PRESENT STATE OF THE INVESTIGATIONS ON THE ARGENTINE ANCHOVY *ENGRAULIS ANCHOITA* (HUBBS, MARINI)

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INTRODUCTION

The present economic structure and the population growth in Argentina render more manifest every day the necessity for paying increased attention to problems concerning sea fisheries in this country. The importance of the Argentine sea, with its abundant fishery resources, as a source for obtaining basic proteins has become increasingly evident, and therefore the need for studying the marine environment and its resources becomes a very necessary task.

As one would naturally assume, priority is given to those marine organisms whose economic importance is greatest. Among these species of economic interest is the anchovy (anchoita).

Research on the anchovy, up to 1960, the date on which the "Instituto de Biología Marina" of Mar del Plata was created, was in a preliminary stage, with some few papers on the subject that, although quite valuable, were rather scattered. From that date on these studies were intensified, and became a long term project. Despite the existence of several obstacles of various kinds, *e.g.* the lack of a sea research ship for field work and exploratory fishing, financial problems, etc., the research done on the anchovy to date constitutes a considerable progress towards a basic knowledge of this species.

The aim of the present work is to compile the available data on the Argentine anchovy which refers to fishery, general biology, and its economic importance to Argentina.

FISHERY

The fishery exploitation of the anchovy reflects the overall picture of fisheries in Argentina. It is typically of little intensity, has low efficiency per unit effort, is limited to a short seasonal period, and is associated with an underdeveloped canning industry, which is concentrated in a single port (Angelescu, 1963).

The anchovy together with the mackerel (caballa), both of which are of great economic importance, form the basis of the coastal fishery production.

Coastal fishery is understood herein to be that wherein natural resources in the proximities of the coast are exploited with low tonnage boats (3–30 tons), having operational range of 1 to 6 days, and without refrigeration facilities (Figure 1). The predominant type of vessel for coastal fishing is a small boat without any cabin, manned by a skipper and a crew from 4 to 10 sailors. In the fishing of the anchovy, pairs of boats generally work in association. In most cases the fishing is done within a radius of from 2 to 30 miles from the port. The boats leave at dawn and return to port from noon up to the early hours of the night.

The fishing craft used for the anchovy is a type of roundhaul net.

The figures given below illustrate and emphasize the importance of the anchovy in the Argentine fisheries. These figures refer to the last available data for the year 1963 given by the "Direccion General de Pesca y Conservacion de la Fauna". (General Directory of Fisheries and Wild Life Conservation) of Argentina (1963).

TABLE 1
PRODUCTION OF COASTAL SEA FISHERY IN METRIC TONS FOR 1963

Anchovy (anchoita) *Engraulis anchoita*	Mackerel (caballa) *Scomber japonicus*	Other Species	Total
12,520.4	11,585	28,933	53,039.2
23.6%	21.8%	54.6%	100%

Although the large schools of anchovy are scattered throughout vast extensions of the sea, the area of exploitation is quite small, and almost the totality of the fishing is done in the area bounded by the parallels 37° and 39° S. The principal port, both for the fishing and the industrialization of the anchovy, is Mar del Plata, in the Province of Buenos Aires (lat. 38° S). In 1963, out of the 12,520.4 tons of the total catch of anchovy, 11,795.6 tons came from the Mar del Plata area.

The fishing for anchovy is a seasonal activity depending upon the migrations performed by this species between the coastal region and the open sea. The catches of anchovy are obtained mainly in the months of September, October and November. The greatest peak appears in October. In 1963, 88.6% of the total catch for the anchovy was obtained during these 3 months. During the anchovy season, the majority of the coastal boats work on anchovy fishing.

A certain portion of the catch is destined for consumption as fresh fish, but the greatest part is industrialized. For this reason the fishing of the anchovy is mainly regulated by a *pro rata* system. The canning industry communicates its needs to the center which groups the skippers of coastal fishery boats, and they distribute the requested amount according to the number of boats serving the factories.

It is to be emphasized that the Argentine fishing industry concentrates mainly on the elaboration of products from the mackerel and the anchovy. There

