Diet of anchovy *Engraulis encrasicolus* (Engraulidae) in Moroccan Atlantic coast

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Abstract. The feeding of anchovy, *Engraulis encrasicolus* (Linnaeus, 1758) was investigated for the first time in Moroccan Atlantic coast during the period between January 2016 and December 2016. Samples were collected onboard the commercial purse-seine fleet. A total of 234 specimens were collected monthly, with total lengths and weight ranging 6 to 16.5 cm and 1.24 to 58 g. The diet of *E. encrasicolus* was studied through qualitative and quantitative analysis of stomach contents. The vacuity index depending on the seasons shows that the most empty stomach were encountered during summer (56%) followed by winter (46%), spring (24%) and autumn (10%). According to the frequency of occurrence, there was a clear dominance of crustaceans for all seasons and for the whole sizes. Copepod was the preferential prey group which is dominated by calanidae, centropagidae and oncaeidae families while other taxa (e.g. mollusks, fish (eggs and scales) and echinoderms) had less importance in the diet of anchovy. The use of the Hierarchical Ascendant Classification (HAC) based on the relative index of importance revealed that the anchovy is divided in two size groups (small and adults specimens) with different dietary preferences.
Key Words: vacuity index, frequency of occurrence, prey, stomach content.

Introduction. The European anchovy *Engraulis encrasicolus* (L., 1758) is a small pelagic fish which is widely distributed from the North Sea to Central Africa, and throughout the Mediterranean Sea (Pauly & Froese 2012). This species plays an important role in transferring the energy from plankton to large predators (Cury et al 2000). Anchovies are also essential for the ecosystem given to its position in the trophic chain (Palomera et al 2007; Coll et al 2009). Despite the signifycant abundance (67,000 tones) and economic importance of this species along the Moroccan Atlantic coast (INRH/DRH 2015), scarce information is availableon its ecology.

The feeding preferences of fish species are important in classic ecological theory, on the whole, to identify feeding competition (Bacheler et al 2004), structure and stability of food webs (Post et al 2000) and assessing predator-prey functional responses (Dörner & Wagner 2003). However, papers on fish feeding in Moroccan Atlantic coast are rare. The key role of feeding studies for fisheries biology, ecology and fisheries management was uncovered only the last decade with the use of trophic level in predicting the effects of fishing on the balance of marine food webs (Pauly et al 1998). The study of feeding of species can be used to understand growth variations, some aspects of reproduction and food intake (Rosecchi & Nouaze 1987). The diet of *E. encrasicolus* has been described in the western Mediterranean (Tudela & Palomera 1997; Plounevez & Champalbert 2000; Bacha & Amara 2009), in the eastern Mediterranean (Nikolioudakis et al 2012) and in the Baltic Sea (Schaber et al 2010; Raab et al 2011).

The aims of the present work are to study the feeding habits of anchovy in central Atlantic coast according to the size classes and seasons, to identify the nature of its feeding ecology (i.e., specialist or generalist), and to compare its diet in Moroccan coast with that of other populations throughout its distribution.

Material and Method. Stomach contents of anchovy were examined monthly during the period between January 2016 and December 2016. Samples were collected onboard the commercial purse-seine fleet of the central of Moroccan Atlantic coast. The frequency of sampling is based on the availability of anchovies since they are not always available in the fishing zones (Figure 1). A total of 234 specimens of *E. encrasicolus* were collected monthly in the studied area. Samples were frozen at -20°C to block any digestion process (Ferraton 2007). In the laboratory, all specimens were measured (Total Length, TL) with 0.1 cm accuracy, and weighed (Total weight, W) with 0.1 g accuracy. The sex of each fish was determined. The stomachs were immediately fixed in the ethanol 70%. Once opened, the stomachs were removed, rinsed with water to carefully detach preys. These last were identified under a binocular loupe using determination guides (Rose 1933; Trégouboff & Rose 1957; Larink & Westheide 2011). Prey items were identified to large taxonomic groups, counted and weighed with 0.001 mg accuracy.

