# INVESTIGATIONS OF FOOD AND FEEDING HABITS OF LARVAE AND JUVENILES OF THE ARGENTINE ANCHOVY *ENGRAULIS ANCHOITA*[1]

JANINA DZ. DE CIECHOMSKI
Instituto de Biologia Marína
Mar del Plata, Argentina

## INTRODUCTION

Up to the present time no papers on the feeding of the larvae of marine fishes have been produced in Argentina. The present contribution is the first study of this nature referring to this area of the Southwest Atlantic and it deals with problems related to the feeding habits of the larvae and juveniles of the Argentine anchovy.

The purpose of this paper is to study the food and feeding habits of the anchovy larvae from the time at which the larvae begin to be able to feed, to the time when the juveniles approach the adult stage. This study has been based upon a quantitative and qualitative determination of the food components, to obtain a better assessment of the contribution of the different groups of organisms to the diet of the larvae and juveniles of the anchovy. The characteristics of the feeding of the young forms of the anchovy at different stages of development were studied in relation to the morphological changes which take place throughout the growth of the individuals. The morphological characters most closely related to the feeding process in fishes are: the digestive tract, the gill rakers and the dimensions of the mouth. Therefore, in the present work, special emphasis has been given to a detailed study of these morphological elements. Also, an analysis of the changes in the feeding of the larvae and juveniles of the anchovy during different seasons of the year has been attempted.

Together with the anchovies, juvenile indivudals of another species, *Austroatherina incisa*, were gathered. The individuals of this species share the habitat of, and are found mixed with those of the anchovy. The purpose of collecting other material was to study the intestinal content of the individuals of this other species with the aim of obtaining comparative material as a frame of reference for the anchovy, taking especially into account the competition for their food supply. The results of the analysis of the feeding habits of the juveniles of *A. incisa* will be found in another paper by this author (Ciechomski, in press).

## MATERIALS AND METHODS

The larvae and juveniles of anchovy which were used as material for this study were collected from coastal waters off Mar del Plata. The juveniles were obtained from every month of the year. The larvae of sizes 3.0–4.9 mm and 5.0–22.0 mm were obtained only during the summer. A total of 1,705 larvae and juveniles has been studied, ranging in size from 3.0 to 90.0 mm. From these, 503 individuals contained food, the remainder having their digestive tracts empty.

For the elaboration and presentation of the data, the months of September, October, and November have been considered spring, December, January, and February were considered as summer, March, April, and May autumn, and June, July, and August winter.

The material to be studied was fixed on the spot, right after its collection, with formaldehyde, in order to stop the digestive processes, since this was convenient in view of the study made of the intestinal content. Further treatment of the material was continued in the laboratory.

Each individual was measured and its digestive tract was separated under a magnifying glass. The examination of the intestinal content was performed under the magnifying glass and the microscope. All of the components were separated, counted and measured by means of a micrometric eyepiece. For assessing the weight of the individuals, a list of mean weights was made in which the larvae and juveniles of anchovy were classed in total length classes with 2 mm intervals.

Plankton samples were obtained together with the anchovies, and the predominant forms were noted. Although this appraisal was not made in a quantitative manner and was not expressed numerically, it was considered useful as an indication of the feeding selectivity of the fishes which were studied.

In the quantitative treatment of the data, one of the methods used was the determination of the frequency of occurrence. The calculation of the weight of the total food ingested and of the percentage composition of the various food components was based on the mean live weight of the planktonic organisms which make up the diet of the anchovies. Since at the present time no data are available on the weight of these planktonic organisms, which are the basic food supply of the larvae and juveniles and, in some cases, of adult planktofagous fishes, for the most of the planktonic components the volume was determined by the method of volume shift. In other cases, when dealing with very small organisms of irregular shape, such as some diatoms (*Coscinodiscus, Triceratium*, etc.) the volume determination was accomplished geometrically. Multiplying the volume by the corresponding group index (Hagmeier, 1961) the mean weights of the organisms were obtained. The following

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table shows the values calculated for the volume and weight of some of the planktonic components.

TABLE 1

**WEIGHT OF SOME PLANKTONIC ORGANISMS MOST FREQUENTLY FOUND IN THE FOOD OF THE LARVAE AND JUVENILES OF MARINE FISHES**

| Organisms | Mean dimension (m) | Mean volume ($mm^3$) | Hagmeier coefficient | Mean weight (mg) |
|---|---|---|---|---|
| Diatomea | | | | |
| *Coscinodiscus* spp. | 124 x 32 | 0.000160 | 1.1 | 0.000175 |
| *Triceratium* spp. | 145 x 114 x 60 | 0.000496 | 1.1 | 0.000545 |
| Peridinea | | | | |
| *Exuviaella* sp. | 48 x 36 | 0.0000325 | 1.05 | 0.000034 |
| Copepoda | | | | |
| Calanoida | 1000 | 0.0120 | 1.04 | 0.0125 |
| " | 1000–2000 | 0.1330 | 1.04 | 0.1373 |
| " | 2000–3000 | 0.4580 | 1.04 | 0.4714 |
| " | 3000–4000 | 1.4280 | 1.04 | 1.4851 |
| " | 4000–5000 | 4.0000 | 1.04 | 4.1600 |
| Harpacticoida (Euterpina acut.) | 480 x 850 | 0.0095 | 1.04 | 0.0100 |
| Cyclopoida | 356 x 176+ 240 x 130 | 0.0050 | 1.04 | 0.0052 |
| Cladocera | | | | |
| *Evadne nord.* | 420–780 | 0.0092 | (1.04) | 0.0095 |
| Larvae of Lamellibranch | 200–344 | 0.0044 | ---- | 0.0044 |
| Anchovy eggs | 1370 x 720 | 0.3780 | ---- | 0.3780 |
| Fish eggs | 1000 | 0.5230 | ---- | 0.5230 |

Of course, these calculations are not free from error, especially in the case of the Copepoda, which have been classed by great groups and by size classes, instead of by separate species, which would have been more correct. In the present conditions, a more refined treatment was not feasible.

For the calculation of the ingestion coefficient the food weight was divided by the weight of the individual, and the result was multiplied by 1,000.

The measurements of the dimensions of the mouth were made by means of the micrometric eyepiece. The mouth was opened by means of very thin needles and the length and width of the mouth were measured under approximately the same angle. The first branchial arch of the left side was used always for observing the development of the gill-rakers.

