

## Diet study of Atlantic horse mackerel (*Trachurus trachurus* Linnaeus, 1758) (Carangiformes Carangidae) caught in Béni-Saf Bay, Western Mediterranean Sea (Algeria)

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### ABSTRACT

This paper gives a description of the diet of Atlantic horse, *Trachurus trachurus* (Linnaeus, 1758) (Carangiformes Carangidae) living in the bay of Béni-Saf (North-Western Algeria) between November 2015 and October 2016 by analyzing the contents of the stomachs of 488 specimens divided in three classes according to the length of their body. We used several indices such as the coefficient vacancy (V), the percentage of prey (Cn) and the frequency of occurrence of prey (Fc). Of the total stomachs examined, 135 are empty which corresponds to a vacancy coefficient of 27.66. In total, 3912 preys were counted. They belong to ten major taxonomic groups: Copepoda, Euphausiacea, Amphipoda, Mysidacea, Cumaceae Cephalopods, Echinodermata, Molluscs, phytoplankton and Teleosts). The study of diet of *T. trachurus* shows that it has a broad food spectrum, and is a carnivorous and voracious species (benthopelagic). We found that the first class prefers Crustaceans, the second favors Euphausiacea, and the third prefers the predation of Teleosts. The diet varies with the size of specimens which is proportional to the size of the prey.

### KEY WORDS

Diet, Atlantic horse mackerel; *Trachurus trachurus*; Béni-Saf Bay; food spectrum; prey.

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### INTRODUCTION

Understanding the biology and ecology of fish in the wild inevitably involves studying their diet. The analysis of the contents of the stomach or of the entire digestive tract makes it possible to determine indirectly the composition of the diet and to assess the use of the food available. Processing of the collected data can be done by calorimetric (Rosecchi & Nouaze, 1985), numerical, gravimetric, volumetric or occurrence methods (Hyslop, 1980). These different methods have given rise to food indices, which show the most important prey for the preda-

tor's diet and allow inter-specific and intra-specific comparisons. Some authors group together the prey of a studies species, according to their index value, in order to separated the main prey from the others (Zander, 1982). It is in this context that our research falls, namely the study of the diet of the horse mackerel, *Trachurus trachurus* (Linnaeus, 1758) (Carangiformes Carangidae) caught in the west coast of Béni-Saf in western Algerian. We used food indices which tell us about the proportions of prey ingested and group them into "categories".

Horse mackerel has been the subject of several studies on reproduction (Korichi, 1988; Tahari,

2011; Aydin & Erdoğan, 2018; Gherram, 2019; Rahmani & Koudach, 2020), growth (Karlou-Riga & Sinis, 1997; Abaunza et al., 2003; Kerkich et al., 2013), and diet (Olaso-Toca et al., 1999; Cabral & Murta, 2002; Jardas et al., 2004; Šantić et al., 2005; Bahar & Tuncay, 2009; Bayhan et al., 2013; Shawket et al., 2015). However, for the Algerian coasts, no important study has been carried out.

This paper focuses on the diet of Atlantic horse, *T. trachurus*, living in the Béni-Saf Bay (North-West Algeria) with emphasis on vacuity coefficient, the Corrected frequency index of a prey (FC) and the Percentage in number of a prey (Cn%) to complete gaps in life cycle of this Carangidae and better manage this resource in that part of the Algerien coast.

## MATERIAL AND METHODS

The samples of hores mackerel (*Trachurus trachurus*) come from commercial catches landed in the port of Béni-Saf in the western Mediterranean Sea, between the Habibas islands to the east and the tip of Rachgoun to the west, between longitude 1° 10 and 1° 30 West (Fig. 1). Sampling was carried out monthly between November 2015 and October 2016. The individuals come from trawls (bottom and beam trawls) carried out at a depth of 30 and 130 m. For each individual we noted the height and the weight.

They have been divided into three size classes:

- Class 1: total length  $\leq 12$  mm Small.
- Class 2: 12 cm < total length < 20 cm Medium.

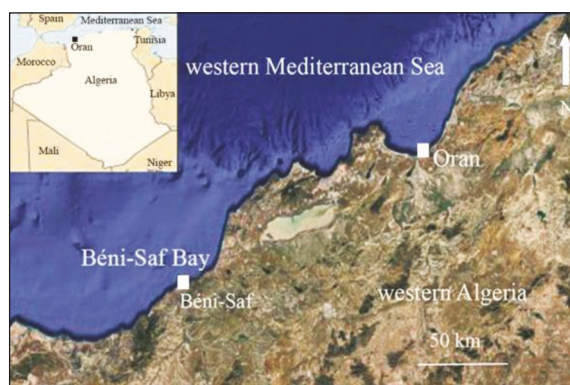


Figure 1. Geographical localization of the study area: Béni-Saf Bay, Algeria.