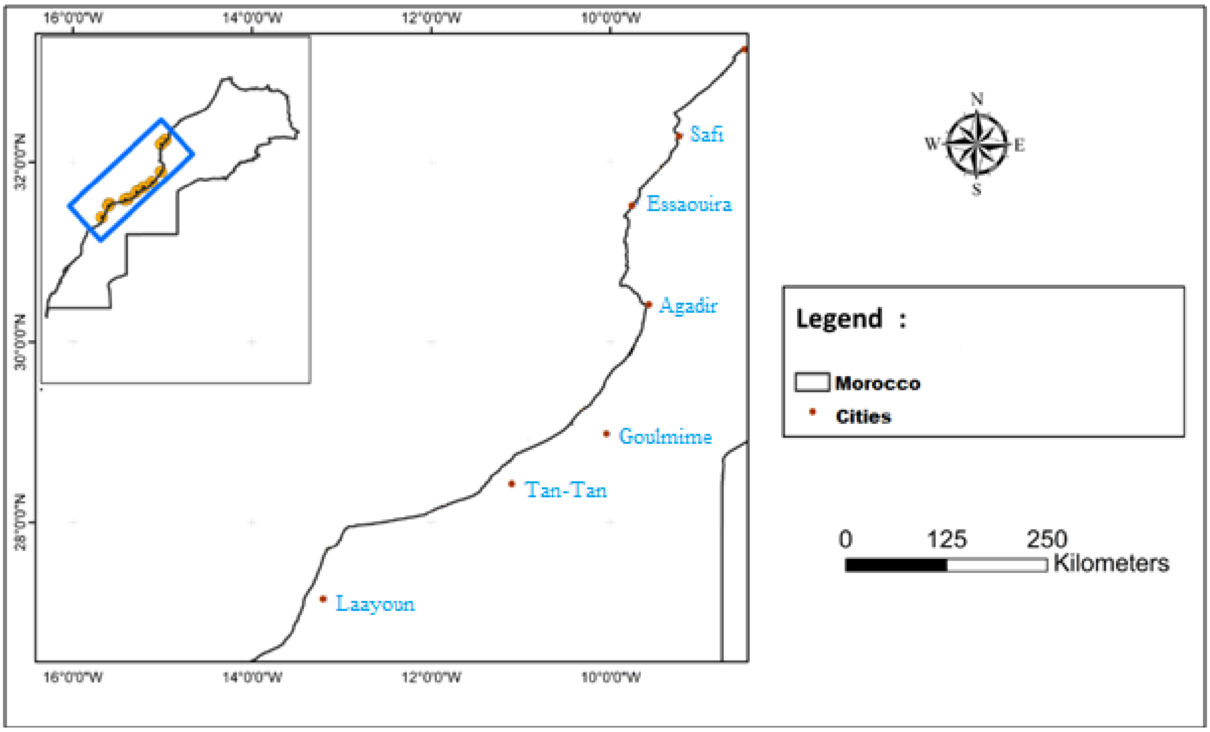

Figure1. Sampling area of *Engraulis encrasicolus* in Moroccan Atlantic coast.

The quantitative importance of different prey in the diet was expressed using five indices (Hureau 1970):

- The vacuity index (VI): it allows to analyzing the intensity of the food activity and corresponds to the ratio in percentage between the number of empty stomachs (ES) and the total number (TN) of stomachs analyzed (Hyslop 1980; Bowen 1996).

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

- The percentage 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.

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

This index makes it possible to know the food preferences of the predatory species. The prey is then classified in three categories:
FO% ≥ 50%: preferential preys.

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

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

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

- The percentage 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.
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$$W\% = \frac{Wp}{Wpt} \times 100$$

- Index of relative importance (IRI%): obtained by combining the FO%, N% and W% (Pinkas et al 1971). It is expressed by the following equation:

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

For the calculation of the degree of similarity of the food preferences between the different anchovy size groups, we used the Hierarchical Ascending Classification (HAC) using the STATISTICA software. As method of aggregation, we used the minimal jump. This method is the most commonly used for this type of analysis. The dendrograms obtained give us the composition of the different classes, as well as the order in which they were formed.

The Analysis of variance (ANOVA) was used to test the variability of the different indices according to size classes and seasons.

Results. Stomach contents were analyzed for individuals with a total length ranging between 6 and 16.5 cm. Of the 234 specimens examined, 90 (38.46%) had empty stomachs. The vacuity index for males (43.26%) was slightly higher than of females (37.96%) (Table 1).

