CANADIAN TRANSLATION OF FISHERIES AND AQUATIC SCIENCES

No. 4935

Biological aspects of the squid *Illex argentinus*

by H.R. Leta

Original Title: Aspectos biologicos del calamar *Illex argentinus*

From: Inst. Nac. Pesca, Inf. Tec. (23), 50 p., 1981

Translated by the Translation Bureau
Multilingual Services Division
Department of the Secretary of State of Canada

Department of Fisheries and Oceans
Northwest Atlantic Fisheries Center
St. John's, Nfld.

1983

57 pages typoscript

CTFAS 4935

ACKNOWLEDGEMENTS

The author would like to express his special thanks to Dr. Hebert Nion, Director of the Fisheries Biology Division of the National Institute of Fisheries, for his advice and constant support throughout this work.

In addition, he would like to thank Mr. Guillermo Arena, Head of the Department of Marine Resources, and Lic. Alvaro Abella, Head of the Off-Shore Marine Resources Section of the above Division for their suggestions and helpful advice.

Last, but by no means least, he would like to thank the staff of the Icthyoplankton Section for having made available valuable material and data.

ABSTRACT

The growing importance of the squid resources during the last 30 years place them among the more important fish resources of the world. Therefore countries traditionally non exploiters or consumers of squid products gave steps toward a better knowledge of the species of cephalopods inhabiting their marine environment. For instance, the contribution of subjects such as the biology lead to a successful development of squid fisheries, among others.

The 1980 research programm of the National Fisheries Institute included an integral study of the exploitation of the squids as a first step toward the development of a squid fishery.

This paper presents the results of a study on the biological aspects of the principal species of the area: Illex argentinus. It is part of three technical reports written by the author on squid resources. These reports are fishery technology and production & marketing of squids in Uruguay.

INTRODUCTION

Squid resources occupy an important place among the world's fisheries. This fact is based on the volumes caught annually by the different countries, the nutritional value of their meat and on the variety of products which may be obtained by their processing.

The resources may generally be divided into two main types: neritic - those found above the continental shelf and oceanic - those found on the high seas. Estimates published by FAO (1975) on the world potential of these resources, indicate that neritic resources range from 8 to 10 million tons annually, while oceanic resources are from 8 to 60 times greater.

Although squid fishing has been carried out for a long time, it is only since the Second World War that it has seen accelerated development. One example of this is in the growth of the fisheries in Japan, which is now the major world exploiter of these resources. Other countries such as Italy, Spain and the Soviet Union follow it in importance.

There are approximately 270 species of squid, 12% of which are exploited commercially. Although the number of species exploited commercially is not high, there is, however, a strong interest in gaining a better understanding of these resources. In this area, the following works stand out: Fields (1950, 1965) on the fishing and biology of squid in California; Amaratunga & Durwald (1979); Durwald, Amaratunga & O'Dor (1979); Ennis & Collins (1979); Mesnid (1977); etc. carried out in the area of the ICNAF (International Commission for the Northwest Atlantic Fisheries); Japanese resources have been described by Hamabe, Kawakami, Watabe, Okutani and Ikeda (1975); in the Southeast Atlantic, Castellanos (1964) describes Argentinian squid fisheries and Klyucknik & Zasypkina (1972) contribute important data on the Argentinian squid _illex argentinus_.

Agrentina, in conjunction with Germany and Japan, is currently conducting research aimed at estimating their squid resources. As yet, the results of these studies are not available.

Because of the fact that Uruguay has important squid resources, the exploitation of which has increased during the last fifty years in response to a growing demand from the overseas market, the National Institute of Fisheries (NIF) together with the FAO as consultants, included the study of these resources in its 1980 research programme.

In the present study, which will serve as a basis for future research, reference will be made to current knowledge on the biology of these resources, taking into account available bibliographic data and the results of research carried out on board the B/1 Lametra (FAO - NIF) in 1979 and 1980.

1. GENERAL BIOLOGY AND CLASSIFICATION

Squids belong to the class of Cephalopoda, the highest in the hierarchy of the Phylum Mollusca.

They are usually active organisms, good swimmers with a solid robust body. They have a short life cycle, which in many cases is less than a year. They die after spawning. Some species (Loliginidae) live as long as 3 years.

Growth in almost all species is notably rapid; _Loligo vulgaris_ approximately 10 mm a month, _Illex illecebrosus_ from 10 to 40 mm a month (Squires, 1967).

They are situated at the top of the food chain. When young, they basically feed on small planktonic crustaceans and fish larvae, whereas in their adult stage they behave like active predators.

They live in all the world's oceans and occupy the littoral, pelagic, benthic and abyssal zones.

Little is known of the ecology of the squid grounds; migrations in some areas consist of movements towards and away from the coast (Voss, 1973). Nor is sufficient data available on their oceanographic characteristics.

Of the orders which make up the class of Cephalopoda, the squid belongs to the order Teuthoidea. This may be subdivided into two suborders:

Myopsidea - Generally neritic squid, sometimes found outside the continental slope. Forms the most important commercial group in the world.

Oegopsida - Oceanic squid which live outside the continental shelf; sometimes found on the shelf.
The most important commercial species belong to the family of the Ommastrephidae; these are: Todarodes pacificus (Pacific Ocean, essentially Japan), Illex illecebrosus (N.W. Atlantic Ocean) and Illex argentinus (S.W. Atlantic Ocean, Uruguay and Argentina).

2. SPECIES OF SQUID INHABITING THE ARGENTINIAN - URUGUAYAN COMMON FISHING ZONE

The Uruguayan fishing area consists of the Plate River and the common fishing zone, in accordance with the Plate River Agreement and its Maritime Front signed with the Argentine Republic (Law No. 14.145, 25/1/74) (Fig. 1).

Of the suborders mentioned above, it is Oegopsida which is the best represented in the waters of the Argentinian - Uruguayan Common Fishing Zone. It contains 3 families and a total of 5 species. Myopsida is composed of 2 families and 3 species.

Suborder Oegopsida

Family Ommastrephidae
Subfamily Illicinae

Illex argentinus (Castellanos, 1960) (Fig. 2)

Habitat: Deep litoral zone and oceanic waters to depths of 800 m (Castellanos and Menni, 1968).

Disbribution: Uruguay and Argentina, between 34°30' and 46° Lat.S, and 52° and 61° Long.W, (Castellanos and Menni, 1968).

Ornithoteuthis antillarum (Adam, 1857)

Habitat: Native to the pelagic zone, caught in the West Indies at a depth of 5 fathoms (Figueiras and Sicardi, 1974).

Distribution: Guadaloupe (West Indies) and Bahamas; Uruguay between Punta Coronilla and Chuy (Figueiras and Sicardi, 1974).

Martialia hyadesi (Rochebrunne and Mabille, 1817)

Habitat: Ocean waters between 100 and 300 m (Castellanos and Menni, 1968).

Distribution: From 38°55' S up to 51°00' S and near the Falklands (Castellanos and Menni, 1968).

Family Onychoteuthidae

Onychoteuthis banksi (Leach, 1917)

Habitat: Ocean waters between 400 and 800 m; euryoic species, prefers temperate - warm waters (Castellanos and Menni, 1968).