## INCIDENCE OF FEEDING

The incidence of feeding was remarkably low, especially in some of the size classes of larvae. In Table 2 the values for the incidence of feeding for larvae of different lengths are shown.

As is shown in Table 2, the incidence of feeding varies greatly with the size of the larvae and juveniles of the anchovy. It is relatively high for the larvae whose lengths fall within the 3.0–4.0 mm class. The larvae in this group have just reabsorbed their yolk and have begun to feed themselves. While the growth of the larvae continues the incidence of feeding decreases sharply, reaching the value 0 for individuals in the 5.0–9.0 mm class length. In those larvae whose lengths exceed 9.0 mm the incidence of feeding begins to increase gradually, but at a low rate, until the time at which the larvae reach a length of 40 mm. Beyond the 40 mm length the number of larvae containing food increases clearly and in the juveniles of 50.0–90.0 mm this number reaches a more or less constant and rather high level. It should be emphasized that the fact that larvae which did not contain food were found in such a scarce number has been experienced during 3 years, regardless of the season of the year.

TABLE 2

**INCIDENCE OF FEEDING IN LARVAE AND JUVENILES OF THE ANCHOVY**

| Length of Organism (mm) | Number of Organisms | Incidence of Feeding |
|---|---|---|
| 3.0– 4.0 | 56 | 52.2 |
| 4.0– 5.0 | 42 | 18.2 |
| 5.0– 9.0 | 50 | 0 |
| 9.0–20.0 | 350 | 5.7 |
| 20.0–30.0 | 360 | 9.2 |
| 30.0–40.0 | 320 | 17.9 |
| 40.0–50.0 | 282 | 57.3 |
| 50.0–90.0 | 245 | 78.6 |
| Total | 1705 larvae<br>503—Number of organisms containing food | |

This low incidence of feeding found in larvae of a species of the family Engraulidae is not an isolated fact, but has been observed with different species of this family and of those of the Clupeidae. Berner (1959) while studying the feeding habits of the northern anchovy, *Engraulis mordax* found that among the 13,620 larvae which he examined only 211 had ingested any food. Lebour (1921), who studied the food habits of numerous young clupeids, found that the percentage of individuals containing food was very low. The incidence of feeding in the larvae of other groups of fishes appears to be higher (Lebour 1920, Wiborg 1948, etc). While studying the food of the larvae and juveniles of *A. incisa* which were collected together with those of the anchovy (Ciechomski, in press) the present author found that all of the individuals which were examined contained food in their intestinal tract.

The phenomenon of the low incidence of feeding in the families Engraulidae and Clupeidae has been a subject of detailed analysis by numerous authors. There exist, as a consequence, several theories which attempt to explain this fact. Some authors try to explain this phenomenon as a consequence of the selectivity of the nets, which would tend to collect those larvae which were weak and underfed (Berner 1959, Soleim 1942, and others). Other authors think of this phenomenon as a consequence of the characteristics of the digestion of these species, which, according to them, is very rapid. The old theory of Pütter, according to whom fishes are able to feed upon the organic matter which is dissolved in the water, has been sustained by Morris (1955). This author thinks this possible on the basis of the fact that the larvae of some species of marine fishes, including those of *Engraulis mordax,* have an extensive layer of mucous cells over the surfaces of the back of the mouth. Morris believes that "... the mucosa might serve as a mechanism for collecting important quantities of dispersed organic matter...". Nothing concrete can be said at this time concerning these assumptions.

Other authors, such as Schumann (1965) take into account the diurnal feeding habits of these species. The diurnal habits of the feeding of fishes and especially of that of their larvae and juveniles have been pointed out by several authors: Schumann (1965) for *Sardinops caerulea,* Ercegovíc (1962) for *Clupea pilchardus,* Duka (1961) for *Engraulis encrasicholus,* etc. No matter what differences may exist among the observations of these various authors, most of them agree that the larvae of these fishes feed exclusively during daylight. They note that during the day, there are times at which the ingestion of food is more intensive, but no ingestion of food has been observed to take place during the night.

In the case of the Argentine anchovy, some assumptions can be made in this connection, taking into account all of the points of view mentioned and the author's own observations. The hypothesis of the effects of net selectivity upon the larvae during their collection was rejected, since the larvae with the lowest incidence of feeding were gathered in great numbers by means of a large net of purse-seine type with which the loss of the larvae was highly improbable. Furthermore, the larvae collected were in very good condition and did not appear to have starved. Plankton samples collected simultaneously showed the presence of numerous organisms which could be used as food by the larvae.

Nothing can be said here on the diurnal feeding habits of the anchovy because it was impossible to obtain samples during the night or during twilight hours. All of the material was collected during daylight and generally at about noon. Therefore, if it is assumed that the anchovy behaves in this respect like other species of marine fishes which feed exclusively during daylight, the fact of finding larvae with their intestinal tract devoid of food can not be accounted for by the diurnal feeding habits.

No studies have been made, up to the present time, which could cast light on the problem of the digestion of food by the larvae of *E. anchoita.* As a consequence of this, the present analysis is based mainly on comparisons with other related species, for which a better understanding of these processes has already been attained. Duka (1961) has reported that the speed of digestion in larvae of 6–7 mm in length of *E. encrasicholus* of the Black Sea, at a temperature of 23° C., is from 2–2.5 hours. But, on the other hand, according to Schumann (1965) the speed of digestion for nauplii of *Artemia salina* by larvae of *E. mordax* of the Pacific, off California, is much greater. This author has observed that "... an average of 25 seconds is required by larvae of 15 mm in length or larger to pass an *Artemia* nauplius from the mouth to approximately one-half of the length of the digestive tract. Progress of a food particle (*Artemia*) through the remainder of the gut is much slower, with an average of 2 minutes required for food to reach the end of the gut and form a food plug." It appears then, that a very short time interval is required for an ingested particle to disappear from the intestinal tract of the larvae of *E. mordax.*