Table 1

Evolution of the vacuity index of *Engraulis encrasicolus* function of sexes

Sexes	*Males*	*Females*	*Total population*
Empty stomach	45	41	90
Total	104	108	234
Vacuity index (%)	43.26	37.96	38.46

The vacuity index depending on the size shows a significant fluctuations ($p<0.05$). For the both sexes, the vacuity index of small individuals (8.5–11 cm) was low, and it was high for specimens with intermediate and large sizes >11 cm (Figure 2).

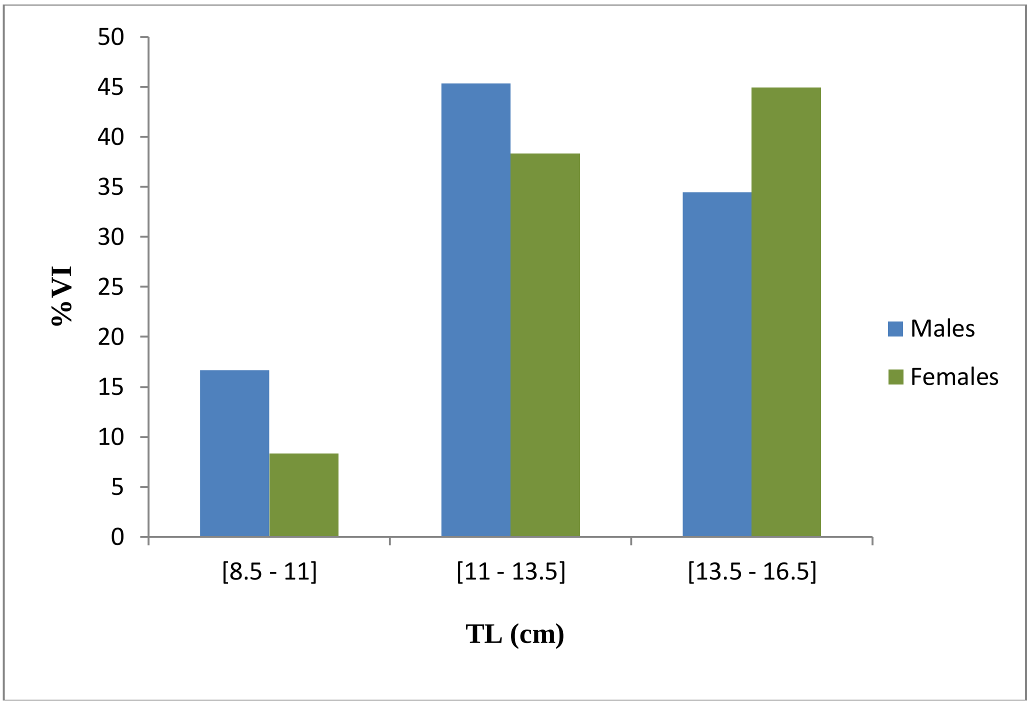

Figure 2. Variation of the Vacuity Index of *Engraulis encrasicolus* function of size and sexes.

The vacuity index shows a significant variation during the season ($p<0.05$). Most empty stomach were encountered during summer (54% for males and 69% for females) followed by winter (58% for males and 40% for females), spring (22% for males and 24% for females) and autumn (11% for males and 8% for females) (Figure 3).