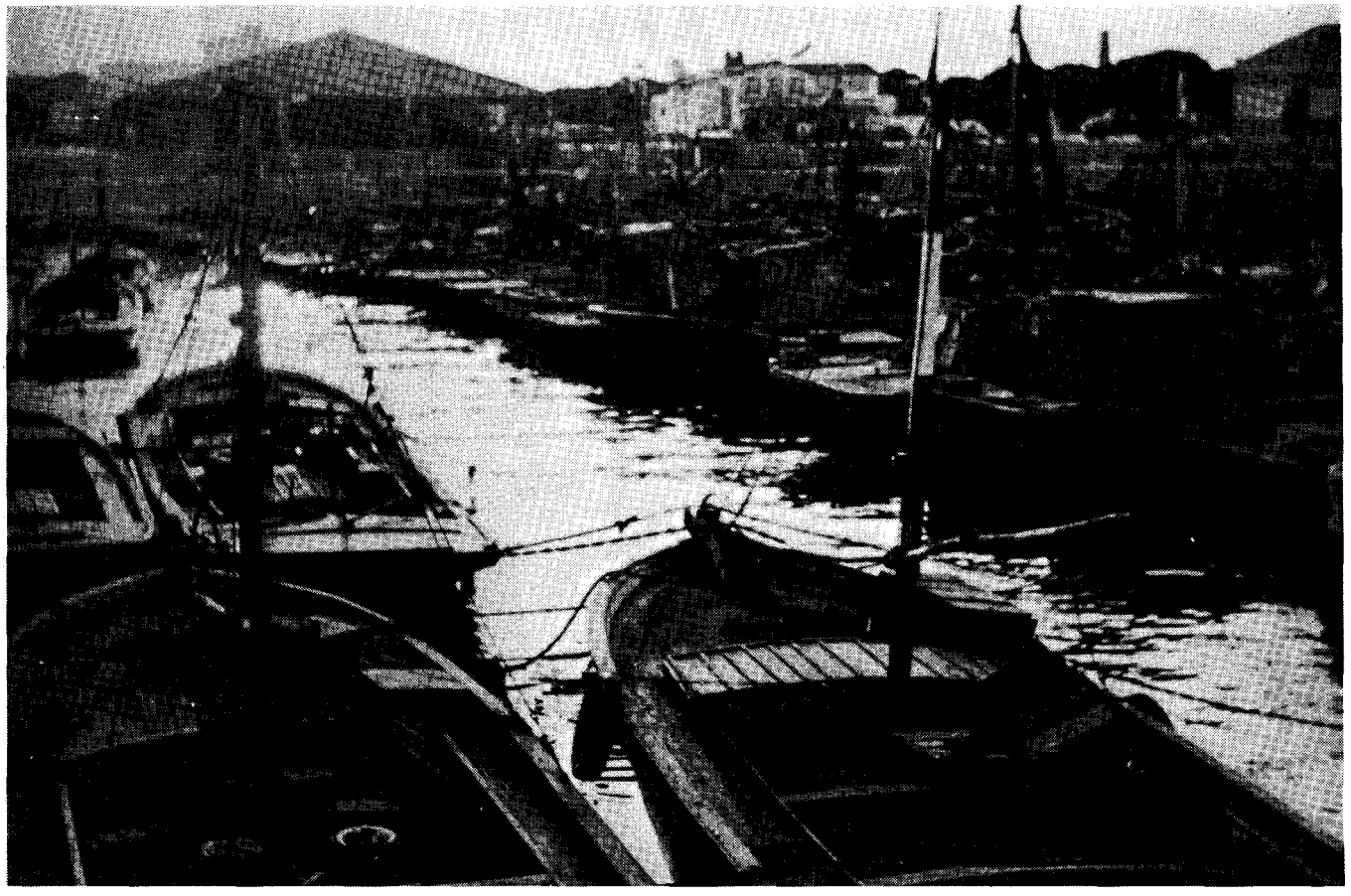

FIGURE 1. Typical coastal boats, Port of Mar del Plata.

are many different processes for the anchovy, ranging from simple salting (similar to herring salting), to sterile canning with oil or sauces.

On the other hand, the scales of the anchovy which become detached very easily from the body and accumulate abundantly on the sides of the boats during fishing, have proved to be valuable material for the manufacture of cosmetics and ornamental objects. During one fishing season, about 15,000 Kg of scales can be gathered.

The possibilities for the exploitation of the anchovy are beyond the present absorption by the canning industry. It will be possible to expand the present exploitation by dedicating the anchovy to other industrial ends, such as production of oils, flour, etc. as well as encouraging and aiding its consumption as fresh fish. Also, by expanding the fishing areas, using better fishing equipment and taking appropriate economic measures, a much greater advantage could be obtained from this important natural resource.

GENERAL BIOLOGY

General Characteristics

The Argentine anchovy was named as a new species, *Engraulis anchoita,* in 1935 by Hubbs and Marini (Marini 1935). This latter author was of the opinion that this species was already included in scientific literature, but under names which were taxonomically inappropriate.

The anatomy of *Engraulis anchoita* shows characteristics typical of the entire genus *Engraulis,* the members of which are particularly distinguished by the large opening of the mouth which is ventrally situated. The snout is projected anteriorly, forming a slight prominence.

The main meristic characteristics of this species, according to Marini (1935) and Fuster de Plaza and Boschi (1958) are as follows: vertebrae 45-45; gill rakers 23-39 and 32-48; anal rays 19-25; dorsal rays 16-19; lateral line scales 40-42.

This species has a wide geographical distribution, from San Sebastian Island, Brasil (lat. 24° S) in the north, to a location near San Jorge Gulf, Argentina, (lat. 42° S) in the south (Figure 2). The vertical distribution depends upon the location of the thermocline. The anchovy does not reach waters with temperatures inferior to 9°–10° C, that is, at depths of 20–50 m in the open sea (Angelescu, Fuster de Plaza, 1962).

The data available on this species refer mostly to the anchovy of the areas of the Province of Buenos Aires, which is the fishing region concerned.