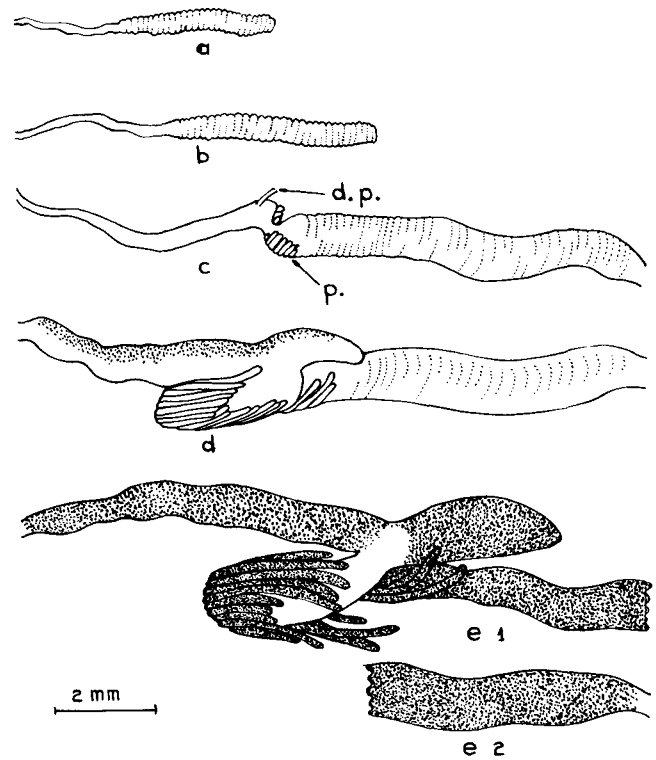


**FIGURE 1. Development of the digestive tract of the anchovy larvae. p—pyloric appendices, d—ductus pneumaticus. The drawings correspond to the following lengths of fish: a—9.2 mm, b—15.0 mm, c—33.0 mm, d—38.0 mm, $e_1$ and $e_2$—50.0 mm.**

Figure 1 shows the development process of the digestive tract of *E. anchoita.*

As is shown in the drawing, the digestive tract of the larvae, until they reach a length of at least 33 mm, is a short and completely straight tube, differentiated only in the anterior and posterior parts. In the larvae of 33 mm length a sketch of the stomach and rudiments of the pyloric appendices appears. At a length of 38 mm the stomach and pyloric appendices show themselves in a rather developed state and the pigment of the anterior part of the intestine begins to appear. In the juveniles of 50 mm, the part corresponding to the stomach is well developed and the whole digestive tract resembles that of an adult individual. This type of digestive tract structure, in the shape of a straight tube, is typical of the engraulids and clupeids. The very straightness and shortness of the digestive tract may favor a rapid digestion and excretion. It can also be assumed that at the moment the anchovy larvae are caught, an artificial acceleration of the excretion processes or the vomiting of the intestinal content could take place. By observing the drawings (Figure 1) it can be seen that the intestinal structure shaped like a straight tube is maintained in those larvae whose incidence of feeding is lowest. The differentiation of the digestive tract coincides with the increase in the incidence of feeding. Mention should be made of the fact that the intestine of the larvae and juveniles of *A. incisa* gathered together with those of the anchovy, and having a 100% incidence of feeding (Ciechomski, in press), is not straight, but presents several folds.

It is more difficult to find an explanation for the relatively high incidence of feeding in the young larvae which are just beginning to feed. A similar phenomenon has been reported by Berner (1959) for *E. mordax*. This author found that the greatest percentage of feeding larvae was among the smaller ones. Further discussion of these facts should be withheld pending more detailed information regarding the physiology of the digestion, and behavior of the anchovy larvae.

## COMPOSITION OF DIET AND SIZE OF FOOD ORGANISMS

The results obtained for different years were very similar, and therefore the material from both annual cycles has been treated collectively. The data are shown in Tables 1 and 2.

In Table 3 the results for the smaller larvae, 3.0–4.9 mm, and for those of 12.5–22.5 mm are given. Table 4 shows similar data for larvae and juveniles whose lengths range from 22.0 to 90.0 mm. The group comprising larvae whose length ranged between 9.0 and 20.0 mm was not included in the tables in view of the scarce number of individuals available. Within the intestines of the larvae falling in this group, the only food found was Copepoda with the following percentage of weight rate for the components: eggs

TABLE 3

PERCENT INCIDENCE AND PERCENT WEIGHT RATES OF DIFFERENT FOOD ORGANISMS IN ANCHOVY LARVAE, IN SUMMER

| | Larvae: 3.0–4.9 mm | | Larvae: 12.5–22.0 mm | |
|---|---|---|---|---|
| | Percent incidence rate | Percent weight rate | Percent incidence rate | Percent weight rate |
| Miscellaneous eggs | 8.69 | 7.20 | 5.58 | 5.58 |
| Eggs of Copepoda | 69.56 | 45.05 | 5.58 | 5.58 |
| Nauplii of Copepoda | 60.86 | 47.75 | ---- | ---- |
| Copepodita | ---- | ---- | 11.76 | 10.37 |
| Calanoida | ---- | ---- | 64.70 | 49.63 |
| Harpacticoida | ---- | ---- | 11.76 | 8.24 |
| Cyclopoida | ---- | ---- | 23.52 | 2.96 |
| Cladocera | ---- | ---- | 23.52 | 17.64 |

TABLE 4

PERCENT INCIDENCE AND PERCENT WEIGHT RATES OF DIFFERENT FOOD ORGANISMS IN LARVAE AND JUVENILES OF THE ANCHOVY, IN DIFFERENT SEASONS OF THE YEAR