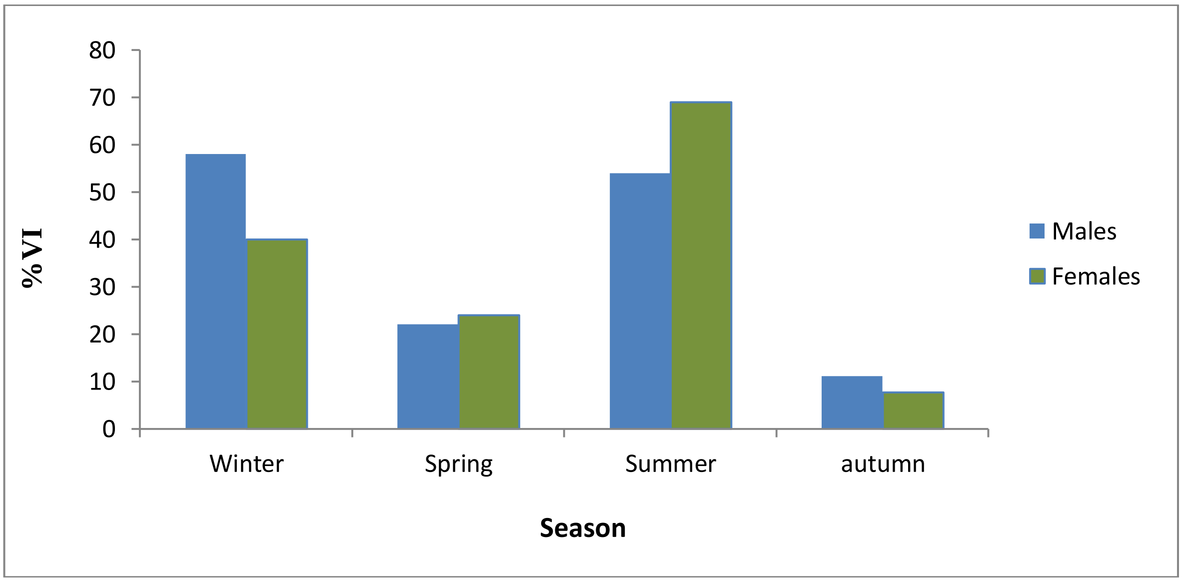

Figure 3. Vacuity Index function of the season and sexes of *Engraulis encrasicolus*.

A total of 4,528 prey items were determined. Frequency of occurrence, numerical abundance, gravimetric composition and index of relative importance values obtained in the study, in which four food groups were found including mollusks, crustaceans, fish and echinoderms are given in Table 2.

According to the frequency of occurrence, there was a clear dominance of crustaceans all season (Figure 4). Copepod was the preferential prey group while other taxa, i.e. mollusks, fish (eggs and scales) and echinoderms had less importance in the diet. The most remarkable quantity of fish scales was observed only in summer.

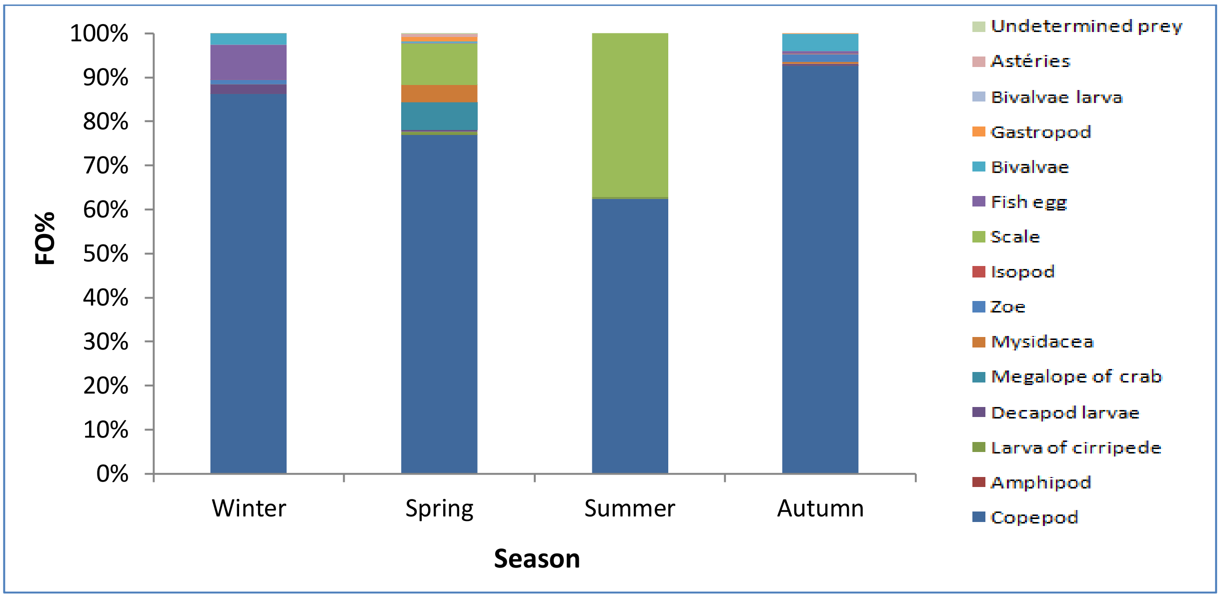

Figure 4. Frequency of occurrence depending on the season for *Engraulis encrasicolus.*

The frequency of occurrence depending on the size classes shows that the crustacean group was dominant for the whole sizes (Figure 5). For the small specimens we have a less biodiversity of prey than the large individuals, we observed the dominance of the copepod followed by the fish scale and other occasionally preys.