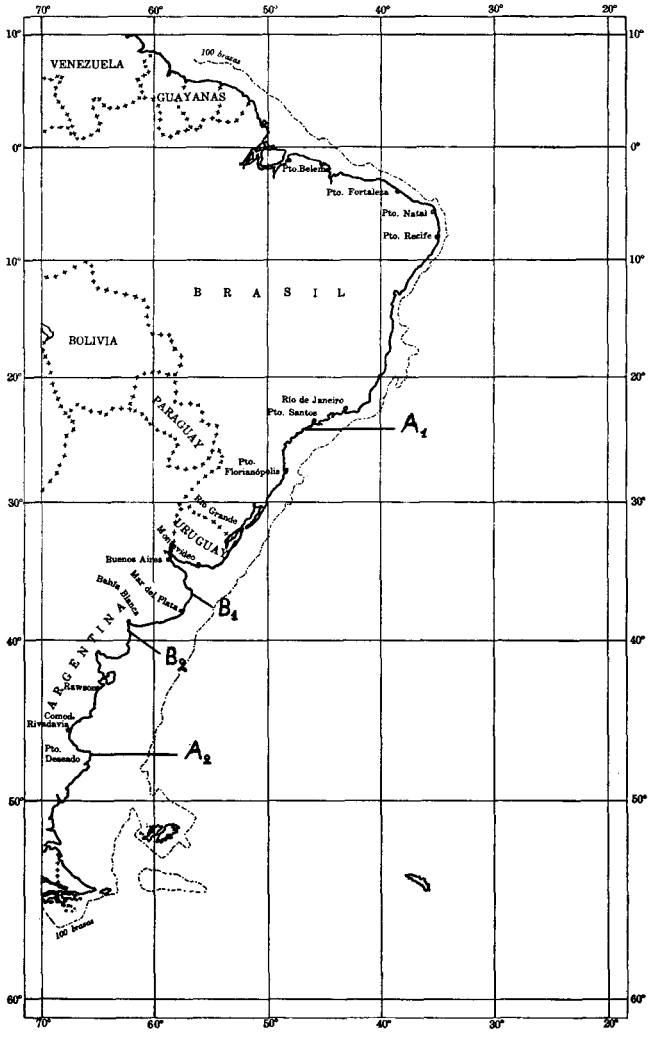

FIGURE 2. Distribution and fishing limits of the Argentine anchovy.
A_1–A_2—Geographical distribution.
B_1–B_2—Area of the approximate fishing totality.

Population Problems

In 1958, Fuster de Plaza and Boschi (1958) had assumed the existence of different anchovy populations with differentiable meristic characteristics. Further investigations by Fuster de Plaza (1964) led to confirmation of this assumption and established the existence of two different anchovy populations: one whose reproduction takes place in the Spring and another, whose reproduction takes place in the Autumn. This conclusion has been based on meristic differences (mean number of vertebrae), distribution of modal classes of the samples over a period of time, biological differences in such variables as growth rate and the attainment of the first sexual maturity in individuals of both populations, and also in observations of the state of maturity of the gonads throughout the year. This conclusion is partially supported by results obtained by the present author (1965). These results are based on data obtained from eggs, larvae and juveniles of the anchovy. They were gathered by systematic sampling throughout the year, and were elaborated with quantitative methods. They show that the reproduction of the anchovy takes place in its most intensive rhythm during October, as temperatures of 11.5°–14° C, and reaches a slight peak in February, at a water temperature of 20° C. The present author has also shown by means of experiments that the optimum temperature for the embryonic development of the anchovies spawning in October is between 10°–17° C, and that a temperature of 20° seems to be off the optimum point. This observation may also lead to the same assumption of the existence of two different populations of the anchovy with different physiological characteristics.

This problem becomes somewhat complicated by the fact, discovered by the present author, that the Argentine anchovy reproduces throughout the entire year. The problems arising from the populations of *Engraulis anchoita,* such as is the case with other species are very complex and await further and more detailed research.

Fecundity

There are data published on the fecundity problem of the anchovy by Fuster de Plaza (1964), who determined the degree of fecundity of the Spring anchovy alone. There are no available data on the Autumn anchovy. This is due to difficulties in obtaining study material, since this population is not subject to commercial exploitation at present. The results obtained are based on counts of the number of ovocites of greater length in the ovaries of mature females. In the ovaries of the females which are in process of maturation, four different egg groups of differing degrees of maturity can be distinguished. When spawning is near, three of these groups can be more clearly observed. During the spawning the females lay the first ovocites from the group of greatest ovocites, and after a certain period of time lay ovocites from the second group. After this partial evacuation, the females leave the spawning area, retaining in their ovaries ovocites in different stages of development.

There exists, in this species, as in several other species of fish, a strong correlation between the number of ovocites in the ovary and the total length of the individual. For instance, the number of ovocites observed in the group of greatest size for females of different total lengths are, according to Fuster de Plaza:

Total length (mm)	115	140	160	175	190
Number of ovocites	4,400	9,368	15,084	21,954	24,920

Reproduction and Early Life History

The first sexual maturity of the anchovy is strongly related to the minimum length and, according to Fuster de Plaza (1964), anchovies of the Spring population reach their first maturity when they are 120–130 mm long, while those from the Autumn population reach theirs when their length is 115–120 mm. This author states that from July to August, adult individuals of the Spring population gradually