Distribution: From Norway to Cape Horn; common in the West Indies (Castellanos and Menni, 1968).

Family Enoploteuthidae

Pterigioteuthis giardi (Fisher, 1895)

Habitat: Ocean waters of medium depth.

Distribution: From the Plate River in the south, and throughout the Pacific as far as Panama (Castellanos, 1970).

Of the above species, only one is caught in large quantities by the Uruguayan Off-Shore Fleet. This is the squid Illex argentinus. Almost 100% of the squid caught by this fleet is made up of this species. Due to its abundance, it is the principal squid resource of the area.

Suborder Myopsida

Family Loliginidae

Loligo brasiliensis (Blainville, 1823)

Habitat: Waters of shallow and medium depth, generally coastal

Distribution: From Cuba, Brazil, Uruguay and Argentina up to the Gulf of San Matias (Castellanos and Menni, 1968).

Lolliguncula brevis (Blainville, 1823)

Habitat: Shallow waters of the littoral zone.

Distribution: In the U.S. from the Bay of Delaware to Florida. Brazil and Uruguay as far as the mouth of the Plate River (Figueiras and Sicardi, 1974).

Family Sepiolidae

Rossia Tenera (Verril, 1880)

Habitat: Rocky depths of the littoral zone (Carcelles, 1944)

Distribution: Atlantic Coast of North America, West Indies, Brazil, Uruguay and Argentina up to the Strait of Magellan; the Chilean coast up to 52°S 68°W (Figueiras and Sicardi, 1974).

Of these species, the squid Loligo brasiliensis is the most abundant.

It is caught in smaller quantities than Illex argentinus and is considered the second most important squid resource in the area.

3. FISHERIES BIOLOGY OF THE SQUID ILLEX ARGENTINUS

This species is exploited by the off-shore fleet between 34°30' and 39°30' Lat.S and between 52°00' and 58°00' Long.W. It is also exploited by the Argentine Republic in the waters of Patagonia between 39°30' and 46°00' Lat.S, and 59°00' and 62°00' Long.W. (Castellanos, 1964).

Although this is a very abundant species, knowledge of its biology is incomplete. Studies on this topic have been carried out by Castellanos (1964, 1970), Castellanos and Menni (1968, 1969), Roper, Lu and Mangold (1969) and Klyuchnik and Zasypkina (1972).

The purpose of what follows is to supplement this knowledge by contributing data on the fisheries biology of this species.

3.1 Oceanographic and Environmental Characteristics of the Argentinian - Uruguayan Common Fishing Zone

The Common Fishing Zone generally shows a gently sloping continental shelf, consisting mostly of sand, mud and tufa. Although there are some rocky outcroppings, the greater part of its area lends itself to the work of the fishing units which use bottom trawl nets with doors. The main rough area consists of the part known as Pozo de Fango., This is an underwater canyon with depths of over 50m and is found in the NE of the zone. From the continental slope (approximately 250 m) the seabed drops abruptly to depths which range from 1000 to 4000 m.

On the other hand, the Common Fishing zone is affected by water masses of different origins. The following three may be distinguished: the cold

FIGURE 1

Map of Argentinian-Uruguayan Common Fishing Zone
(62,941,43 nautical miles^2)

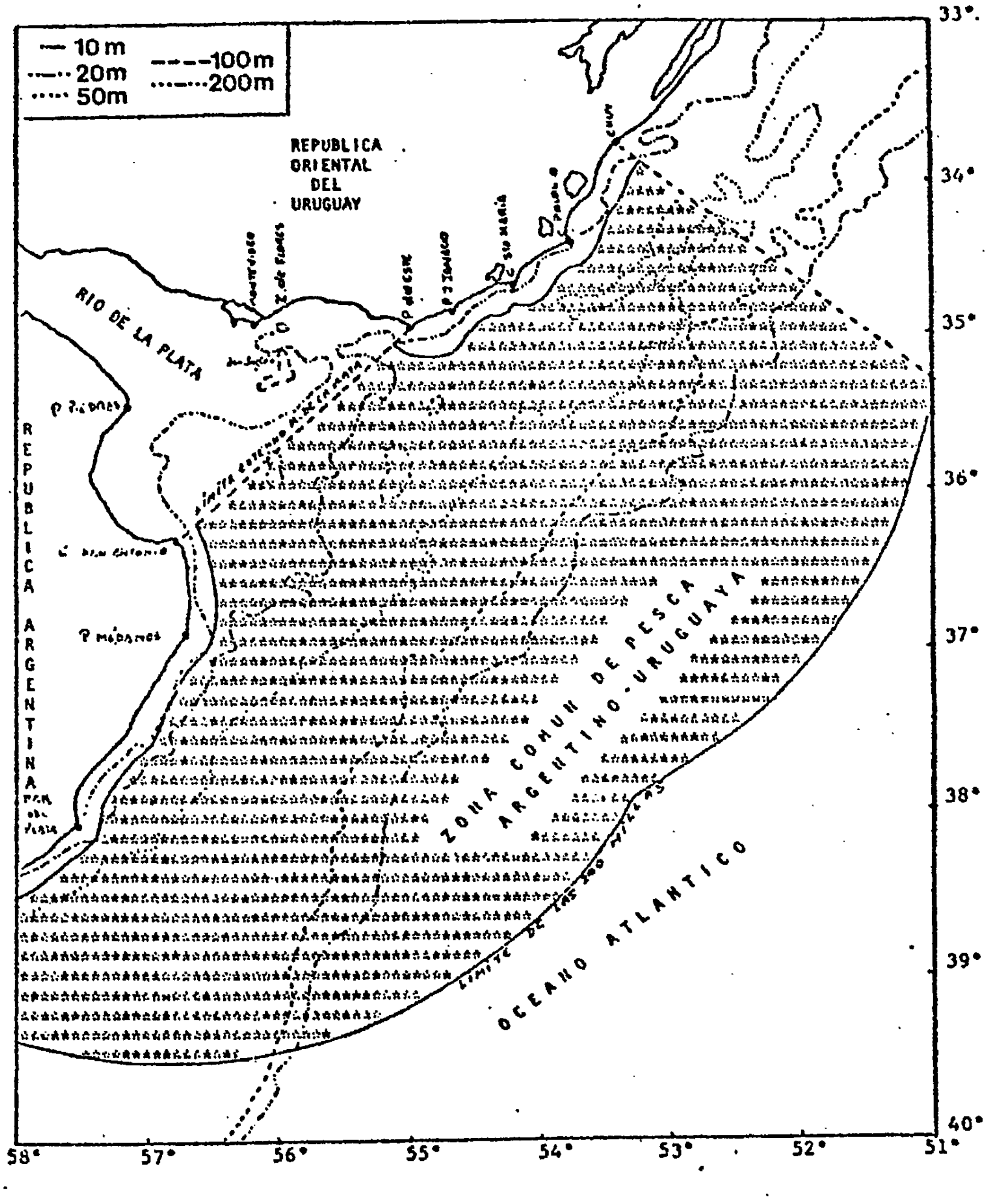
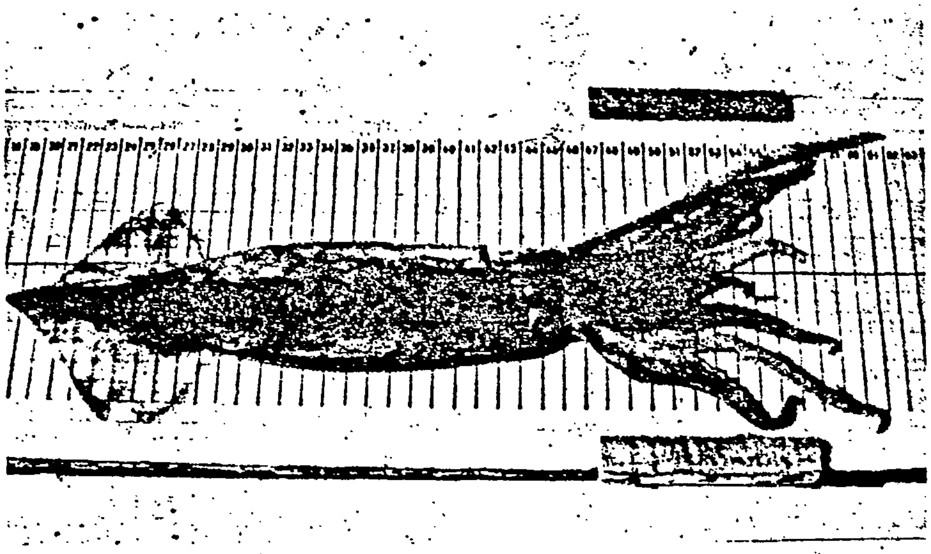