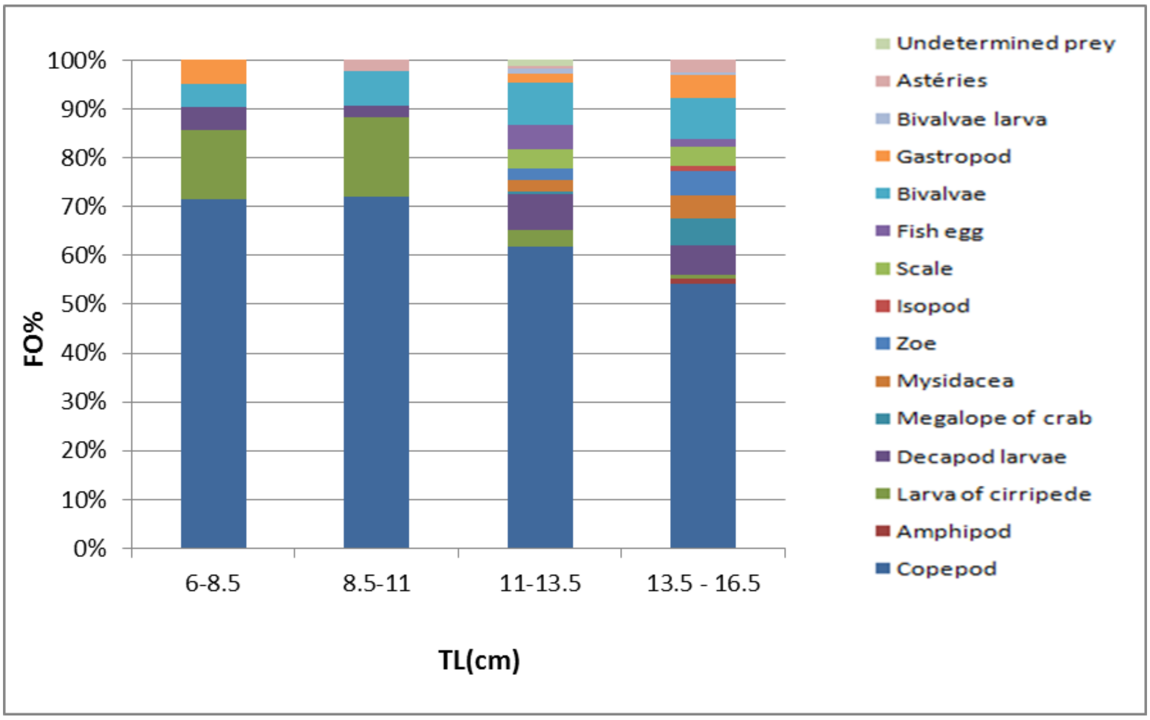

Figure 5. Frequency of occurrence depending on the size of *Engraulis encrasicolus.*

According to the IRI%, crustaceans were the most important prey (IRI% = 90.59), which is dominated by the copepod (IRI% = 84.7) belonging to the Calanidae family (IRI% = 55.61), followed by the Centropagidae family (IRI% = 10.84). The second important prey group was the fish (eggs and scales) which represents a value of 7.04 of IRI% (Table 2).