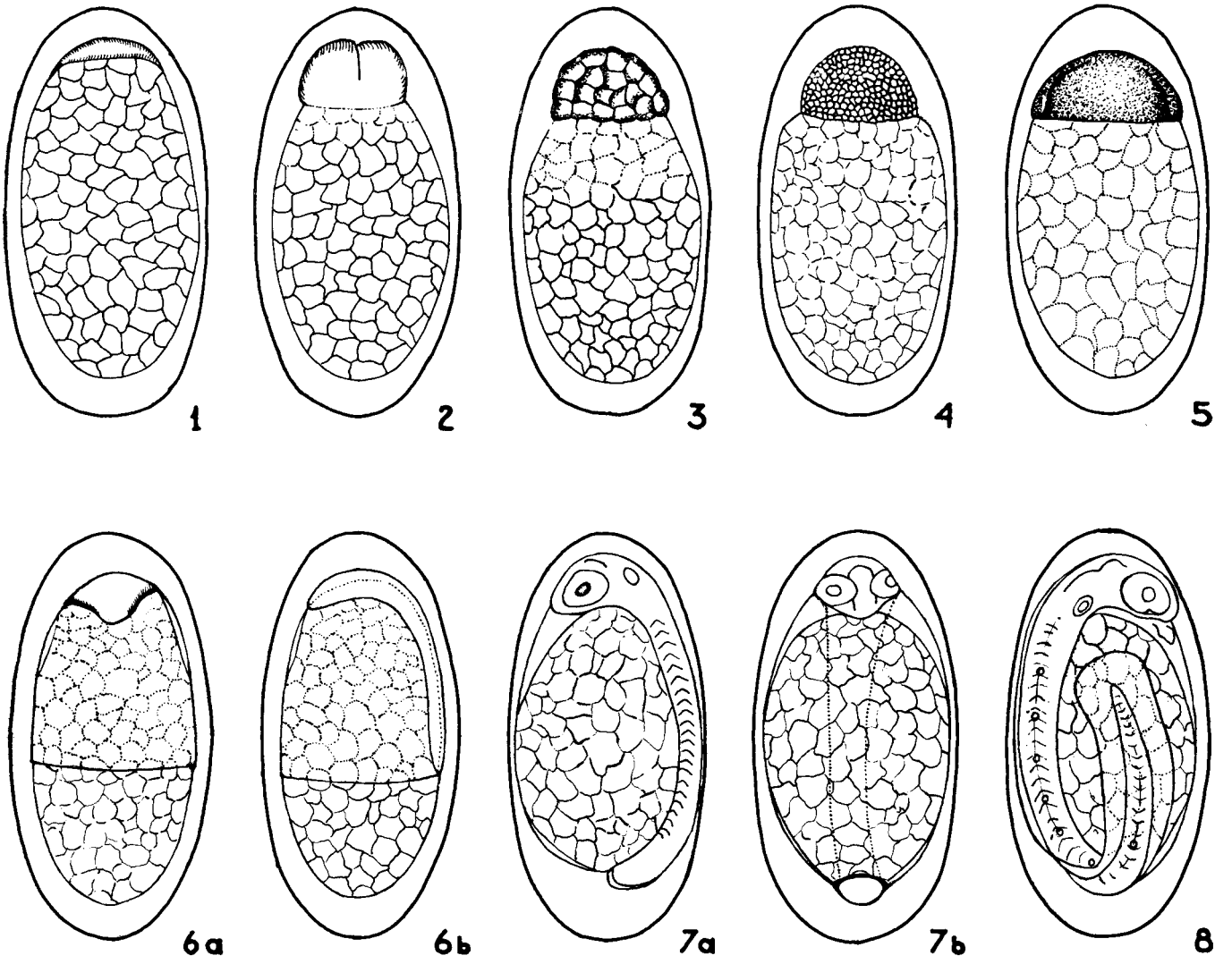

FIGURE 3. Embryonic development of the anchovy (*Engraulis anchoita*). 1. Formation of the first cell; 2. Two-blastomere stage; 3. Formation of the blastula; 4. Blastula; 5. Gastrulation; 6. Neurula, a) frontal and b) lateral view of same; 7. Commencement of the separation of the caudal region from the vitelline sac; 8. Embryo immediately prior to hatching (from Dz. de Ciechomski 1965).

approach the coast in the area near Mar del Plata, where they appear forming great schools from September onwards. The schools stay in the area until the beginning of Summer, when they start moving towards the open sea. A similar migration occurs with the adult individuals of the Autumn population that also migrate for reproduction in the period from February to March. After spawning, they return to the open sea.

The problem of the reproduction and embryonic and larval development of *Engraulis anchoita* has been studied in greater detail by the present author, who has incorporated the results in the papers presently in press. It has been possible to determine the exact period of reproduction of this species on the basis of appearance and disappearance of the eggs, larvae and juveniles of the anchovy in the sea. This has been accomplished by a systematic collection of the material and the use of quantitative methods.

The intensity of spawning was related to changes in sea temperature. The reproduction of the anchovy starts in September, very close to the coast, at a temperature of about 10° C, and reaches its peak in October at a temperature of about 11°–13 °C. From November onwards the anchovy continues its reproduction in a more or less intensive form, and apparently, more towards the open sea. In February, the spawning intensity reaches a slight peak. In March, the intensity of spawning seems to decline and apparently takes place more towards the open sea. Spawning continues in this manner until September. The existence of two periods (October and February) of greater intensity agrees with the results given by Fuster de Plaza (1964) on the basis of an examination of adult individuals.