FIGURE 2

External view of a specimen of I. argentinus
(♂ with 24 cm long mantle)



Falklands current, the warm Brazilian current and the Plate River current. The first two are the most important, not only on account of their volume, but also because their interaction produces what is known as the Subtropical-Subantarctic Convergence. The point where these currents meet is characterized by sudden jumps in temperature and salinity and is pin-pointed by certain plankton organisms, as well as by upswelling. This convergence has its own dynamics and is displaced according to the season between 30° and 43°S.

The cold Falklands current is the result of the diffusion of the Cape Horn current after it passes through Drake Passage. The resulting north branch or Falklands current covers the greater part of the Argentinian and Uruguayan continental shelf with subantarctic waters, but mainly the slope. (Abella, Arena, Nion and Rios, 1979). It reaches the mouth of the Plate River 37°S) where is mixed with waters of continental and subtropical origin and the Brazilian current. Subsequently it flows beneath the mixing waters and continues northward as an underwater current as far as 29°S (Castellanos and Menni, 1968). The salinity of the Falklands current varies between 33.70 and 34.15‰ and its temperature between 4 and 15°C (Thomsen, 1962).

The warm Brazilian current originates in the North off the coast of Cabo San Roque and is the result of the movement of the South Equatorial current toward SW. These subtropical waters follow the edge of the Brazilian continental shelf until they reach a point south of the Plate River (summer), where, under the influence of the western tradewinds and of the Coriolis force, they change direction towards the open sea.

The salinity of this current varies between 34.50 and 36‰, and its temperature between 18 and 24°C.

On the other hand, off the coasts of the area under study and also along them, the coastal or shelf waters are found. These are influenced by continental waters from numerous rivers and their temperature is generally higher than that of the surrounding waters.

The Plate River has an estuary system characterized by the inflow of continental waters from the Parana and Uruguay rivers and the ocean waters from the Atlantic Ocean.

The interaction of climatic factors (wind action), together with astronomical tides (Urien, 1972), favoured by the meeting of the Plate River with the open sea, cause these waters to mix. Under certain atmospheric conditions, these waters may extend over the continental slope and act as a barrier between the Brazilian and Falklands currents.

It should be added that the waters of the Plate River divide up into two important currents, which flow in different directions. One follows the Uruguayan coast eastward as far as the Rio Grande (Brazil), while the other follows the rim of the Province of Buenos Aires (Argentina) towards the Cape of San Antonio.

Changes in salinity depend on the effect of the tradewinds and of rainfall on the basin of the Plate River.

3.2 Population Structure

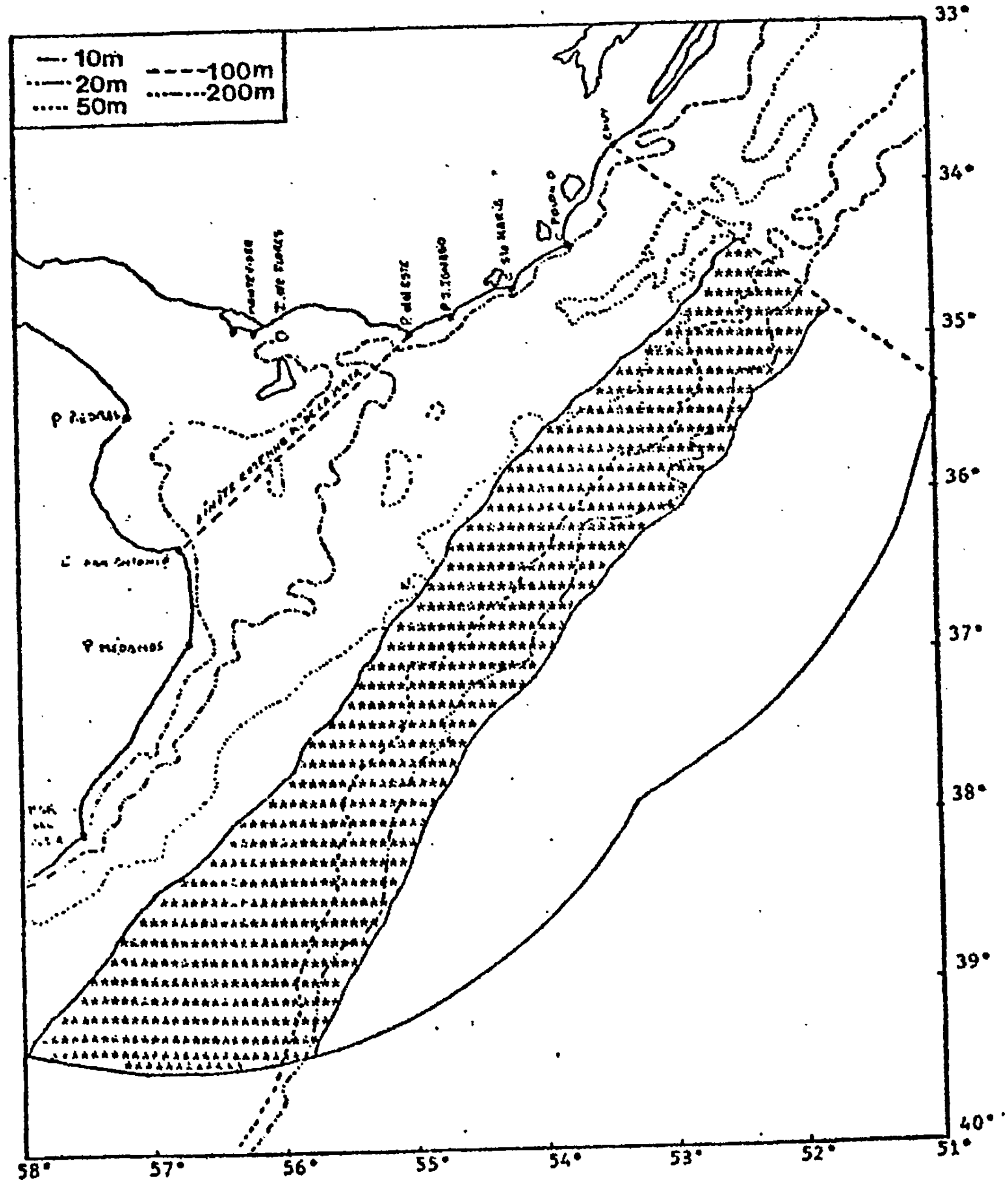
In winter and spring of 1979, two studies were carried out on distribution, abundance, size and sex composition, and sexual maturity,