Table 2

Feeding behavior of anchovy

	Prey	*FO%*	*N%*	*W%*	*IRI%*
Crustaceans	Copepod (Calanidae)	23.7	26.57	10.53	55.61
	Copepod (Candaciidae)	2.71	20.21	12.98	5.69
	Copepod (Centropagidae)	5.42	15.92	15.71	10.84
	Copepod (Ccorycaeidae)	1.81	0.95	0.21	0.13
	Copepod (Ectinosomatidae)	9.26	3.38	0.19	2.09
	Copepod (Indeterminate)	8.13	4.44	1.82	3.22
	Copepod (Oncaeidae)	7.68	11.64	2.97	7.09
	Copepod (Euterpinidae)	1.13	0.33	0.04	0.03
	Amphipod	0.45	0.07	0	0
	Larva of Cirripede	4.06	1.04	0.21	0.32
	Decapod larva	6.09	1.46	0.52	0.76
	Megalope of crabs	2.71	1.99	11.72	2.35
	Mysidacea	3.16	1.55	8.76	2.06
	Zoe	3.16	1.08	0.9	0.4
	Isopods	0.45	0.24	0.32	0.02
	Total	79.91	90.86	66.87	90.59
Fish	Scales	3.39	2.34	24.36	5.72
	Fish eggs	2.71	1.06	6.66	1.32
	Total	6.09	3.4	31.02	7.04
Mollusk	Bivalve	8.13	3	0.44	1.77
	Gasteropod	3.16	0.73	1.18	0.38
	Bivalve larva	0.68	0.09	0.16	0.01
	Total	11.96	3.82	1.79	2.16
Echinoderma	Asteroidea	1.58	1.74	0.17	0.19
	Total	1.58	1.74	0.17	0.19
Undetermined prey	Undetermined prey	0.45	0.18	0.15	0.01

N% - percentage numerical composition, F% - frequency of occurrence, W% - percentage gravimetric composition, IRI% - percentage index of relative importance.

The Hierarchical Ascendant Classification (HAC) based on IRI% values revealed that the anchovy is divided in two size groups with different dietary preferences (Figure 6). The first group is composed by small specimens (6-11 cm), it feed on copepods belonging to the Calanidae and Ectinosomatidae families. The second group is represented by adult specimens (11-16.5 cm), the preference preys of this group were the copepod belonging to the Centropagidae family.

Concerning the seasonal variation of the IRI%, our results show that the anchovy is separated in three groups (Figure 7). The first group indicates a similar dietary between winter and autumn, the preference preys were the copepods belong to the family of Calanidae, Oncaidae and Centropagidae. Whereas, summer and spring stands as a single group with the dominance of fish scale and Calanidae respectively.