- Class 3: total length  $\geq 20$  cm Large.

The individuals are then dissected in order to recover the entire digestive tract immediately after capture, and then the stomach contents are stored in a formalin solution (10%). The ingested preys are identified with a binocular magnifier up to the family level, then under the microscope to possibly continue until the species. The excessively altered remains were classified in the indeterminate group. We used several identification keys (Rioja & Lo Bianco, 1928; Pasteur-Humbert, 1962; Bel-lon-Humbert, 1973; Kensley, 1978; Ruffo, 1982, 1989; Ledoyer, 1983; Sarda, 1984; Fischer et al., 1987a, b).

The stomach contents are grouped by month and by season, to obtain representative samples. These groups are: October, November and December in autumn, February-March in winter, April, May and June in spring and July, August and September in summer. To deepen the study of different diets and their variations, we used the mixed method (qualitative and quantitative), as well as different dietary indices.

### Sex ratio

It is defined as being the proportion of the male or female individuals compared to the total number of individuals. It also gives an idea on the balance of the sexes within the population. The sex-ratio generally translates the rate of femininity or masculinity of the population:

$$SR = F/(M+F) \times 100 \text{ (Kartas \& Quignard, 1984)}$$

F = number of females; M = number of males.

### Vacuity coefficient (V)

It is the ratio (in percentage) of the number of empty stomachs to the total number of stomachs examined. This coefficient makes it possible to identify, over time, the periods of weak and intense trophic activities in fish.

$$V = NEV / NET$$

NEV: number of empty stomachs.

NET: total number of stomachs.

### The Corrected Frequency Index of a prey (FC)

According to Gray et al. (1997), it is calculated as follows:

$$FC = Fi / \sum Fi * 100 \text{ with } Fi = ni P_i$$

$Fi$  = the frequency index of a prey.

$ni$  = number of stomachs containing the prey  $i$ .

$NP$  = number of number of stomachs containing the prey  $i$ .

### Percentage in number of prey (Cn)

It is the ratio (in percentage) of the total number of individuals of a prey  $p$  on the total number of the various prey ingested per batch of  $n$  fish. (Table 1).

$$Cn = 100 * P_i / P$$

$P_i$  = total number of individuals of a prey.

$P$  = the total number of various prey.

## RESULTS

In total, 488 specimens of *T. trachurus* were collected (Fig. 2), 240 males (49.18%), 208 females (42.62%) and 40 unsexed (8.20%).

The length frequency distribution of the entire population is shown in figure 2, male length range was 10.2 to 34.4 cm, female length range was 9.1 to 35.1 cm while males weight varied between 11.38 and 301.27 g and females' weight varied between 5.09 and 343.41 g.

### Sex Ratio

From a 12-month sample represented by a workforce of 488 individuals, we obtained a total masculinity rate of 53.57% for a total femininity rate of 46.43% (Fig. 3). Overall, in our sample, there is a convergence between the two sexes ratio with a slight favor of males. In addition, the variations in sex ratio according to size is in favor of females whose total length is less than 16.5.

In sizes between 16.5 and 35.5 cm, males outnumbered females, except for size 34.5 cm and 35.5 cm, where females outnumbered males. Monthly variations of sex-ratio (Fig. 3) reveal that females

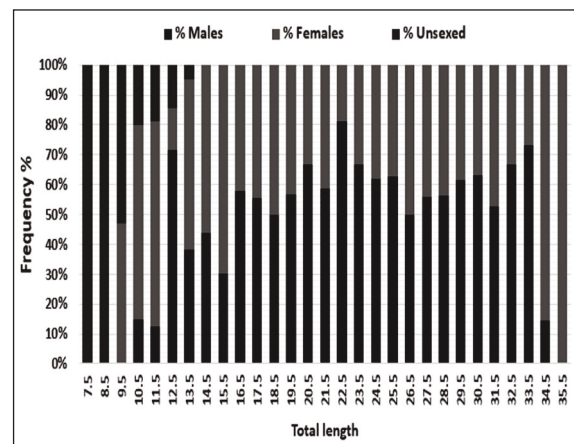


Figure 2. *Trachurus trachurus* length frequency distribution of males and females caught in Béni-Saf Bay.