3.2.1 Chrongological Distribution

The fishing season in the Common Fishing Zone extends almost over the entire year (Feb. - Dec.) in the area shown in Fig. 3.

FIGURE 3

Area of Argentinian-Uruguayan Common Fishing Zone where the squid Illex argentinus is caught between February and November



The species undergoes a monthly latitudinal migration in this area from SW to NE. Maximum dispersion is reached in September (Fig. 4) and maximum northerly penetration in July (Fig. 5).

Beginning in August, it starts to move off towards the SW and by the end of December it is rarely found in this zone.

Castellanos (1964) notes that this species is found in the waters off Patagonia in summer, which is explained by the following considerations

3.2.2 Abundance and bathymetric distribution

The greatest abundance of this species has been recorded towards the end of autumn and during the winter. In these seasons the species is found mainly along the edge of the continental shelf (Figs. 6 & 7).

In the spring and the beginning of summer, it is found over the continental shelf far above the slope (60 to 150 m) (Fig. 8).

3.2.3 Size frequency

Measurements were based on the dorsal length of the mantle. This was becaused this structure is not easily deformed.

Lengths were recorded at the lower interval and expressed in centimeters (cm).

The specimens had been separated by sex and by season considered.

The total population structure (male and female) is given for these seasons so as to provide data which may be useful from the point of view of its economic exploitation.

The following results were obtained;

a. In winter, the sizes of the males were between 18.00 and 31.00 cm, while those of the females were between 15.00 and 34.00 cm. The mean length ($\bar{x}$) of males and females was 24.00 and 27.65 cm. respectively. (Fig. 9).