| | Spring | | Summer | | | | Autumn | | | | Winter | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Juveniles 45.5–86.0 mm | | Larvae 22.0–42.0 mm | | Juveniles 42.0–90.0 mm | | Larvae 28.0–42.0 mm | | Juveniles 42.0–86.0 mm | | Juveniles 41.0–86.0 mm | |
| Organism | Percent incidence rate | Percent weight rate | Percent incidence rate | Percent weight rate | Percent incidence rate | Percent weight rate | Percent incidence rate | Percent weight rate | Percent incidence rate | Percent weight rate | Percent incidence rate | Percent weight rate |
| Eggs of Copepoda | -- | -- | 6.89 | 1.72 | -- | -- | -- | -- | -- | -- | -- | -- |
| Nauplii of Copepoda | 8.69 | 0.26 | 8.62 | -- | 4.76 | 2.29 | 5.26 | -- | 8.33 | 0.19 | -- | -- |
| Copepodita | -- | -- | 13.79 | 0.95 | 4.76 | 7.14 | 10.52 | -- | 4.16 | 1.40 | -- | -- |
| Calanoida | 100.00 | 55.25 | 48.27 | 39.14 | 61.90 | 30.36 | 89.47 | 79.21 | 95.83 | 41.11 | 65.95 | 40.56 |
| Harpacticoida | 86.95 | 29.56 | 13.79 | 9.13 | 11.90 | 12.20 | 73.68 | 14.20 | 66.60 | 32.08 | 29.78 | 11.30 |
| Cyclopoida | 34.78 | 2.05 | 5.17 | 2.50 | 2.38 | 3.45 | 21.05 | 0.50 | 16.66 | 1.20 | 12.76 | 1.20 |
| Cladocera | 21.73 | 0.06 | 51.60 | 30.99 | 30.95 | 4.45 | 26.31 | 2.13 | 60.41 | 2.48 | 29.78 | 15.96 |
| Larvae of Decapoda | 13.04 | 0.63 | 3.44 | 0.85 | 2.38 | 2.00 | -- | -- | 8.75 | 2.87 | 2.12 | 0.61 |
| Larvae of Cirripedia | 4.34 | -- | -- | -- | -- | -- | -- | -- | 25.00 | 4.56 | 2.12 | -- |
| Amphipoda | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.18 | 2.12 |
| Euphausidae | -- | -- | -- | 11.90 | -- | 6.98 | -- | -- | 6.25 | 0.63 | -- | -- |
| Undetermined Crustacea | -- | -- | 3.44 | 1.41 | 11.90 | 7.36 | -- | -- | -- | -- | 4.25 | 4.05 |
| Larvae of Polychaeta | 4.34 | -- | -- | -- | -- | -- | -- | -- | 4.16 | 0.82 | -- | -- |
| Larvae of Lamellibranch. | 26.08 | 0.30 | 1.72 | 1.72 | -- | -- | -- | -- | 43.75 | 1.34 | 14.89 | 0.42 |
| Apendicularia | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.38 | 0.27 |
| Miscellaneous Eggs | 13.04 | -- | 5.17 | 6.67 | 57.14 | 7.89 | -- | -- | 10.41 | -- | 21.27 | 2.12 |
| Fish Eggs | 17.39 | 1.19 | 1.72 | 0.02 | 7.14 | 1.32 | -- | -- | 8.33 | 1.62 | -- | -- |
| Fish Larvae | -- | -- | 1.72 | 1.72 | 11.90 | 6.63 | -- | -- | -- | -- | -- | -- |
| Anchovy Larvae | -- | -- | 1.72 | 1.68 | 7.14 | 7.14 | -- | -- | -- | -- | -- | -- |
| *Peridinium* sp. | -- | -- | -- | -- | -- | -- | -- | -- | 16.66 | -- | 19.14 | -- |
| *Exuviaella* sp. | 34.78 | 1.67 | 5.17 | -- | 4.76 | -- | 5.26 | 3.96 | 47.91 | 0.17 | -- | -- |
| *Ceratium* sp. | -- | -- | 1.72 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Miscellaneous Diatomea | 52.17 | 0.02 | 1.72 | -- | 2.38 | -- | -- | -- | 31.25 | -- | 31.91 | 0.06 |
| *Coscinodiscus* spp. | 69.56 | 1.15 | -- | -- | -- | -- | -- | -- | 70.83 | 6.36 | 55.31 | 4.97 |
| *Triceratium* spp. | 43.47 | 3.96 | -- | -- | -- | -- | -- | -- | 4.16 | 0.04 | 21.27 | 10.04 |
| *Biddulphia sinensis* | 4.34 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.12 | -- |
| Foraminifera | 4.34 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.25 | -- |
| Radiolaria | -- | -- | 17.24 | -- | 33.30 | -- | -- | -- | -- | -- | -- | -- |
| Detritus and Sand | 17.39 | 1.66 | -- | -- | -- | -- | -- | -- | 12.50 | 1.05 | 27.65 | 5.92 |
| Undetermined | 13.04 | 2.24 | 1.72 | 1.00 | 4.76 | 0.79 | -- | -- | 3.08 | 2.08 | 19.14 | 2.40 |

of Copepoda, 5.0%; Calanoida, 79.2%; Cyclopoida, 15.8%. Information on the food of larvae within the 5.0–9.0 mm length class is lacking, since, as is noted in Table 1, no individuals of this class containing food in their intestinal tracts were found.

As is shown clearly in the tables, the larvae and juveniles of the Argentine anchovy are zooplanktofagous from their earliest stages, and the contribution of the phytoplankton to their diet is quite small. Furthermore, Fuster de Plaza and Boschi (1958), and Angelescu and Cousseau (1966), have found that the diet of the adult anchovy is made up almost exclusively of zooplankton.

The diet of the larvae which are just beginning to feed actively is made up almost exclusively by eggs and nauplii of Copepoda. The basic food supply for the 9.0–22.0 mm length class is also comprised of the Copepoda at various stages of their development. The highest frequency of occurrence and the highest percentage of weight correspond to the Calanoida. Together with the copepods the Cladocera appear abundantly. These results refer only to the summer season, since it was not possible to collect larvae of anchovy of this small size during other seasons of the year.

For the larvae and juveniles in the 22.0–90.0 mm length class, it was possible to give an account, as shown in Table 4, of the food composition throughout the year. As can readily be seen, the main components of the diet for this group are also various groups of Copepoda, especially the Calanoida. Among these groups the Cyclopoida are the least important, in this respect. Among the Calanoida, the most frequently encountered species were *Paracalanus parvus* and *Centropages spp.* and among the Cyclopoida, *Oithona minuta* and *Corycaeus spp.* Among the Harpacticoida, only one species was found: *Eutherpina acutifrons.*

After the Copepoda, the Caldocera, which are especially abundant in both summer and winter, follow in importance as food for the larvae and juveniles of the anchovy. They are represented by two species: *Podon polyphemoides* and *Evadne nordmanii.*

Larvae of Decapoda and Lamellibranchiata are found in some individuals during all seasons of the year, but in quantities of slight significance in respect to the total food supply. The same observation applies also to the eggs of various marine organisms, although their share in the total weight is somewhat greater than that of the aforementioned larvae. Most of the eggs of fishes found in the food content were anchovy eggs in spring, during October, and eggs of *Prionotus sp.* during February and March.

Under the heading "undetermined", remains of fish muscles, which originated in all probability from the bait used by fishermen, were included.