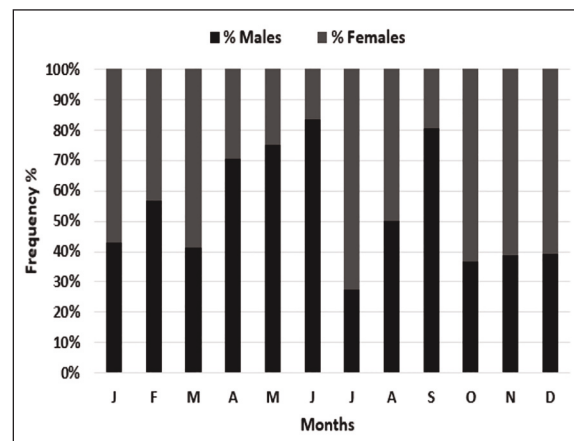


Figure 3. Monthly evolution of Sex ratio of *Trachurus trachurus* caught in Béni-Saf Bay.

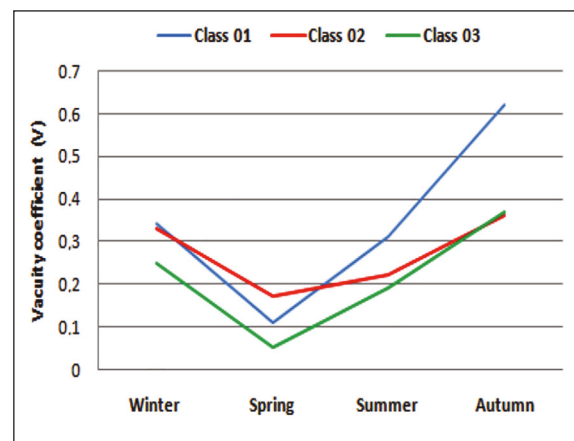


Figure 4. Seasonal variation of vacuity coefficient of *Trachurus trachurus*.

dominate during the months of January, March, July, October, November and December. And males dominate during February, April, May, June, and September, with a numerical equality in August. Evolution of sex-ratio related to seasons (Fig. 5) showed that females dominate in the winter period while males dominate in the spring-summer-autumn period.

### Vacuity coefficient (V)

The Vacuity coefficient shows seasonal fluctuations (Fig. 4). This coefficient displays the lowest values during the spring season, which is explained by the abundance of prey in the environment. While it marks the highest values in the autumn period, which indicates the scarcity of prey in the environ-

ment, which leads to feeding difficulties and cause the fish to eat less.

### Composition of the diet according to the season

#### Class 1

The food spectrum included 8 preys in winter, 14 in spring, 7 in summer and 5 in autumn (Fig. 5).

In winter, Copepoda are the main prey. Amphipoda, Cumaceae and Euphausiacea are secondary prey. The Nauplius and eggs of Teleosts constitutes the complementary prey of 2nd order. The rest are accidental prey. In spring, prey appears more diverse. The Copepods constitute the main prey, the Euphausiacea constitute the secondary prey. Amphipods, Cumaceae and *Nauplius* are complementary prey (1st order). The Mysidacea, squid and eggs of Teleosts are complementary prey (2nd order). The remains of Brachiopods, Echinoderms and Mollusc are accidentally preyed. In summer, the consumption is focused on Crustacea, but there is no main prey. The Euphausiacea and the Amphipods constitute the secondary accessory prey, the eggs of Teleosts and Nauplius are complementary prey (2nd order). There is no accidental prey. In Autumn, the foods of this fish is based on the Copepods which constitute the main prey. Euphausiacea and Amphipods take a more important place but remain secondary prey. Eggs of Teleosts are complementary prey. There is no lack of accidental prey.

Cn%	Fc%	Category of Prey
Cn > 50 Main prey	FC > 30: Preferential	Main Preferential
	FC < 30: Occasional	Main Occasional
10 < Cn < 50 Secondary prey	FC > 10: Frequent	Secondary Frequent
	FC < 10: Accessory	Secondary Accessory
1 < Cn < 10 Complementary prey	FC > 10: 1 <sup>st</sup> Order	Complementary 1 <sup>st</sup> Order
	FC < 10: 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order
Cn < 1: accidental prey	accidental prey	accidental

Table 1. Classification of prey according to Cn and Fc (Hureau, 1970).