FIGURE 4

Maximum dispersion reached by the squid
Illex argentinus in September

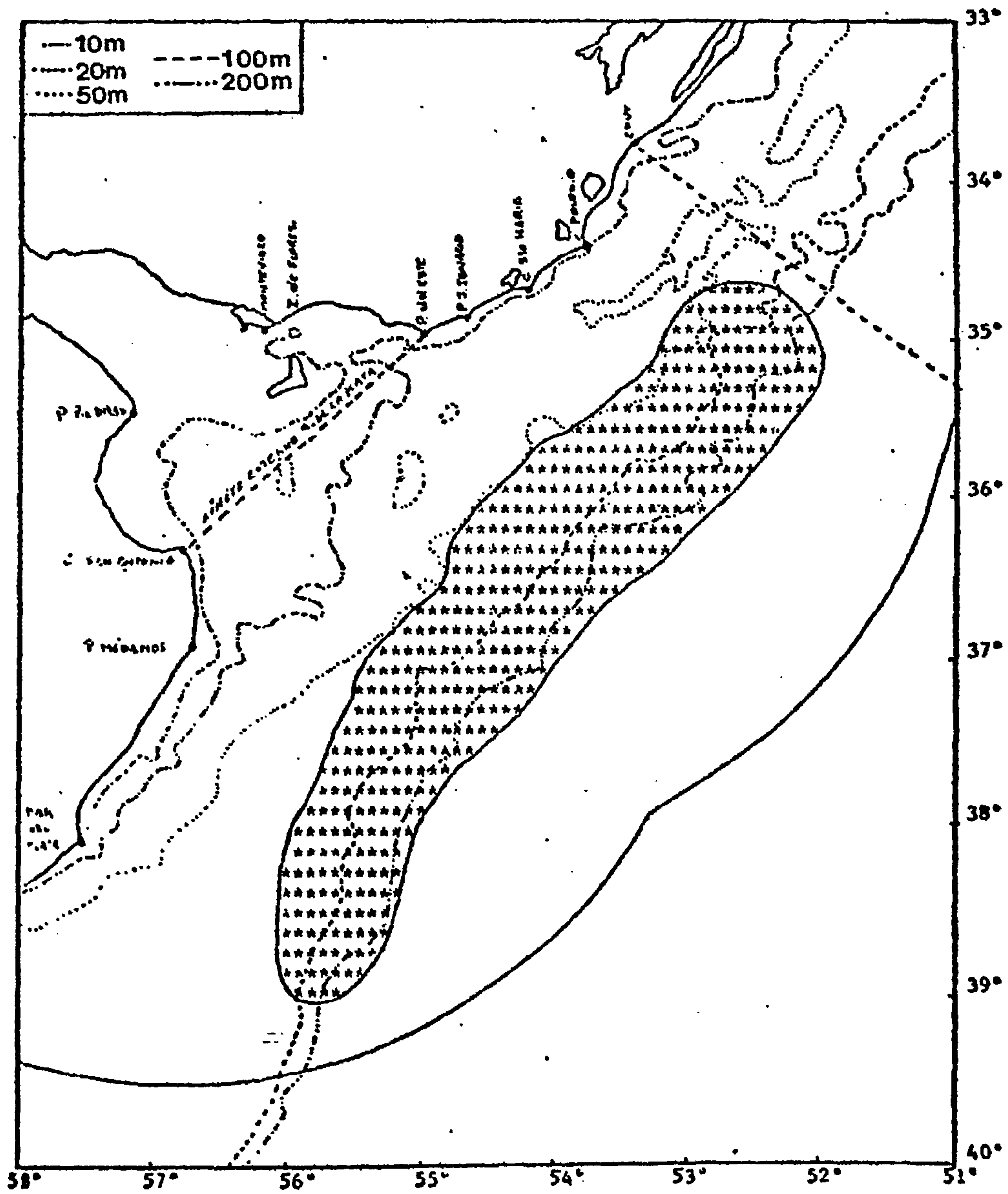


FIGURE 5

Maximum northerly penetration of
Illex argentinus in July

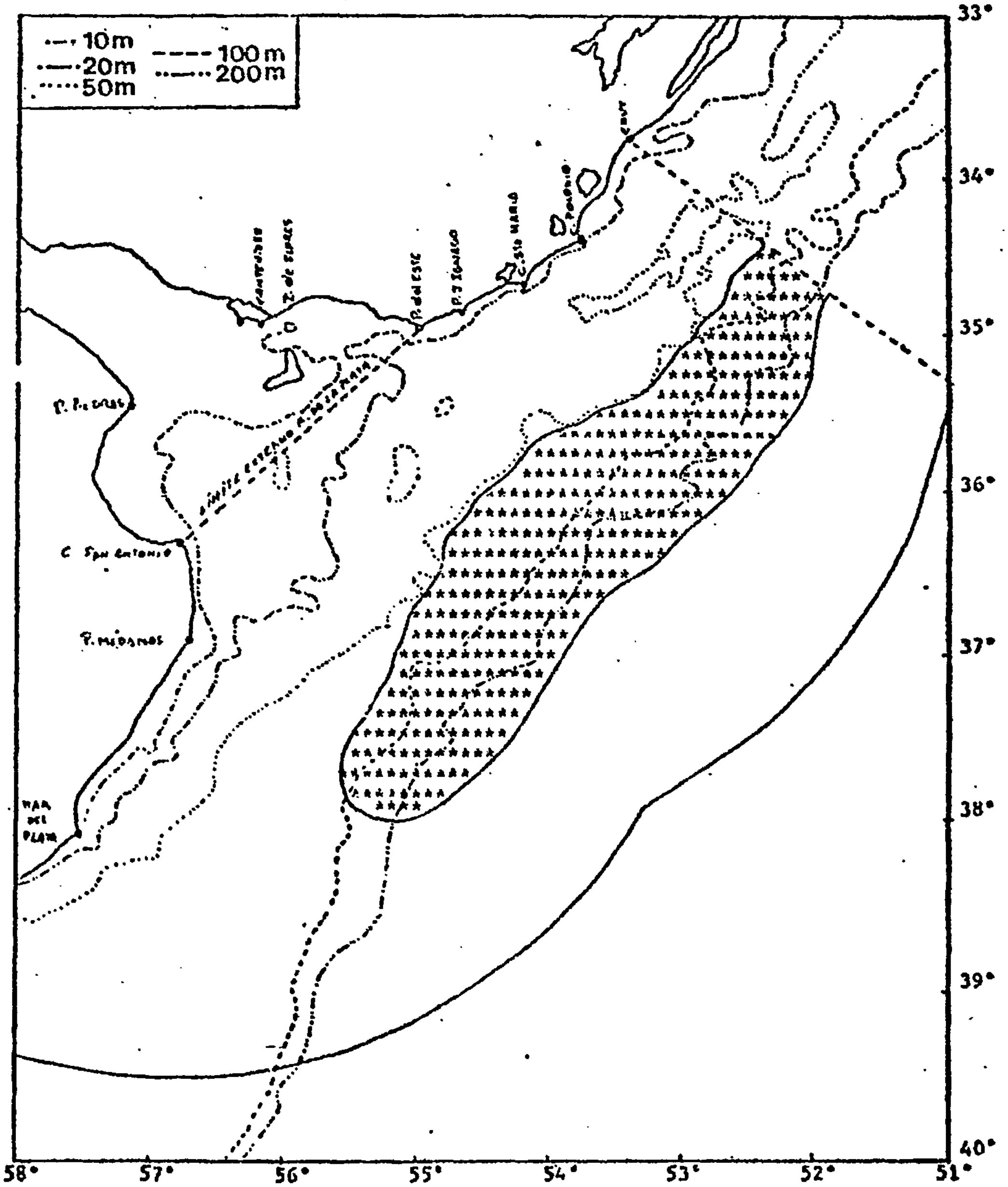


FIGURE 6

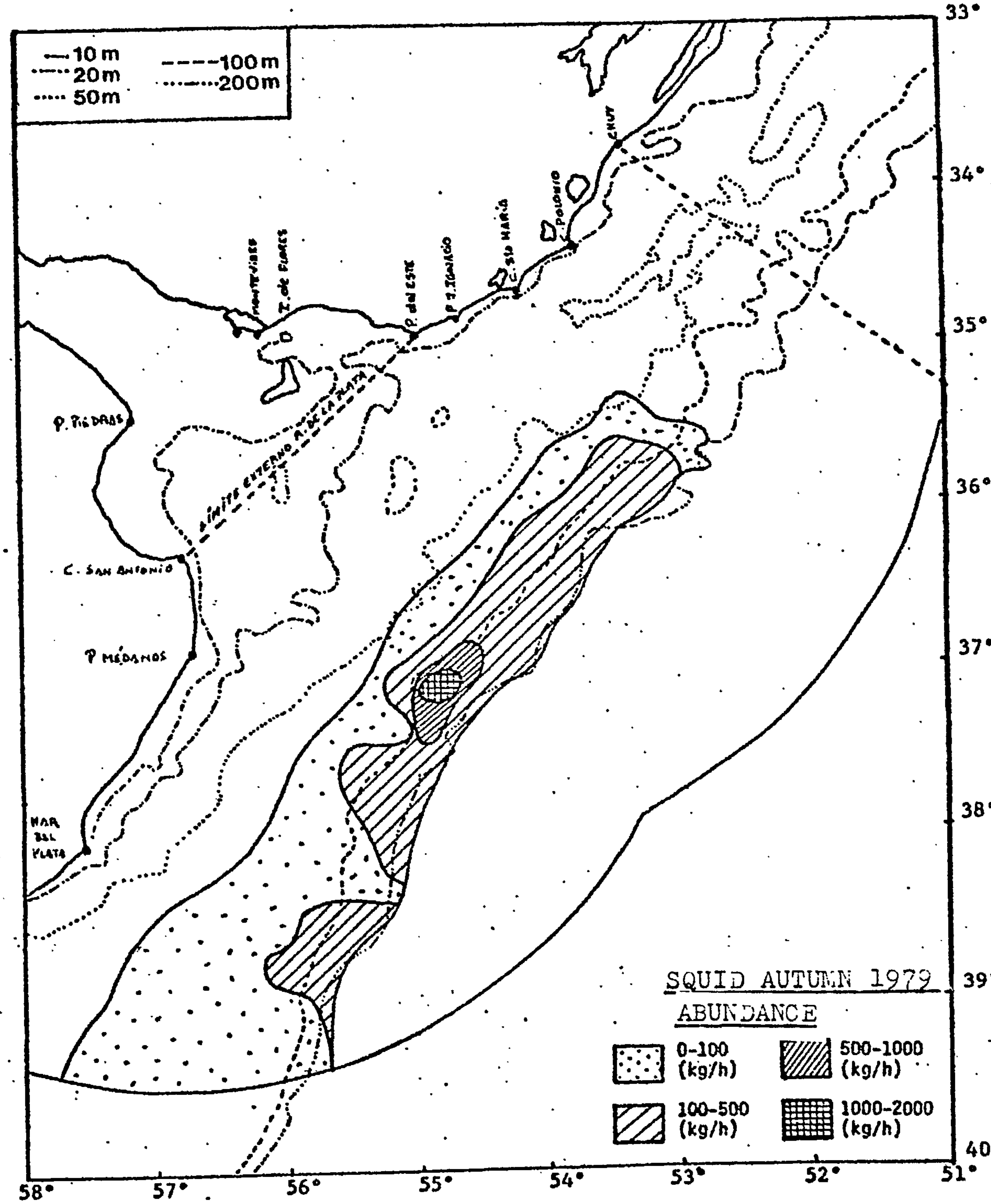

10 m
20 m
50m
100m
200m
CHUY
POLONIO
C. STA MARÍA
P. J. IGNACIO
P. del ESTE
I. de FLORES
MONTEVIDEO
LÍMITE EXTERNO R. DE LA PLATA
P. PIEDRAS
C. SAN ANTONIO
P MÉDANOS
MAR DEL PLATA
SQUID AUTUMN 1979
ABUNDANCE
0-100 (kg/h)
500-1000 (kg/h)
100-500 (kg/h)
1000-2000 (kg/h)
33°
34°
35°
36°
37°
38°
39°
40°
58°
57°
56°
55°
54°
53°
52°
51°