There occurs in the anchovy a daily spawning rhythm, ranging from 8 pm until 12 pm. The determination of this daily rhythm by the present author

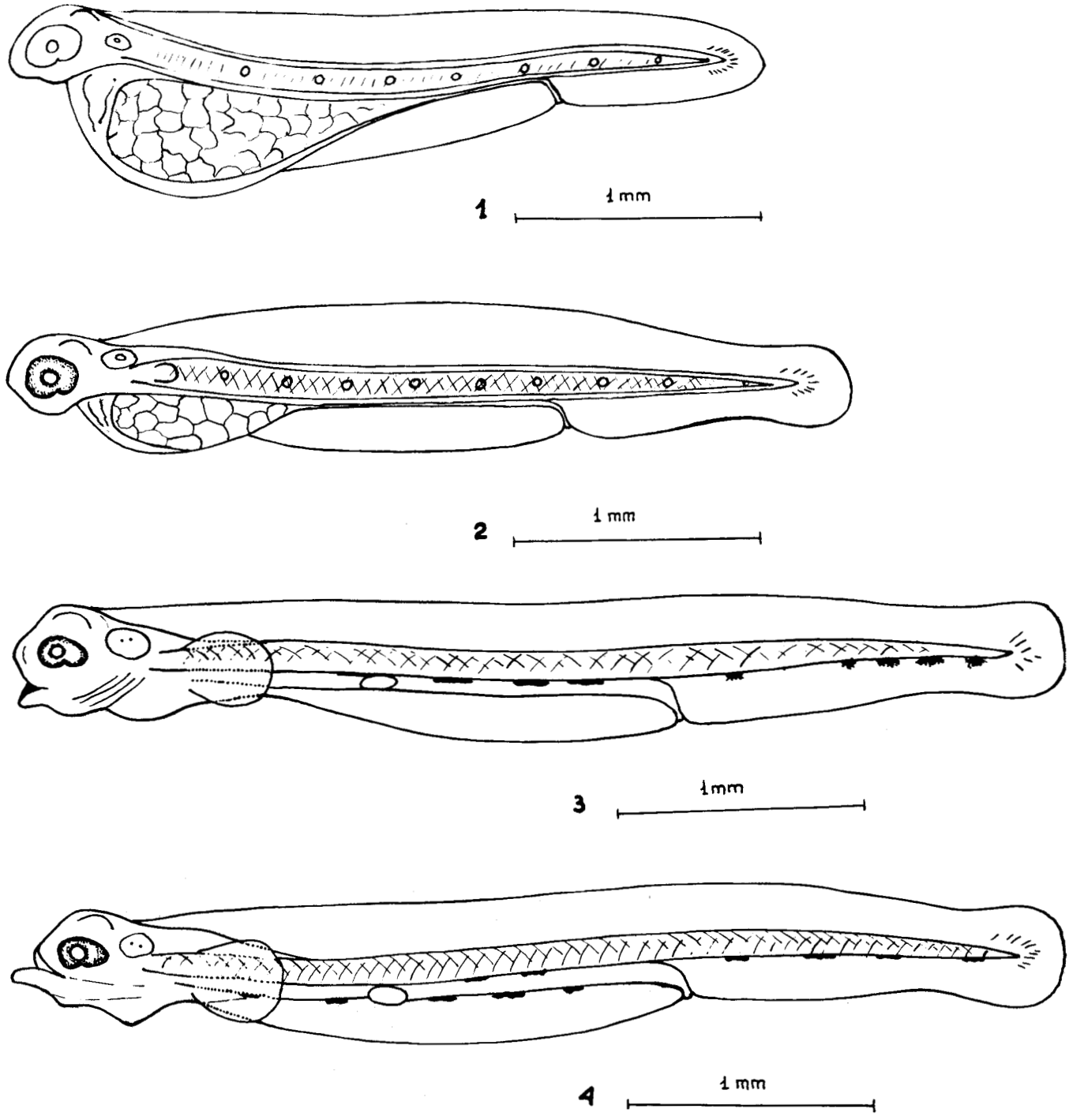

FIGURE 4. Larval development of the anchovy (*Engraulis anchoita*). 1. Recently hatched larva; 2. 2½-days larva; 3. 4-days larva; 4. 10-days larva (from Dz. de Ciechomski 1965).

enabled her to obtain mature female anchovies (which is impossible during other hours of the day), and to successfully achieve their artificial fecundation.

The embryonic development of the anchovy is quite rapid. The most detailed drawings and descriptions of the embryonic and larval development have been given in a paper by the present author, "Observaciones sobre la reproduccion y desarrollo embrionario y larval de la anchoita argentina (*Engraulis anchoita*)" (Figures 3, 4, 5).

The measurements of the eggs show rather pronounced variations: 1.15–1.55 mm for the major axis and 0.66–0.80 mm for the minor axis.

In the earlier stages of development, the eggs float vertically with their blastodiscs pointing downwards. As the enveloping of the yolk progresses, the

orientation of the eggs becomes increasingly horizontal. At the stage of Kupffer's vesicle, the egg floats horizontally, coming closer to the bottom during the last stages of development.

The hatching mechanism is always the same. Once this stage is reached, the membrane of the egg suffers a neat incision at a distance from the cephalic end equal to $\frac{1}{3}$ the total length of the egg. After rupture has taken place, the embryo frees itself from the egg membrane in about 3 minutes. It should be emphasized that the rupture occurs always at the same distance in respect to the total length of the egg.