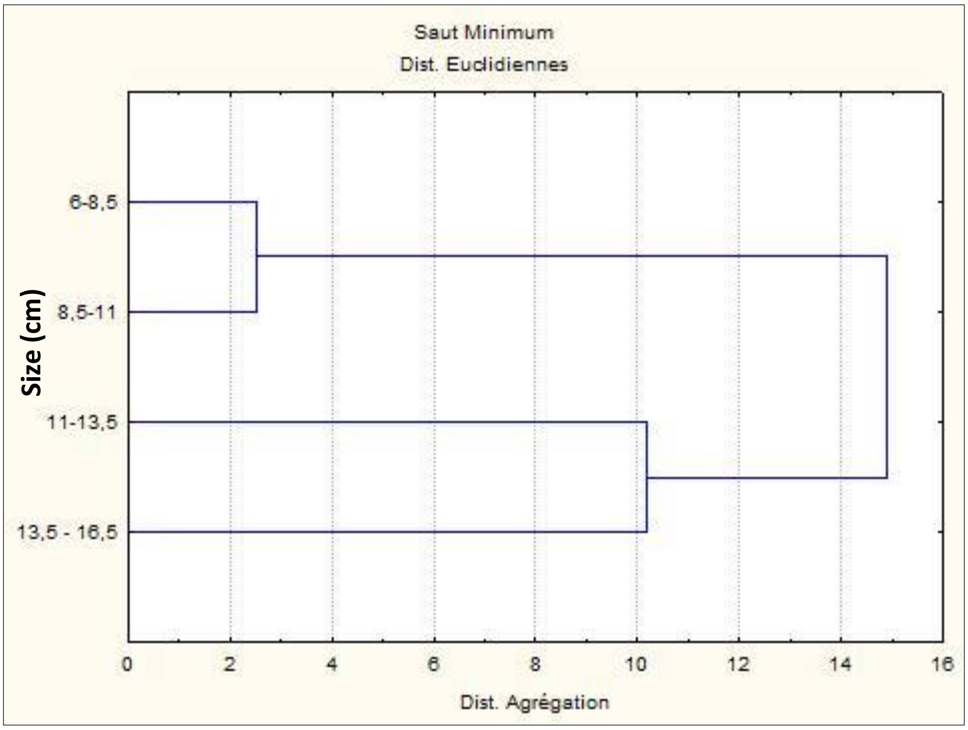

Figure 6. IRI% depending on the size of *Engraulis encrasicolus.*

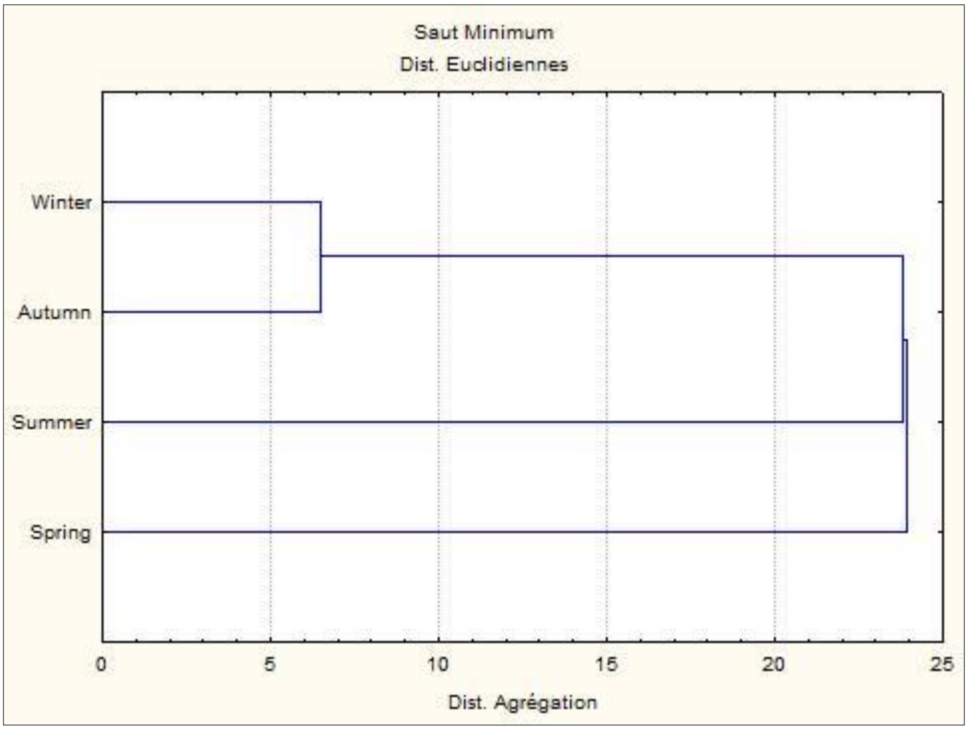

Figure 7. IRI% of *Engraulis encrasicolus* depending on seasons.

Discussion. Understanding the diet of fish is essential for the development of food web models (Costalagoetal 2014). The study of the feeding of a species can be used to explain growth variations, certain aspects of reproduction, migrations and the behavior of research and food intake (Rosecchi & Nouaze 1987). The analysis of the diet of natural populations is most often indirect, by examining the contents of the stomach or the entire digestive tract (Hyslop 1980).

The feeding ecology of *E. encrasicolus* in the central part of Moroccan Atlantic coast has never been looked at. Therefore, we can only compare our data to those of other Mediterranean or Atlantic sites. Trophic ecology studies of anchovy carried out in our studied area emphasize that this species feeds on zooplankton, the main prey items being copepods, and to a lesser extent on fish eggs and scales, molluscs and echinoderma. The dominance of copepods was mentioned by Tudela & Palomera (1997) and Palomera et al (2007) in the Catalan Sea, Plounevez & Champalbert (1999; 2000) in the Bay of Biscay and Golf of Lions, Bacha & Amara (2009) and Bacha et al (2010) in Algerian coast and (Beauchard et al 2014) in the Atlantic ocean. Thus sporadic phytoplankton feeding is reported in the Black Sea (Mikhman & Tomanovich 1977), the Azov Sea (Bulgakova 1993), in black Sea (Yunev et al 2005) and in the upwelling zones (Van der Lingen et al 2009).