FIGURE 7

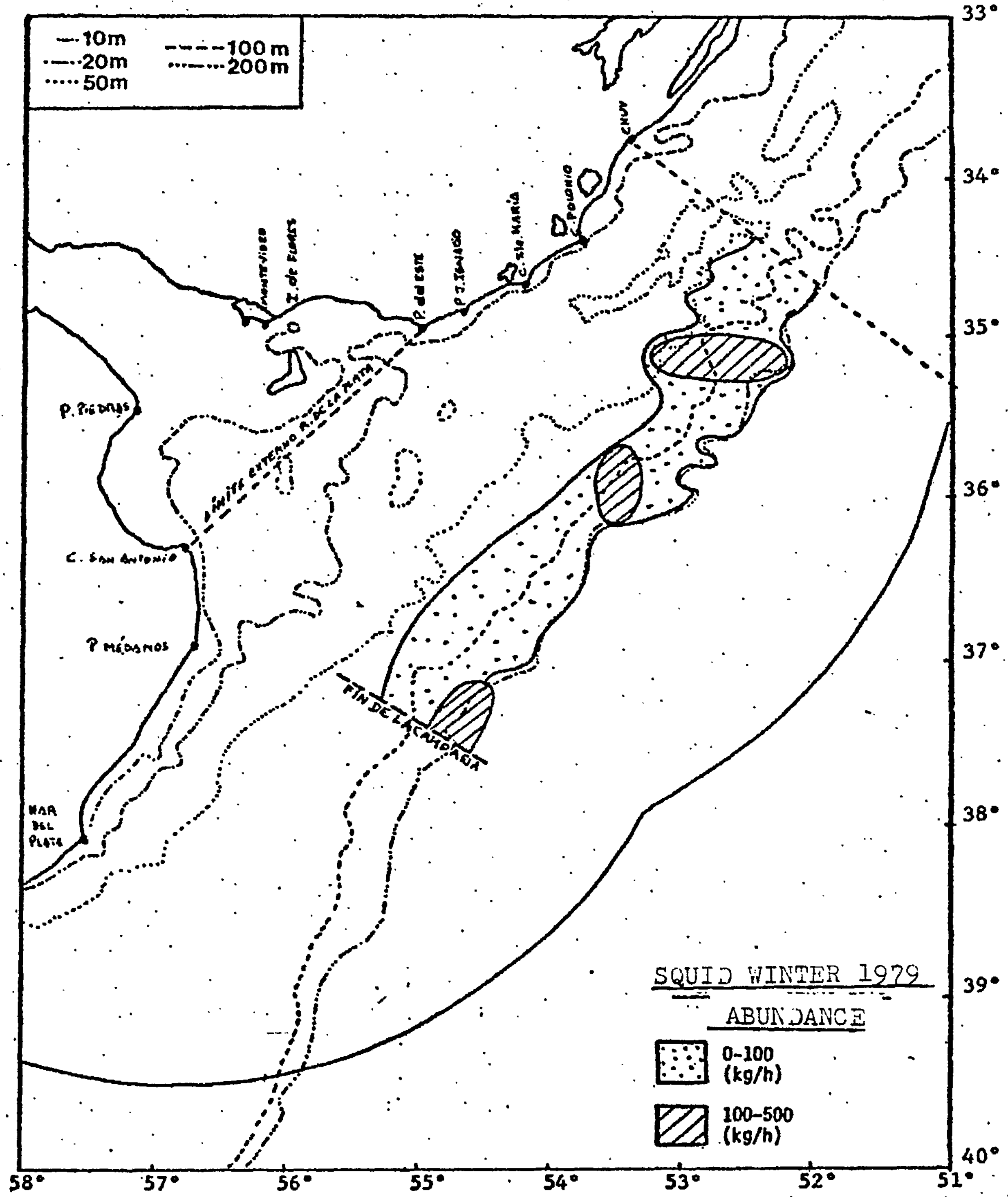

10m
20m
50m
100 m
200 m
33°
34°
35°
36°
37°
38°
39°
40°
58°
57°
56°
55°
54°
53°
52°
51°
SQUID WINTER 1979
ABUNDANCE
0-100
(kg/h)
100-500
(kg/h)