The vitelline larva of the anchovy measures 2.70–3.40 mm at birth. The larva is rather undeveloped at birth and does not show pigmentation on any part of its body. The heart at work is quite visible, but no blood circulation can be observed in the vessels. These appear to be typical characteristics of planktonic larvae. The pigmentation begin to appear the third day after hatching. After 4 or 5 days, the vitellum has been reabsorbed and the mouth begins to be functional.

It is impossible at present to breed larvae of the anchovy in aquaria for a period of more than 8 to 10 days. After this time all the larvae die, probably because of the lack of appropriate food.

Ossification in the larvae of the anchovy commences relatively late, and the first ossified elements, *cleithrum* and *dentale,* appear when the larvae have a total length of 6 mm. When the larvae have reached a length of 33–34 mm, they have lost all of their larval characteristics except the snout. At the length of 44–45 mm, they resemble completely the adult individuals, and therefore pass into the juvenile stage.

The influence of some environmental factors: temperature, salinity, light and mechanical factors, upon the embryonic development of the anchovy is known. This information has been obtained by the present author by means of experimental research, and has been given in a paper presently in press. The temperature has of course a certain influence upon the speed of development. As was stated above, the development is quite rapid. It lasts for 68–72 hours at a temperature of 14°–15 °C and for 50–53 hours at 19°–20° C. The optimum temperature for embryonic development appears to be in the range of 10°–17° C. These data refer to the October anchovy which reproduces at lower temperatures than the Autumn anchovy, whose temperature range might be different. A temperature of 4° C is lethal.

Experiments upon the influence of salinity have shown that the Argentine anchovy is not so tolerant in respect to salinity threshold as some of its relatives, such as *Engraulis encrasicholus.* The salinity boundaries within which *Engraulis anchoita* develops in more or less normal manner might be fixed between 25.8% and 50%. Outside of this range, the development is abnormal, with frequent production of monstrosities.

Light does not seem to have any sensible influence upon the embryonic development of *Engraulis anchoita.* The embryos of the anchovy are very sensitive

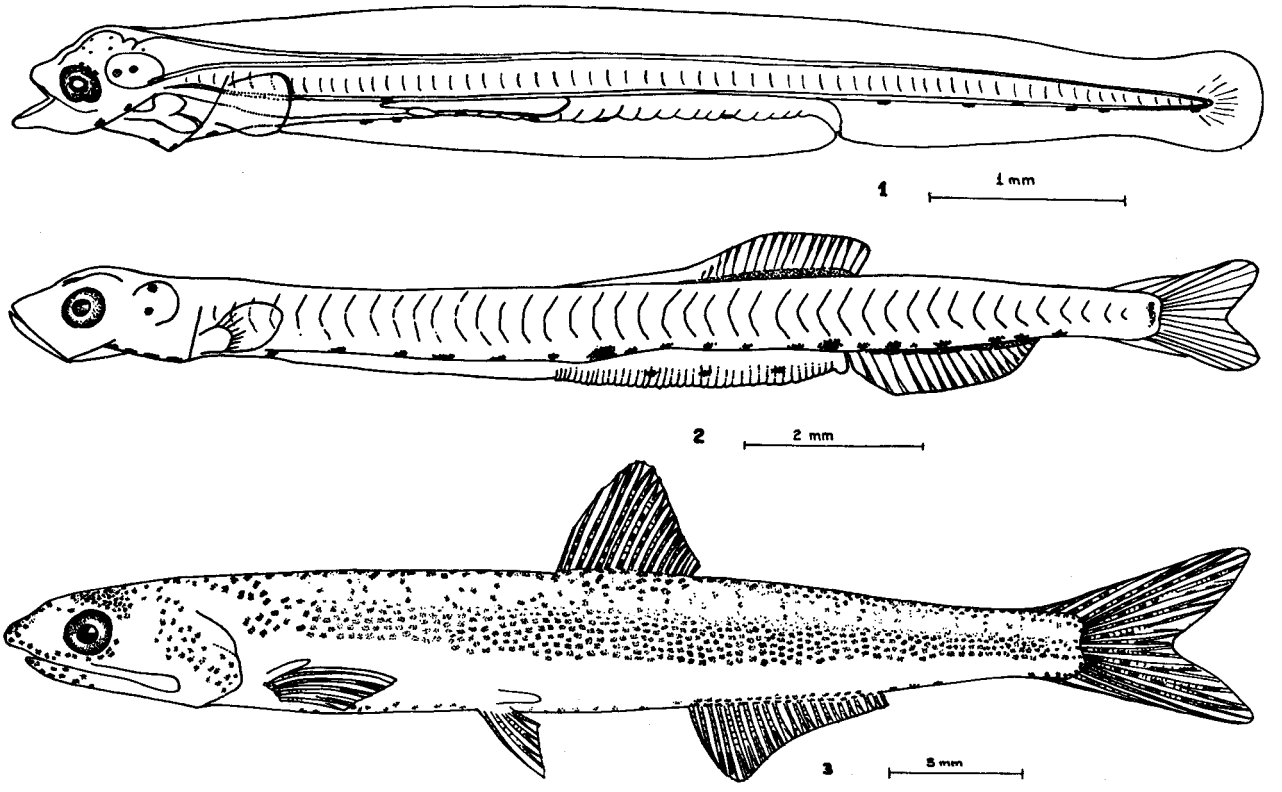

FIGURE 5. Termination of larval development of the anchovy (*Engraulis anchoita*). 1. 6 mm larva; 2. 13.5 mm larva; 3. Juvenile of 44 mm (from Dz. de Ciechomski 1965).

to the influence of mechanical factors. This sensitivity is at its peak in the earliest stages of development, including early gastrulation. In view of this fact the present author believes that high seas and storms might have some influence upon the fate of anchovy embryos which are, at the time, in this stage of development.