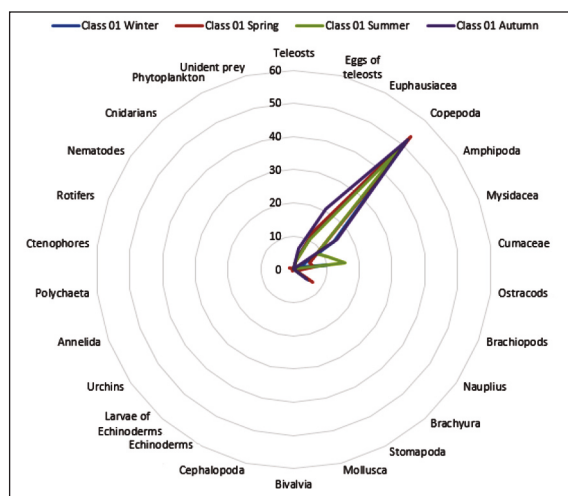


Figure 5. Seasonal composition of the diet of *Trachurus trachurus* (class 1) caught in Béni-Saf Bay.

#### Class 2

The food spectrum includes 12 preys in winter, 20 in spring, 11 in summer and 8 in autumn (Fig. 6).

In winter there is no main principal prey. Compared to the first class, Euphausiacea occupy a large place. The decrease in the consummation of Copepods was offset by an increase in that of Euphausiacea which then became the preferred prey of this size class, but it remains classified in the category of secondary prey. In addition, we note the emergence of a new prey, Small fish (Teleosts) and squid as secondary prey. Amphipods are complimentary prey (2nd order). We have also recorded the appearance of Stomatopods, Bivalvia, and larvae of Echinoderm as accidental prey.



In spring, the fish keep the same winter feeding behaviour with the appearance of new preys. The Ostracoda, the Rotifers and Bivalvia as complementary prey (2nd order). The rest (crabs, Molluscs, echinoderm, Polychaeta, Ktenophores, Cnidarians, phytoplankton) constitute accidental prey.

During summer and autumn the fish maintain the same eating behaviour with slight differences, such as a higher predation of squid in autumn. Molluscs and Cnidarians appear as both accidental and new prey in summer.

### Class 3

The food spectrum included 13 preys in winter, 20 in spring, 10 in summer and 8 in autumn (Fig. 7).

In winter, consumption is focused on the Small fish (Teleosts) which constitute the main prey, while Euphausiacea are secondary accessory prey. Our results show a significant reduction in Crustaceans considered complementary prey after having been a staple food of the two previous classes. The diet has also seen the emergence of a new prey of bivalvia as a complementary prey of the 2nd order, the rest of the food represents accidental prey.

In spring and summer, the diet is almost identical; it does not contain main prey. In both seasons, it prefers to feed on Small fish but remain classified as secondary prey, followed by predation of Mysi-

dacea and squid. The difference between the two seasons shows that the spring diet is more varied and results in the emergence of a new prey; the Stomatopoda as complementary prey (2nd order).

In autumn, the diet is entirely dominated by Small fish (Teleosts) (preferential primary prey), Euphausiacea and Amphipods are frequent secondary prey. The rest are accidental preys.

## DISCUSSION

The diet study of *T. trachurus* has shown that this species has a wide food spectrum, and is an omnivorous and euryphagous fish. Its food is dominated by benthic (mainly Crustaceans) and pelagic (Copepods, Teleosts) prey, which is confirmed by (Jardas et al., 2004; Šantić et al., 2005; Bahar & Tuncay, 2009; Cabral & Murta, 2002; Bahar et al., 2013; Shawket et al., 2015; Koç & Erdoğan, 2019).

The annual vacancy factor is 22.55% (110 empty stomachs), and we notice that it decreases with an increase in the size of individuals, as the highest values were recorded in young individuals and this is consistent with Shawket et al. (2015) and Koç & Erdoğan (2019). The low vacancy factor during the spring and summer is due to the availability of prey. Also, the nutritional activity may be affected by physiological and ecological phenomena (such as reproduction and migration).