Anchovy presents two feeding behaviors: it can feed by filtration by absorbing suspended matter in the water column, mainly during the day or by predation when visually locating large prey (Ganias 2014; Plounevez & Champalbert 2000; Palomera et al 2007). This makes him an opportunistic species capable of maximizing his food intake by using one of two modes of nutrition according to the environmental conditions encountered such as concentration or type of prey (Van der Ligen et al 2009).

The study of the vacuity index shows a high values during winter and summer, and full stomachs were observed in spring and autumn. The low values of the vacuity index in these last seasons can be an indication of the availability of food and/or the frequency of trophic activity of anchovy. Therefore, the high value of the vacuity index during the summer is explained by the presence of individuals at spawning stage, because the mature ovaries take place and exert a compression on the digestive tract of the species, which results in the reduction of the trophic activity. Stress generated by pelagic trawls may also influence the rate of vacuity index. The low value of the vacuity index in winter was indicated also by Bacha & Amara (2009) in Mediterranean Sea. It should be noted that the vacuity index must be treated with caution, because it is based on the estimation of stomach filling. It can vary according to the stage of digestion at the time of the analysis (Plouvenez & Champalbert 2000), the availability of prey accessible in the studied area, the type of food (soft prey is quickly digested) or the time of fish capture during the day (Morote et al 2010). The vacuity index does not necessarily reflect the food intensity of the fish (Jamaa et al 2016).

The main preys' families for anchovy along the Atlantic Moroccan coast were Calanidae, Centropagidae, Oncaeidae, Candaciidae, Echtinosomatidae. These copepods are similar from those recorded in the Algerian coast (Tudela & Palomera 1995, 1997; Plounevez & Champalbert 2000; Bacha & Amara 2009). This similarity in prey families may be attributable to the availability of these preys in Mediterranean Sea as in Atlantic Ocean. Whatever the season, copepods dominated the anchovy diet. However, diet differences occurred between seasons. Summer and spring have distinct prey assemblages and showed low diet similarities with the two other seasons. Conversely, winter and autumn were clustered together, indicating a similar diet. These results were in agreement with those obtained by Bacha & Amara (2009) in Algerian coast.

The presence of cannibalism on anchovy eggs in the present study is probably due to the non-discrimination spatio-temporal of feeding and spawning activity as suggested in *Engraulis anchoita* and *Engraulis capensis* (Angelescu 1982; Valdés et al 1987). This is not always the case: Tudela & Palomera (1997) and Bacha & Amara (2009) reported the absence of cannibalism in *E. encrasicolus* for the Catalan Sea and Algerian coast.

The Hierarchical Ascendant Classification (HAC) based on IRI% values revealed that the smallest specimens of anchovy feed on small and medium preys belonging to the Calanidae and Ectinosomatidae families. The preference preys of adult specimens belonging to very large preys such as copepod appurtenant to Centropagidae family, we notice also the presence of amphipods, fish scales and Mysidacea. These results were in agreement with those obtained by Bacha & Amara (2009), who confirms the presence of small prey for the small specimens and the large one for the adult specimens. We also remarks that some stomachs contained large prey together with much smaller ones, which indicated a mixed feeding with raptorial feeding mechanism on large prey concurrently with filter feeding on smaller ones as suggested for *E. encrasicolus* in the NW Mediterranean (Tudela & Palomera 1997; Plounevez & Champalbert 2000), the SW Mediterranean (Bacha & Amara 2009), for Cape anchovy *E. capensis* (James & Findlay 1989) and Northern anchovy *Engraulis mordax* (Leong & O'Connell 1969).

Conclusions. The analysis of stomach contents of *E. encrasicolus* in the Central of Moroccan Coast shows that crustaceans, mollusks and fish (eggs and scales) constitute the main food of this species. Whatever the season, or the fish size, anchovy is exclusively zooplanktivorous and dominated by copepods belonging to the Calanidae, Centropagidae and Oncaeidae families. Unlike other regions, our results show the presence of echinoderms with a low percentage. Seasonal variation of the vacuity index shows a high values during summer which can be explained by the dominance of individuals at spawning stage.

Anchovy represents a fundamental link between plankton production and predators of upper trophic levels. Thus, data on feeding habits are important in marine ecosystems. These results will be used to develop management strategies of this species which has economic value for Moroccan Atlantic coast.

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