Growth, Age, Condition Factor, and Metabolism

The Argentine anchovy is a fish of short life that reaches its sexual maturity and becomes already a subject of commercial fishing at the age of one year. The problems concerning its growth, age, condition factor and metabolism were studied by Fuster de Plaza (1964). The results obtained by the same worker are based upon a statistical elaboration of data, applying the method of Petersen. According to Fuster de Plaza, the distribution of the samples in modal classes through time show the existence of two populations of anchovy; the spring and autumn populations, with their corresponding growth parameters. Both populations show an active growth until the end of the third year of life. From then on, growth decays sensibly. The calculated length at the fourth year of life is 185 mm for the spring anchovy, and 175 mm for the autumn anchovy. Growth is halted in both populations during the winter months. According to Fuster de Plaza, the total lengths of the anchovy during the first 4 years of life are as shown in Table 2 (Petersen Method).

TABLE 2

MODAL CLASSES IN MM

	1_1	1_2	1_3	1_4
Spring population	130	150	175	185
Autumn population	110	135	165	175

Little is known about the growth of the anchovy in its first stages of life. In a paper currently in press, the present author shows that the analysis of the monthly distribution of length frequencies of larvae and juveniles, taking into consideration the first moments of intensive spawning, seems to indicate that the juveniles of anchovy reach a length of 60 mm when they are in the third month of life.

According to Fuster de Plaza, the rate of weight increase in the adult anchovy is greater than the rate of length increase, and the development of the body takes place in a more or less harmonious manner along the three body axes. Also, the value of the Condition factor K shows a progressive increase with the growth of the individuals. For adult individuals in the open sea, during their period of intense nutrition, this factor is of 0.70 to 0.90, whereas for juveniles individuals in coastal waters, the same factor ranges from 0.50 to 0.73.

The degree of fatty accumulation in the viscerae of the anchovy is related to the stage of development of the sexual glands. The greater deposits of fat are found in anchovies which have gone through the reproductive process and are in a state of repose.

Fuster de Plaza has determined also the metabolic specific factor k, following criteria due to Bertalanffy, who considered the metabolism of fishes to be proportional to body surface. The average value of this factor for the anchovy is 8.75. It also appears that there is no sensible decline of the metabolic rate with the increase of the length.

Feeding

The present author has undertaken studies of the food and feeding habits of larvae and juveniles of anchovy. The characteristics of the alimentation at different developmental stages have been related to the morphological changes taking place throughout the development of the individual. The first results (not yet published) show that the anchovy larvae which are 3–5 mm long (that is, after reabsorption of the vitellus) feed almost exclusively on the eggs and nauplii of Copepoda, and small eggs from other organisms. In larvae from 5 mm to 35 mm long, it has been impossible at the present to find remnants of food. This should be due to the structure of the digestive tract, which in this stage of development is like a straight tube, with a slight ketch of stomach in the greater larvae. From the length of 35 mm on, the percentage of individuals in whose intestines food is found, becomes higher.

The basic food for individuals from 35–80 mm long are Copepoda in all stages of development: eggs, nauplii and adult forms. Besides Copepoda, there are also to be found juveniles of Decapoda and other Crustacea, eggs from various marine organisms and more rarely, larvae from fishes and Mollusca. In the food of juveniles from 40 mm long are found Radiolaria, and Acantharia, but in scarce amounts. In the food of juveniles with a length of more than 50 mm there appear Diatomea and Dinoflagellata, always with other zooplanktonic forms.

Fuster de Plaza (1964) and Fuster de Plaza and Angelescu (1962) obtained somewhat different results with respect to the alimentation of the juveniles of anchovy. They found their food to be primarily composed of phytoplankton. In individuals from 50 mm to 100 mm long in the primarily phytoplanktonic food, they found a predominance of Diatomea. As the juveniles approach the adult stage, the alimentation becomes preferentially zooplanktonic.

According to said authors in the food of individuals from 150–190 mm long, there are Copepoda, especially from the family Calanidae, pelagic Amphipodae (*Parathemisto* spp.), Sergestidae (*Sergestes* spp.) and sometimes juveniles of anchovies and other fishes.

The anchovy is plainly a plankton feeding species and is located in a low trophic level, near the primary production link.

Migrations

Although many data are lacking for a precise determination of the population dynamics of the anchovy, it is possible with the available data to reach some conclusions on the migration of large schools of anchovies in the area of the Province of Buenos Aires.

As was shown in the preceding sections, the migrations of the anchovy are both trophic and reproductive in character. On this matter there are data published

by Fuster de Plaza (1964), and Angelescu and Fuster de Plaza (1962).

During the vital cycle of this species, the juveniles find their first trophic habitat in coastal waters, where they remain the entire year until they reach their first sexual maturity. After spawning they migrate toward open sea regions, where they find abundant food. The same thing happens to the older adults that reach coastal waters in order to reproduce. Therefore trophic migrations are complemented by reproductive migrations in an alternating cycle throughout the seasons of the year, between coastal and open sea waters.

