study area is characterized by the cohabitation of three species of horse mackerel (*Trachurus trachurus, Trachurus trecae* and *Caranx rhonchus*), in variable proportions, in addition to other species of small pelagic fish (sardines, anchovies, mackerel and sardinella). Clupeidae and Engraulidae are planktonophagous with diets composed, in large part, of phytoplankton for sardines and zooplankton for anchovies and sardinella (Plounevez & Champlabert 2000; INRH 2002; Ould Taleb 2005). Concerning the other species of Carangidae, *Trachurus trecae* has a diet like that of *Trachurus trachurus*, composed mainly of Decapoda (shrimps), juvenile anchovies, Myctophidae and Carangidae (FAO 1983; COPACE 1984); *Caranx rhonchus* is rather carnivorous, consuming mainly fish, shrimp, and squid (Chavance et al 1991). For mackerel (*Scomber japonicus*), the diet is composed mainly of pelagic crustaceans, in addition to fish and Cephalopoda (Wahbi et al 2011).

All species of small pelagic fish can be potential competitors for *Trachurus trachurus* at different stages of its life cycle. However, the coexistence of these species is favored by the heterogeneity of the Moroccan Atlantic ecosystem and the availability of trophic resources.

Conclusions. Examination of the stomach contents of *Trachurus trachurus* reveals their very diverse planktonophagous diet. It is essentially composed of entomostraceans (Copepoda) and malacostraceans (Euphausiacea, Mysidacaea, Isopoda, Penaeidae and Decapoda). The Euphausiacea constitute the dominant fraction of its diet. The abundance of prey, the size of individuals and their biological parameters have an influence on its diet. These results, and others like them, are of great importance for decision-makers in the good governance and sustainable management of national fish stocks.

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