The contribution of phytoplankton to the diet of the anchovy deserves a more detailed analysis. As is shown in Table 4 the phytoplankton most frequently found in the food supply were the diatoms *Coscinodiscus spp.* and *Triceratium sp.* and the dinoflagellates *Exuviaella spp.* Although these organisms are found in many individuals and are occasionally very abundant, their significance in the total weight is low. The most important place among the phytoplankters is certainly occupied by *Coscinodiscus spp.* and *Triceratium sp.* During the summer a lesser contribution of the phytoplankton organisms is observed in the anchovy diet.

*Biddulphia sinensis,* which appeared with the other diatoms, was treated separately, since the presence of this diatom, with long and acute appendices, in the food supply of the anchovy was considered to be of interest. The rather limited contribution of the phytoplankton to the diet of the anchovy as shown by the data of the present paper does not coincide with the results obtained by Fuster de Plaza and Boschi (1958), who found a predominance of phytoplankters in the diet of the juveniles of this species.

An interesting fact that should be noted is the absence of phytoplanktonic organisms from the diet of the larvae of smaller sizes. This is partially coincident with the findings of some authors, who have shown that the larvae or juveniles of some species of fishes feed upon relatively large organisms at first, and then change to smaller items as they grow. This is the case for *Cetengraulis mysticetus* (Bayliff 1963), *Sardinops caerulea* (Hand and Berner 1959), *Brevoortia tyrranus* (June 1957) *Sardina pilchardus* (Andreu 1960), etc. It seemed logical to expect to find phytoplankters more abundantly in the diet of the smaller larvae, and this was assumed so before completing this study, since these organisms are the smallest components of the diet. The larvae of the smallest size in whose digestive tract some individuals of *Exuviaella* were found measured 26.0 mm. This was an exceptional case, since the phytoplankters were found in greater abundance and most frequently in larvae of 38.0–40.0 mm in length and longer.

Figure 2 shows the relationship between the width of the mouth and the range of prey width. The width of the prey has been considered rather than the length, in the assumption that the possibility of ingestion for a given organism depends more upon its width than upon its length. The correlation found between the width of the mouth and the length of the larvae is lineal.

After the time at which the larva reaches a length of 40 mm the width of the mouth increases at a greater rate, and the mouth begins to resemble that of an adult anchovy. The dimensions of the largest organisms ingested by larvae with lengths of 3.0–5.0 mm range between 100 and 150 μ. In the larvae of 12.0–40.0 mm, although the dimensions of the mouth have increased considerably, the size of the largest prey stays at a more or less constant level, between 200 and 500 μ. Preys of much greater size are rarely found. The organisms of the smallest size begin to appear in the intestinal content from the time at which the larvae reach a length of 38 mm.

The phenomenon of the retention of organisms of small sizes is related, as is well known, to the filtering action of the gill-rakers.

In Figures 3 and 4 the development of the gill-rakers in the larvae whose length ranges from 13.5 to 90.0 mm is shown. The first sketches of the future

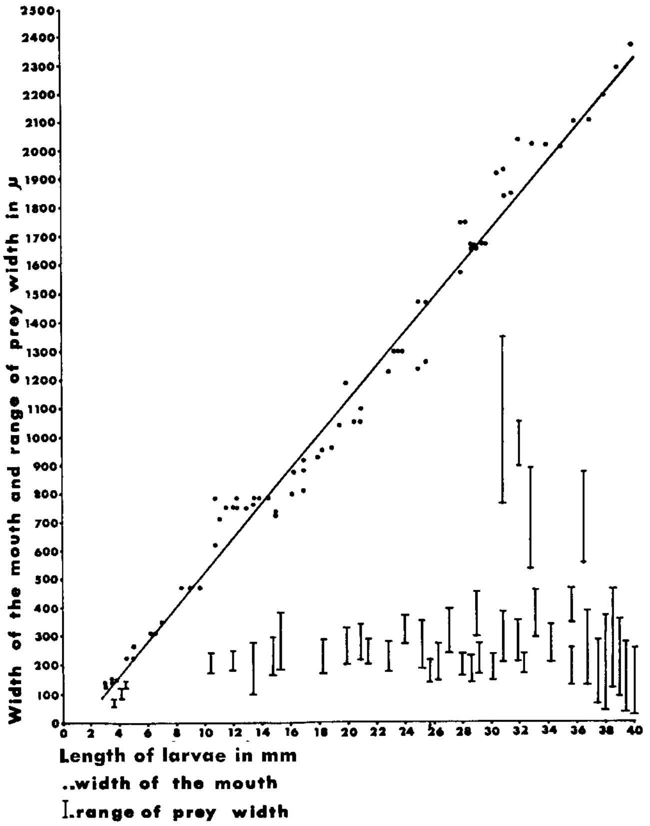


FIGURE 2. Relationship between the width of the mouth and range of prey width in the anchovy larvae of different lengths.

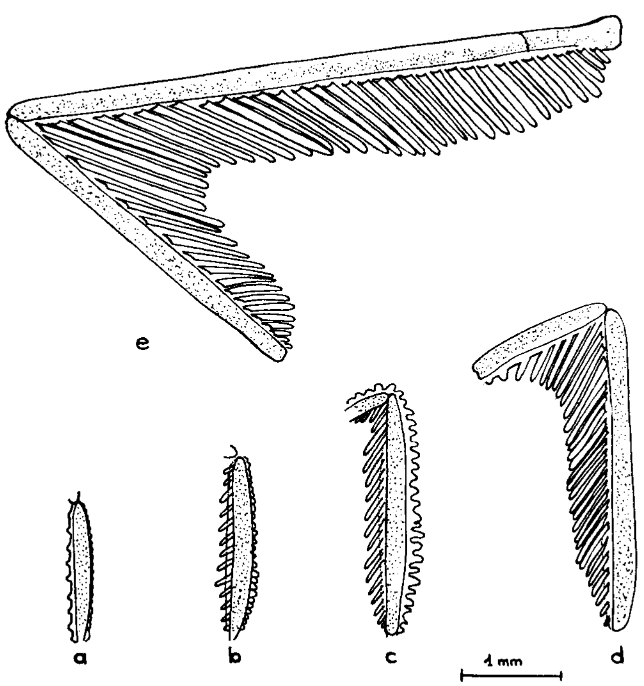


FIGURE 3. Branchial arches of anchovy larvae, showing the appearance and development of the gill-rakers. The drawings correspond to the following lengths of fish: a—13.5 mm, b—18.2 mm, c—24.0 mm, d—31.0 mm, e—42.0 mm.