FIGURE 8

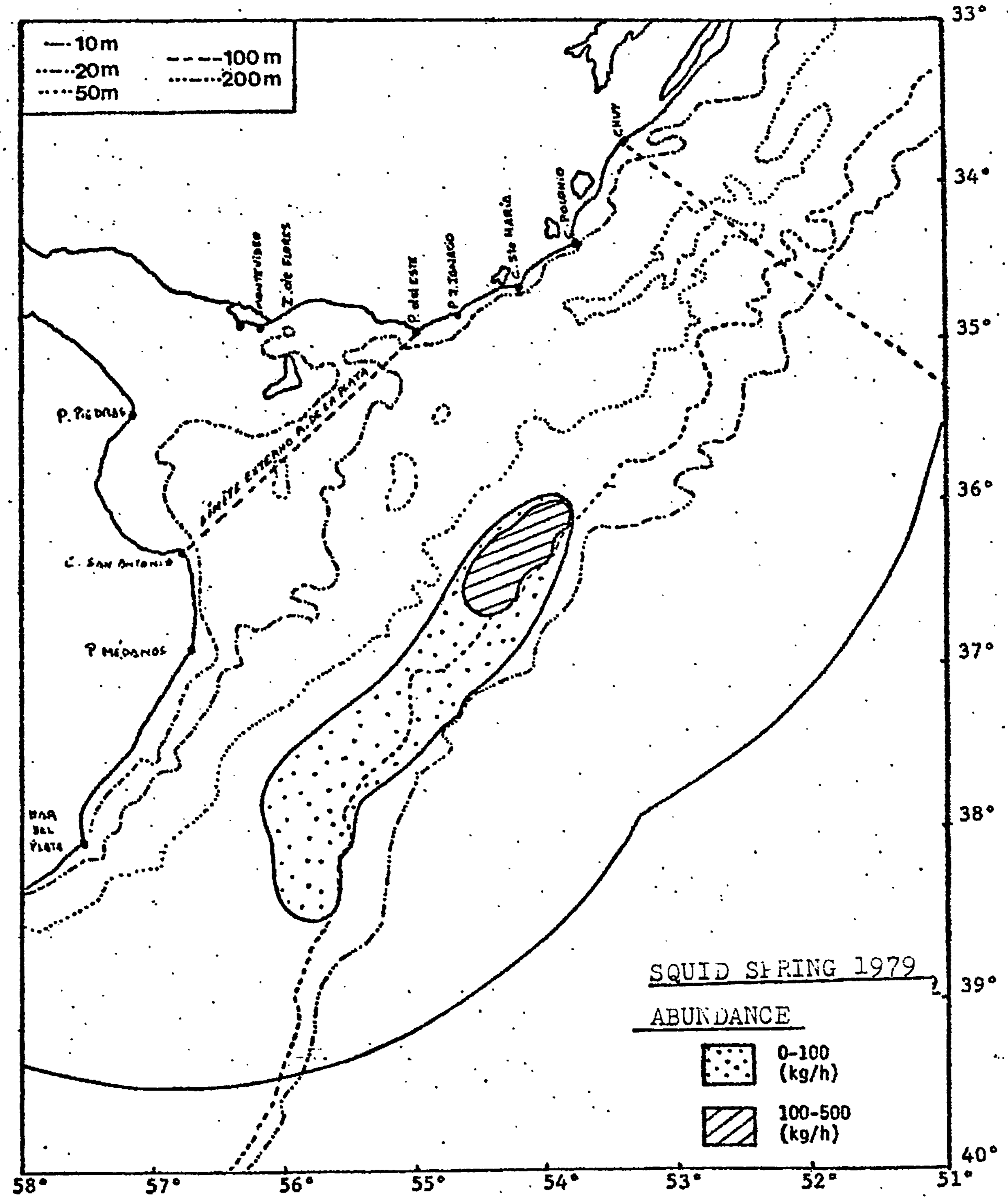
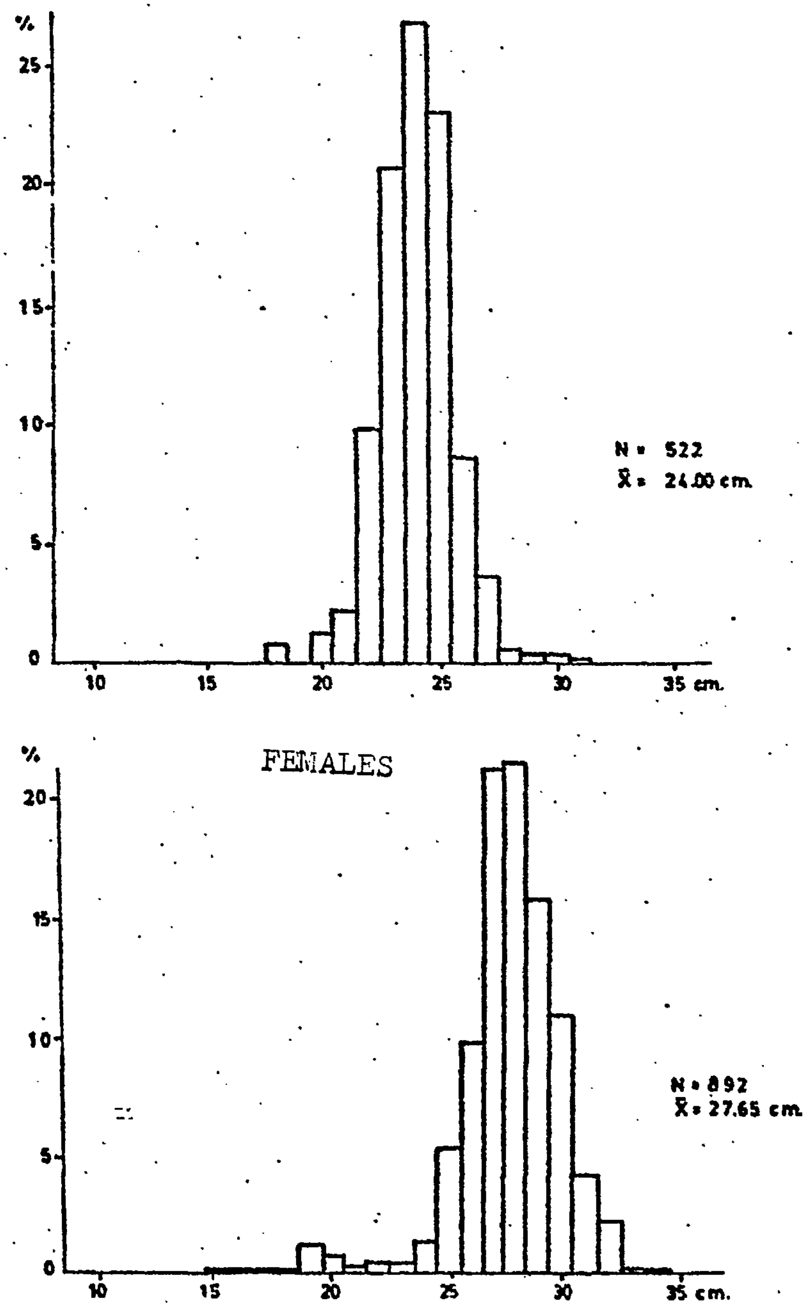

10m
20m
50m
100m
200m
33°
34°
35°
36°
37°
38°
39°
40°
58°
57°
56°
55°
54°
53°
52°
51°
CHUY
POLONIO
P. PIEDRAS
C. SAN ANTONIO
P. MÉDANOS
SQUID SPRING 1979
ABUNDANCE
0-100 (kg/h)
100-500 (kg/h)

FIGURE 9

Squid Illex argentinus
Frequency of sizes (mantle legth)

Winter 1979

MALES



In this season, the population consists of sizes ranging from 15.00 to 34.00 cm, with an average ($\bar{x}$) of 26.30 cm. (Fig. 11)

b. In spring, on the other hand, the sizes recorded are significantly smaller. Males were found to have lengths of between 11.00 and 20.00 cm, and females between 11.00 and 25.00 cm. The mean length ($\bar{x}$) of males and females was 16.28 and 18.25 respectively (Fig. 10). As may be seen, the population consisted of sizes ranging from 11.00 to 25.00 cm, with a mean ($\bar{x}$) of 17.14 cm. (Fig. 11)

From an analysis of these results, we may arrive at the following conclusions:

- that the species shows a sexual dimorphism in size with males being significantly smaller than females.
- that the population in the seasons in question is made up of groups of notably different sizes (winter -large; spring -medium).

3.2.4 Sex Composition

The winter samples consisted of 422 males and 892 females, corresponding to 36.92% and 63.08% of the total, respectively.

On the other hand, the spring samples consisted of 588 males (56.54%) and 452 females (43.46%).

In summer, the proportion of males increased from south to north following the increase in depth. The greater proportion of females recorded in this season can be explained if we consider that the males begin spawning before the females, after which they die. This is supported by the fact that immature fertilized females have been observed and that males mature faster than females.

In spring, although slightly more males than females were recorded, it can be reckoned that the population contained equal proportions of both sexes in that season.