In the period from November to May, the majority of the schools made up by adult anchovies concentrate in the middle region of the continental shelf and in the neighborhood of the continental slope. The summer trophic habitat of the adults coincides with the areas of greatest wealth in nutrients and plankton. From July to August, with the maturation of the sexual glands, the adults of the spring population begin to approach the coastal waters for spawning. In this way, large schools of anchovies appear in the coastal waters from September on. After spawning is accomplished they return to open sea regions.

The same migration pattern is shown after a certain period of time by the adults of the autumn population. As a result of these migrations, the anchovy reaches during the summer months its greatest extension in the horizontal plane of the Buenos Aires continental shelf.

Other Data

There are some preliminary data from studies of the blood of *Engraulis anchoita*. According to Conroy and Rodriguez (1964) and Conroy (personal communication) the quantity of erythrocytes in 1 cc of blood is 2,300,000 and their dimensions are 7.5 microns wide and 12.0 microns long. The average percentage of hemoglobin (Sahli) is 79. In gm/100 ml this value is 12.64. Another study by Conroy (personal communication) on bacteria shows that the viable bacterial count of the anchovy immediately upon arrival in port is between 158,000 and 250,000/g of flesh.

BIOECONOMICAL IMPORTANCE OF THE ANCHOVY

As was shown earlier, the anchovy is an important commercial product. Nevertheless, its greatest bioeconomical value evolves from the fact of its being a true "forage fish" for a great number of fishes, and, therefore, due to its low trophic level, a carrier of energy towards the upper trophic levels.

The subject of the importance of the anchovy in general bioeconomics has been widely treated by Angelescu and Fuster de Plaza (1962) and Fuster de Plaza (1964). These authors show that the anchovy, due to the great density of its schools and its wide distribution, is a key link in the intermediary stage of the bioproduction process, in connection with fishery exploitation in various areas of the sea.

Anchovy populations are subject to intense predation by mackerel (*Scomber japonicus*) and hake (*Merluccius merluccius hubbsii*), both of which are basic species of the Argentine fishery industry. As was pointed out by the aforementioned authors, the distribution of the anchovy in the area of the Province of Buenos Aires encompasses within its geographic boundaries the distribution area of the hake in the open sea. In the first region mentioned, the anchovy is the most important food, available in its juvenile stage, for the mackerel. In the second region it becomes, at the adult stage, the main source of food for the hake. In order to emphasize the importance of the anchovy in the bioeconomics of fisheries, the above mentioned authors made an approximate determination of the amount of anchovies taken by the mackerel and the hake during the warm weather season. According to these calculations, the fishing volume of the anchovy with an annual average of 10,000 tons, represents only a 3.3% of the amount consumed by the biomass of mackerel and hake caught commercially. The total catch of these two species during the Summer is approximately equivalent to a consumption of biomass of juveniles and adults of anchovy of up to 300,000 tons.

On the other hand, the anchovy is a major source of food for other fish eating marine organisms, especially predatory fishes of economic importance, marine mammals, and birds.

It appears from these facts that the anchovy, due to its intermediary position between primary production, zooplankton, and the consumers at higher trophic levels, is the species of maximum importance in the maintenance of the biomass of predatorial fishes.

A detailed study of these interspecific trophic relationships, by Angelescu and Fuster de Plaza is at present in an advanced stage of elaboration.

RESEARCH PROGRAM

Because of the great bioeconomic importance of *Engraulis anchoita,* it was considered opportune to establish an extensive plan of studies for this species in all the stages of its vital cycle.

The biological study of the anchovy, which is a part of the research program of the "*Instituto de Biologia Marina*" of Mar del Plata, has been conceived as a ten-year project, and includes the analysis of meristic characters, fecundity, reproduction, alimentation, growth rate, sexual maturity and length distribution. A biostatistical sampling project of commercial landings of anchovy in the Mar del Plata area has been organized. This project is carried forth throughout the entire year, with the aim of establishing the structure and the dynamics of the populations.

Studies are aimed at a better understanding of the biology of the anchovy in its earliest life stages, that is, at problems related to the embryonic and larval development, alimentation and growth of larvae, and their behavior.

An intensive research programme is at present under way on the trophic relationship between the anchovy and other species of fishes, especially the mackerel and the hake, whose rates of ingestion, duration of digestion, total metabolism, etc., are being determined.

In the chemical aspect of the programme, studies are being made on the seasonal variation of the chemical composition, and on the bacterial spoilage of the anchovy under various conditions.

All these studies will be improved and intensified at the beginning of 1965 from a plan of technical assistance for fisheries drawn by the United Nations Special Fund and the Argentine Government.

On the other hand, experiments for another technique of anchovy fishing have recently been started, with different commercial aims. With this technique, a larger type of fishing vessel and another type of round trawl net are used in order to catch a greater number of fishes in a single haul. The product of these catches will be used in the manufacture of fish flour.

SUMMARY

In the present paper existing data of the investigations on the Argentine anchovy *Engraulis anchoita* are given. The following problems are considered:

1) Fishery
2) General biology
   a) general characteristics
   b) population problem
   c) fecundity
   d) reproduction and early life history
   e) growth, age, condition factor, and metabolism
   f) feeding
   g) migrations
   h) other data
3) Bioeconomical importance of the anchovy
4) Research program

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