gill-rakers appear as small protuberances on the first branchial arch, when the larva reaches a length of 13.5 mm. In the larva whose length reaches 24 mm, the gill-rakers, of which there are about 20, reach a length of 315 μ. Over the gill-rakers, some slightly noticeable protuberances appear. These protuberances will transform themselves into the future denticles. In the larvae having a length of 31 mm the gill-rakers (about 32) reach a length of 720 μ and the number of protuberances corresponding to future denticles increases. As the larvae grow the gill-rakers also increase rapidly in length, and they reach a length of 1,800 μ in the larvae having a length of 42 mm. At this stage the protuberances have become denticles. The juvenile having a length of 50 mm has approximately 50 gill-rakers, which are slightly den-

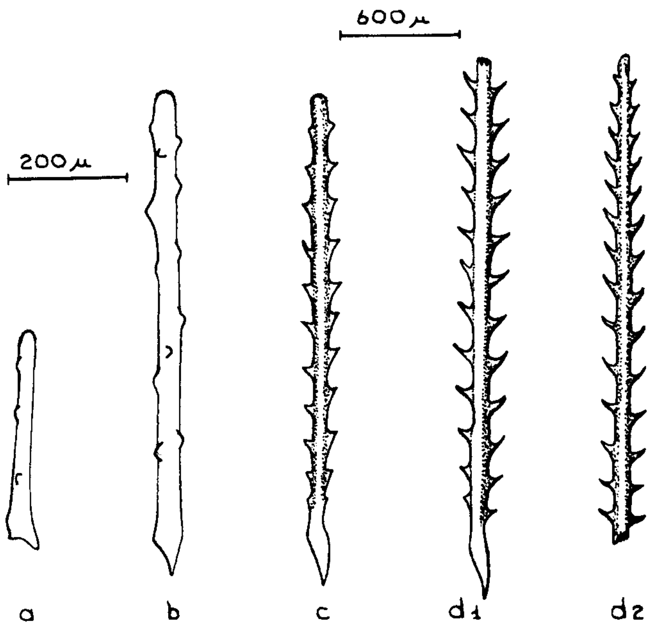


FIGURE 4. Development of the gill-rakers in the larvae and juveniles of the anchovy, showing the development of the denticles. The drawings correspond to the following lengths of fish: a—24.0 mm, b—31.0 mm, c—50.0 mm, d 1 and d 2—90.0 mm.

ticled and have a length of about 2,250 μ (Figures 4c and 5a). The juvenile with a length of 90 mm has some 90 denticled gill-rakers measuring 4,800 μ in length (Figures 4d and 5a).

As is seen through this brief analysis of the development of the gill-rakers, the filtering apparatus of the anchovy begins to be functional by the time the larvae have reached a length of 38 mm. Just at this stage of development the small phytoplanktonic organisms begin to appear in the diet, probably by having been retained in the filtering net of the larvae. It can be further assumed that the absence of phytoplankters in the diet of the adult individuals of anchovies of larger sizes is also related to changes which take place in the filtering apparatus, which could become a coarser filtering net because of the increase in the distance between the gill-rakers, which is produced by the growth of the branchial arch.

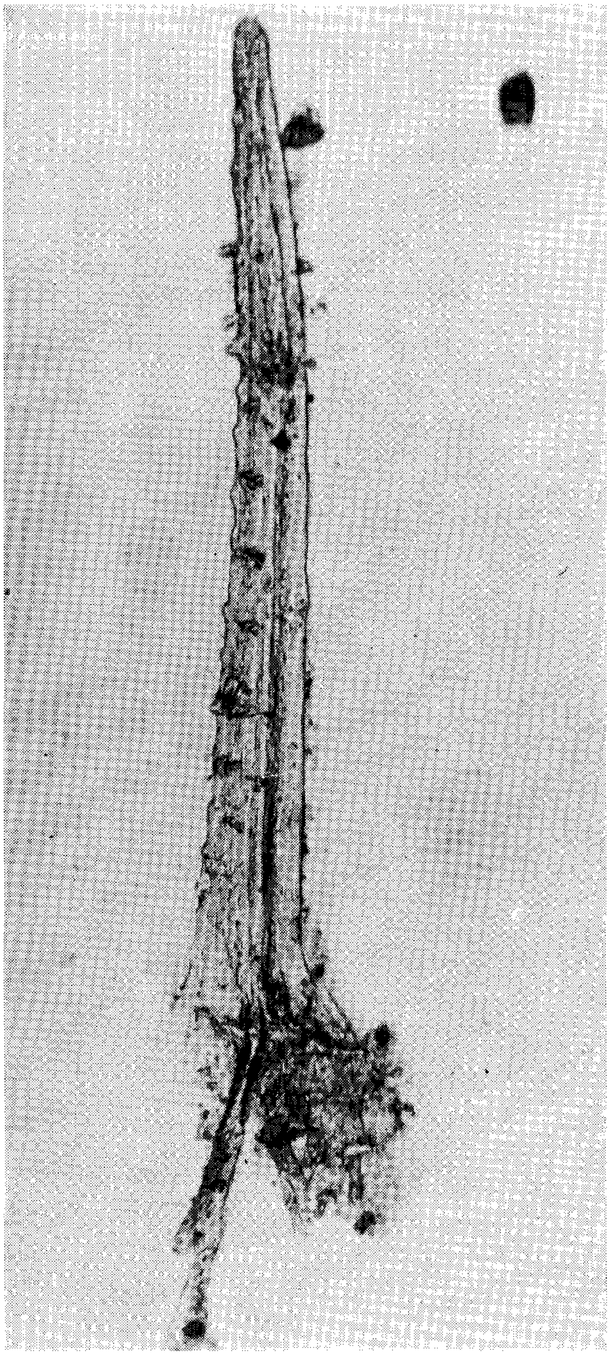

FIGURE 5a. Gill-raker of the anchovy *Engraulis anchoita*, 50 mm long.