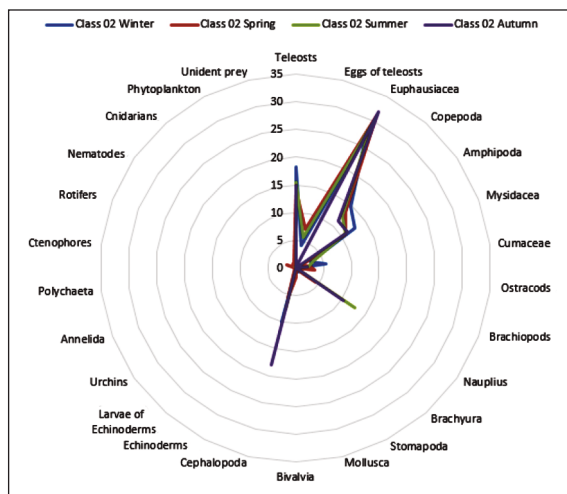


Figure 6. Seasonal composition of the diet of *Trachurus trachurus* (class 2) caught in Béni-Saf Bay.

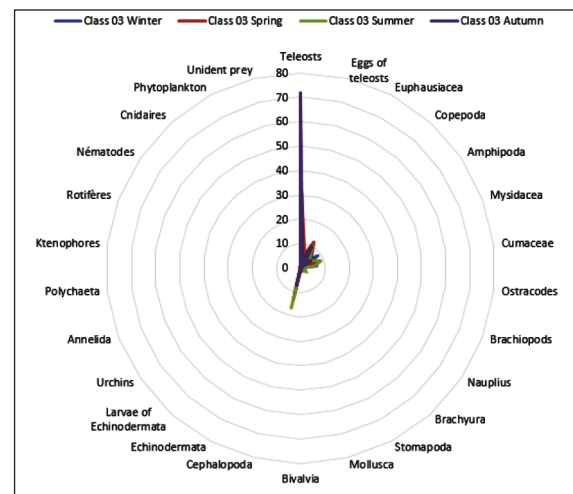


Figure 7. Seasonal composition of the diet of *Trachurus trachurus* (class 3) caught in Béni-Saf Bay.

As the size class increases, the qualitative and quantitative composition of the food evolves, and the dietary diversity in the large *T. trachurus* suggests that they exploit a wide range of prey. The selection of the types of prey is in relation to the size of the predators (Chapman et al., 1988; Bayhan & Tuncay, 2009; Shawket et al., 2015;), the size classes of *T. trachurus* exploit different types of prey, which would decrease the competition between small and large individuals, which is confirmed by Bănară & Harmelin-Vivien (2009).

The composition of the diet of this species is based on six major taxonomic groups (Euphausi-

acea, Copepoda, Amphipoda, Mysidacea, Cumaceae and Teleosts), which is confirmed by several authors (Kompowski, 1976; Šantić et al., 2005; Bănară, 2008; Bahar & Tuncay, 2009; Bahar et al., 2013; Koç & Erdoğan, 2019). The presence of supra-benthic taxa (Stomatopoda, Bivalvia, Echinoderma, cephalopoda, Brachyura) indicates, however, their expediency or aptitude to use sometimes more resources at the bottom. This fish shows a great plasticity of its diet and can feed whatever the environment, which is consistent with the study of Bănară (2008).

The results that we obtained in this study show

Cn %	Class 01				Class 02				Class 03			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Teleosts	0	0	0	0	18.29	13.94	15.56	14.84	53.06	41.61	40.46	71.7
Eggs of teleosts	3.16	2.21	2.48	6.42	4.18	7.31	5.66	0.23	0.47	5.8	2.93	3.02
Euphausiacea	12.69	13.11	10.34	20.67	27.26	31	29.05	31.86	11.77	11.69	10.32	9.94
Copepoda	51.11	53.4	49.01	52.04	14.71	13.5	12.56	11.36	4.77	6.59	5.39	2.14
Amphipoda	14.67	8.53	8.34	15.96	12.8	10.75	10.88	11.28	8.7	4.27	5.6	5.02
Mysidacea	1.8	5.25	10.97	0	2.89	0.63	3.5	0	0.3	8.31	8.99	0
Cumaceae	10.64	6.1	15.68	0	5.47	2.5	2.26	2.08	6.51	0.82	5.88	0
Ostracodes	0	1.73	0	0	0	3.44	0	0	0	0.3	0	0
Brachiopods	0	0.12	0	0	0	0	0	0	0	0	0	0
Nauplius	5.54	6.89	2.94	4.91	3.15	4.38	12.77	10.36	1.22	2.23	2.77	0.26
Brachyura	0	0	0	0	0.1	0.81	0	0	0.43	0.42	0	0.61
Stomatopoda	0	0	0	0	0.88	0	0	0	0	1.56	0	0
Mollusca	0.11	0.03	0	0	0	0.22	0.1	0	0.06	0.72	0	0
Bivalvia	0	0.09	0	0	0.1	1.66	0	0	1.1	0.96	0	0
Cephalopoda	0	0	0	0	10.12	5.66	7.51	17.99	11.13	13.2	16.98	7.31
Echinodermata	0	0	0	0	0	0.06	0	0	0	0	0	0
Larvae of Echinodermata	0	0.54	0	0	0.05	0.28	0	0	0	0.18	0	0
Urchins	0	0.06	0	0	0	0	0	0	0	0	0	0
Annelida	0	0	0	0	0	0	0	0	0	0.18	0	0
Polychaeta	0	0	0	0	0	0.28	0	0	0	0	0	0
Ktenophores	0	0	0	0	0	0.13	0	0	0	0	0	0
Rotifères	0	1.49	0	0	0	1.66	0	0	0	0.3	0	0
Nématodes	0	0	0	0	0	0	0	0	0.3	0.66	0	0
Cnidaires	0	0	0	0	0	0.03	0.15	0	0	0.06	0.05	0
Phytoplankton	0	0	0	0	0	0.88	0	0	0	0.14	0	0
Unident prey	0.28	0.45	0.24	0	0	0.88	0	0	0.18	0	0.63	0