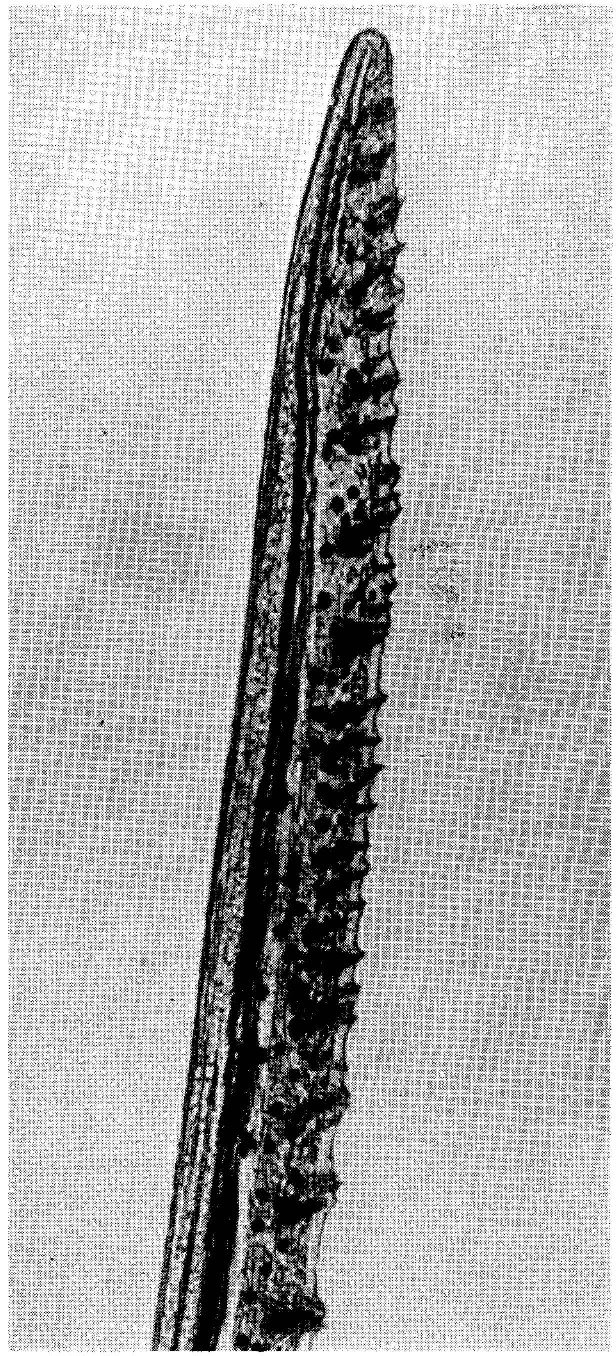

FIGURE 5b. Gill-raker of the anchovy *Engraulis anchoita*, 90 mm long.

In order to effect a better interpretation of the relationship between the structure of the filtering apparatus and the diet of the anchovy, it seemed to be of interest to compare the structure of the gill-rakers of the Argentine anchovy with those of the Peruvian "anchoveta" *Engraulis ringens*, whose diet is based on the phytoplankton. This comparative study was made possible through the kind assistance of R. Jordán, of Peru, who sent, at the request of this author, larvae and juveniles of the Peruvian "anchoveta". The results obtained from the examination of this material are quite interesting. As can be observed in Figures 5a and 6a the structure of the gill-rakers of the juveniles of 50 mm in length is quite similar in both species. On the gill-rakers of the juvenile of *E. ringens* the denticles appear to be just a little longer than those of *E. anchoita*. The study of the intestinal content of 10 juveniles of this length of *E. ringens* showed that it is somewhat similar to that of *E. anchoita* at this stage of development, and that

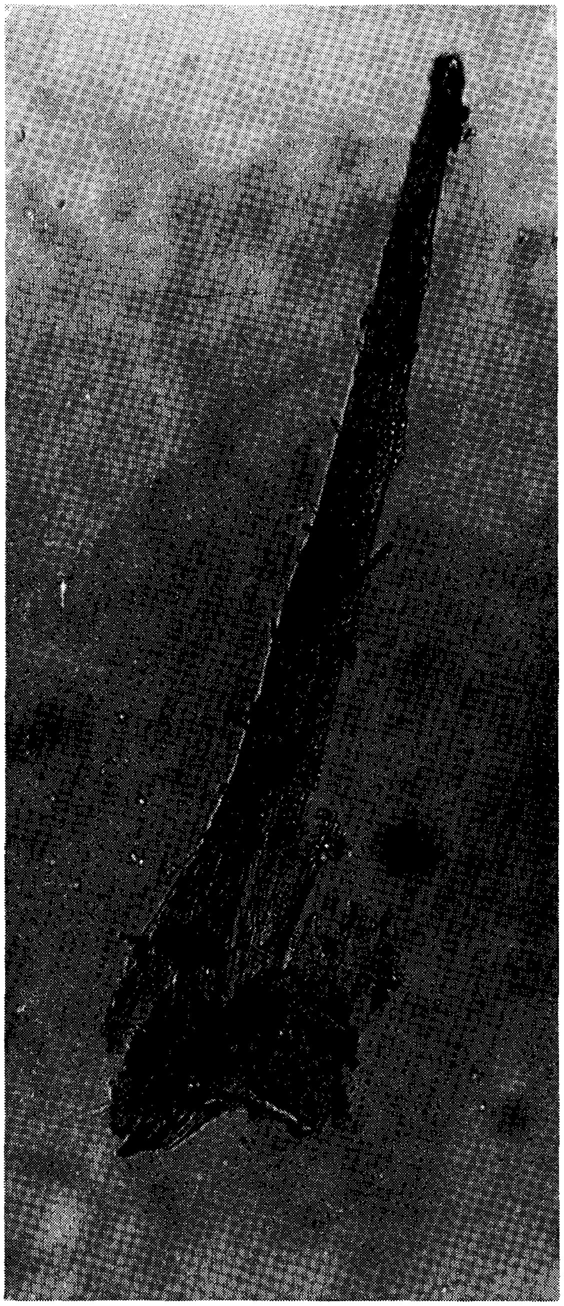

FIGURE 6a. Gill-raker of the anchoveta *Engraulis ringens*, 50 mm long.

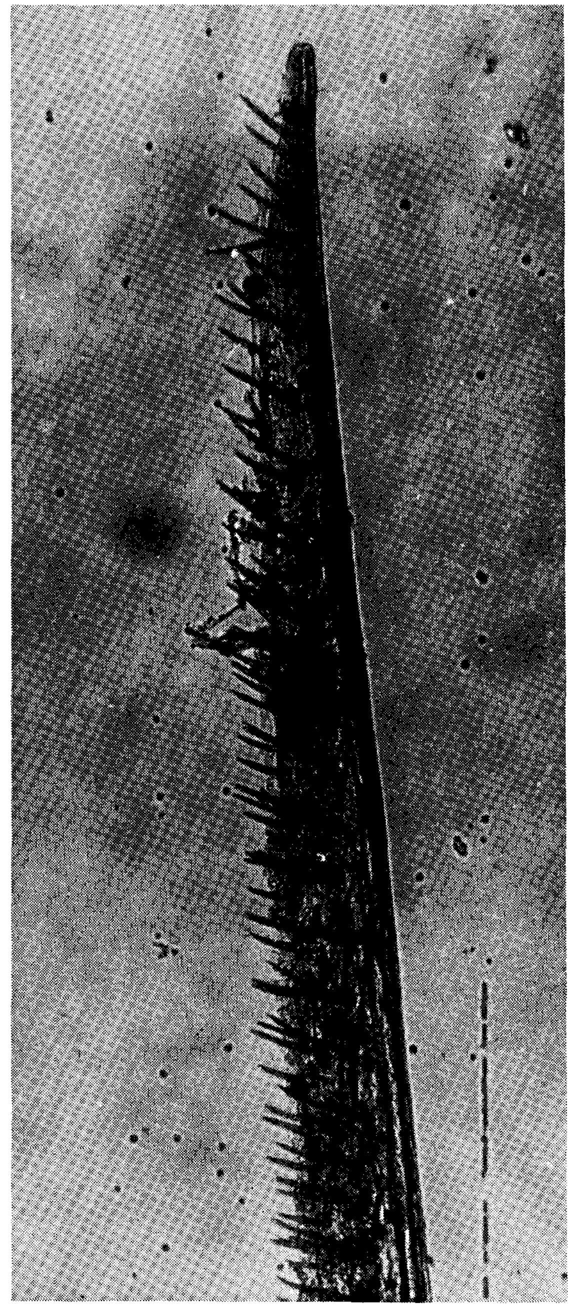

FIGURE 6b. Gill-raker of the anchoveta *Engraulis ringens*, 90 mm long.

it is made up mainly by Copepoda. On the contrary, the aspect of the gill-rakers of the juveniles having a length of 90 mm shows great differences between the two species (Figures 5b and 6b). The gill-rakers of the juveniles of *E. ringens* are longer and with more numerous and longer denticles. At this stage of their development the individuals of this species have a diet based completely on phytoplankton.

Another finding which deserves to be interpreted is the presence of an amount of detritus and very fine sand grains in the intestinal content of some of the juveniles of the 41.0–90.0 mm length class. The intestinal content of these individuals contained also a great quantity of *Triceratium*, a diatom which is abundant in water layers which are close to the bottom. In the spring the skeletons of benthic Foraminifera were found in the food of three individuals.

The highest value, both for the frequency of occurrence and for the percentage weight rate, of detritus in the intestinal content of the juveniles of the anchovy was found during the winter. During the summer, on the contrary, no individual has been found containing benthic elements in its intestine. The aforementioned findings show that the juveniles of the anchovy which live in waters which are not deep have some tendency to look for their food near the bottom. These iliofagous tendencies are more marked during the winter.

## SELECTION OF FOOD

In connection with the problem of the selection of food by the Argentine anchovy, only some general considerations can be made. The lack of exact quantitative data on the composition of the plankton collected with the fishes studied precludes a more detailed analysis of this subject. Nevertheless, the available data allow some general conclusions on this problem.

The species of copepods from the group of the Calanoida and *Euterpina acutifrons,* which are frequently and abundantly found in the diet of the larvae and juveniles of the anchovy are also the most abundant species in the plankton. The great quantity of Cladocera in the intestinal content, especially during some winter and summer months, coincides with the abundance of this microcrustacean in the plankton. Again, the presence of fish eggs in the food supply, especially during the spring and summer, coincides with the appearance of these eggs in the plankton. In some cases, remains of fish muscles were found in the food, which in all probability was part of the bait used by the fishermen to attract the fishes, as was mentioned earlier.

All of the information obtained suggests that the larvae and juveniles of the anchovy do not select much of their food, and that they feed upon the food which is present in greater abundance. As a consequence, their diet may be quite dependent upon the patterns of plankton dispersal. Another very important factor is the accessibility of the food as determined by the size of the prey and the dimensions of the mouth of the fish. Only more detailed quantitative data on the composition of the plankton and experimental studies on the feeding habits of the larvae of the anchovy can clarify this interesting problem.

## OTHER CONSIDERATIONS

Another interesting fact in the study of the larvae and juveniles of the anchovy is that the quantity of food found in their intestinal tracts was generally small. In many cases the ingestion coefficient was lower than 0.01. It was believed, as a consequence, that any analysis based on the calculation of these coefficients as, for instance, in the case of the juveniles of *A. incisa* which were studied simultaneously (Ciechomski, in press), could lead to erroneous conclusions.

In respect to the problem of feeding competition between the larvae and juveniles of the anchovy with those of *A. incisa,* it can be assumed that, in spite of the great similitude between their diets, there is no real chance that these species should compete for their food. This is based on the abundance of the planktonic organisms and on the fact that all of the individuals studied were apparently in good condition.

## SUMMARY

The subject of the present paper has been the food and feeding habits of the larvae and juveniles of 3.0–90.0 mm of length of *E. anchoita* from coastal waters off Mar del Plata, Argentina. The following results have been obtained.

The incidence of feeding found varies with the size of the larvae and juveniles. The lowest values are found in larvae of 5.0–30 mm in length. The assumption is made that this phenomenon can be likely related to the structure of the digestive tract of the larvae at this stage of development.

The Argentine anchovy is almost exclusively zooplanktofagous from its earlier life stages. The main component of the diet of both larvae and juveniles is Copepoda in all of their developmental stages. Among them the Calanoida are the most abundant group.

Phytoplanktonic organisms were found in greatest abundance in the diet of juveniles of 38.0 mm of length and larger. This phenomenon is related to the changes which take place in the filtering net of the larvae along with the development of the gill-rakers.

The comparisons between larvae and juveniles of the Argentine anchovy *E. anchoita* and those of the Peruvian "anchoveta" *E. ringens* has been made.

The juveniles of the anchovy show some iliofagous tendencies, especially during winter.

The assumption is made that the larvae and juveniles of the anchovy do not choose their prey much and that they ingest the food that they find in greater abundance.

It is assumed that there is no chance of feeding competition between the larvae and juveniles of the anchovy and those of *A. incisa.*

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