Table 2. Composition of the diet of *Trachurus trachurus* according to Cn%.

that the main prey of the horse mackerel of the Bay of Béni-Saf are crustaceans for a size of fish lower than 20 cm. Beyond this size (TL 20 cm) Small fish (Teleosts) are the preferred prey.

## CONCLUSIONS

Our study has shown that the horse mackerel *T. trachurus* of Béni-Saf bay (North-Western Mediterranean Sea) is a carnivorous species (benthopelagic), whose food spectrum consists mainly of Crustaceans (Copepods, Euphausiacea, Am-

phipods, Mysidacea, Cumaceae), Cephalopods and vertebrae (Teleosts and Eggs of teleosts). In the first two size classes (Lt <20 cm), Crustaceans constitute the most important group of prey, for class 3 (Lt > 20 cm), Teleosts (anchovies, sardines) constitute the group most preferable prey. We conclude that the diet of this fish is very flexible as it changes prey in proportion to predation capacity and environmental conditions.

There is little seasonal variation in the diet, crustaceans were the dominant prey in all seasons for the first two size classes, while fishes were the dominant prey in class 3 (Table 3).

	<i>Class 1</i>	<i>Class 2</i>	<i>Class 3</i>
<i>Teleosts</i>	---	Secondary Frequent	Main Preferential
<i>Eggs of teleosts</i>	Complementary 1 <sup>st</sup> Order	Complementary 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order
<i>Euphausiacea</i>	Secondary Frequent	Secondary Frequent	Secondary Frequent
<i>Copepoda</i>	Main Preferential	Secondary Frequent	Complementary 2 <sup>nd</sup> Order
<i>Amphipods</i>	Secondary Frequent	Secondary Frequent	Complementary 1 <sup>st</sup> Order
<i>Mysidacea</i>	Complementary 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order
<i>Cumaceae</i>	Complementary 1 <sup>st</sup> Order	Complementary 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order
<i>Ostracods</i>	accidental	accidental	accidental
<i>Brachiopods</i>	accidental	---	---
<i>Nauplius</i>	Complementary 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order	Complementary 2 <sup>nd</sup> Order
<i>Brachyura</i>	---	accidental	accidental
<i>Stomapoda</i>	---	accidental	accidental
<i>Mollusca</i>	accidental	accidental	accidental
<i>Bivalvia</i>	accidental	accidental	accidental
<i>Cephalopoda</i>	---	Secondary Frequent	Secondary Frequent
<i>Echinoderms</i>	---	accidental	---
<i>larvae of</i>	accidental	accidental	accidental
<i>Echinoderms</i>			
<i>Urchins</i>	accidental	---	---
<i>Annelida</i>	---	---	accidental
<i>Polychaeta</i>	---	accidental	---
<i>Ctenophores</i>	---	accidental	---
<i>Rotiferes</i>	accidental	accidental	accidental
<i>Nematods</i>	---	---	accidental
<i>Cnidarians</i>	---	accidental	accidental
<i>Phytoplankton</i>	---	accidental	accidental
<i>Unident prey</i>	accidental	accidental	accidental

Table 3. Categories of preys ingested by horse mackerel (*Trachurus trachurus*).

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