FIGURE 10

Squid Illex argentinus
Frequency of sizes (mantle length)

Spring 1979

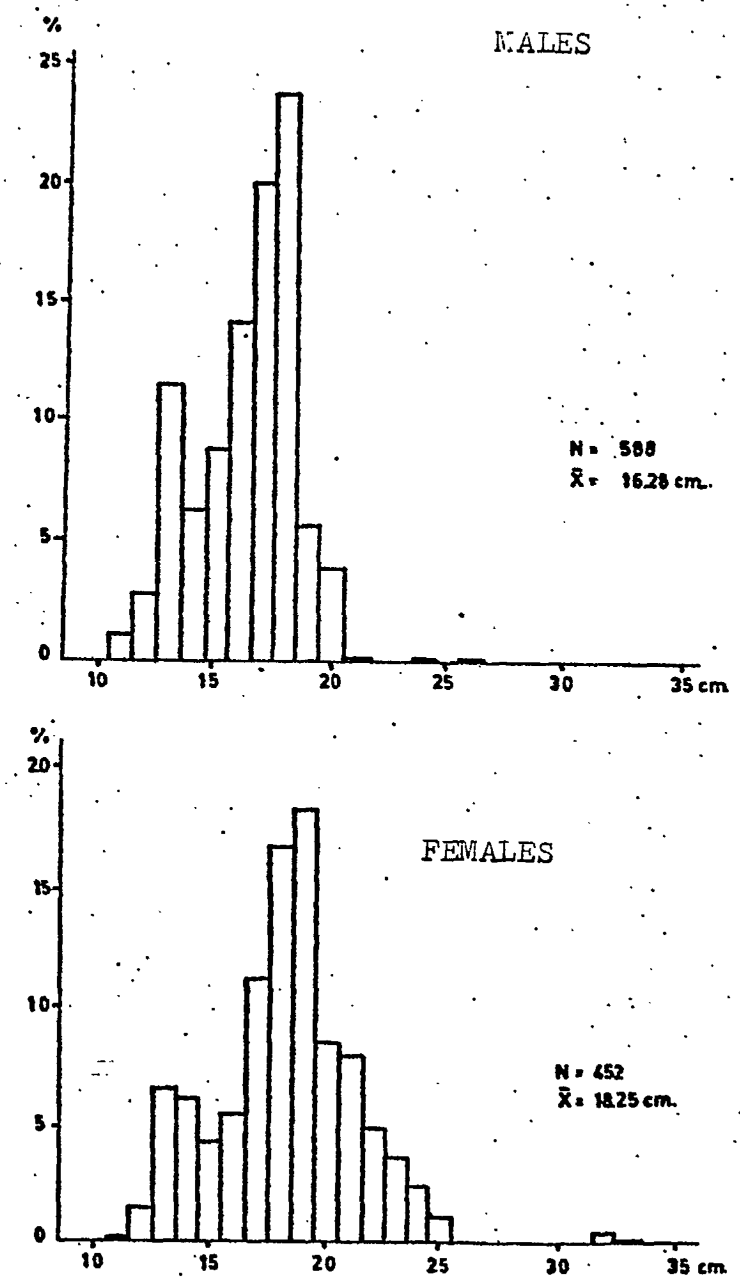
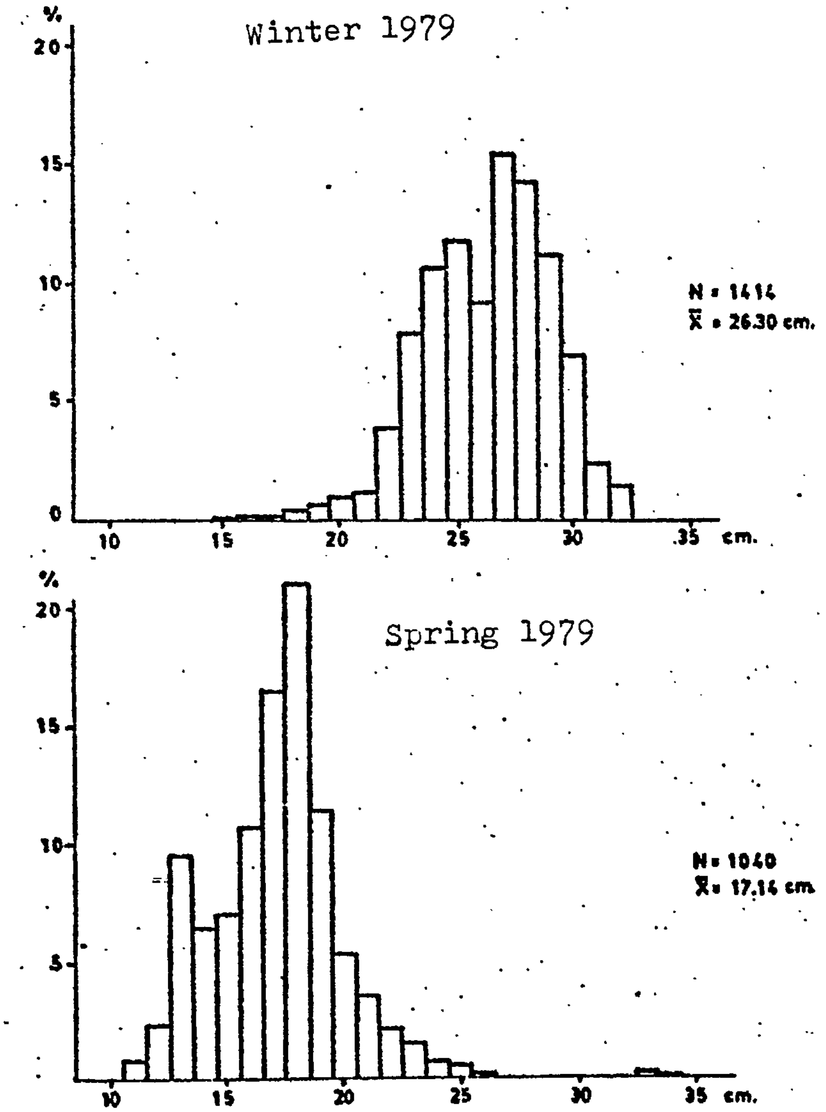


FIGURE 11

Squid Illex argentinus

♂♂+♀♀

Frequency of sizes (mantle length)



3.3 Growth

The study on growth was carried out on the basis of the relationship between mantle length and total weight. Mantle length was measured as in Frost and Thompson (1932), dorsally from the tip of the tail to the small protuberance at the edge of the mantle. This length was recorded at the lower interval and its value expressed in centimeters.

The data were obtained from fresh specimens, since it has been observed that in the case of specimens preserved in formol the length of the mantle is shorter (3%) than in fresh ones (Squires, 1957).

With the data obtained, the function which describes this relation was determined. The equation which relates both variables is the following:

$W = aL^b$ (1) where

W = weight in grams

L = length of mantle expressed in centimeters

a and b = constants

This equation was linearized logarithmically:

$\text{Log } W = \text{Log } a + b \text{ Log } L$ (2)

Later, the parameters Log a and b were estimated, by the method of least squares, where a of equation (1) corresponds to the intersept of equation (2).

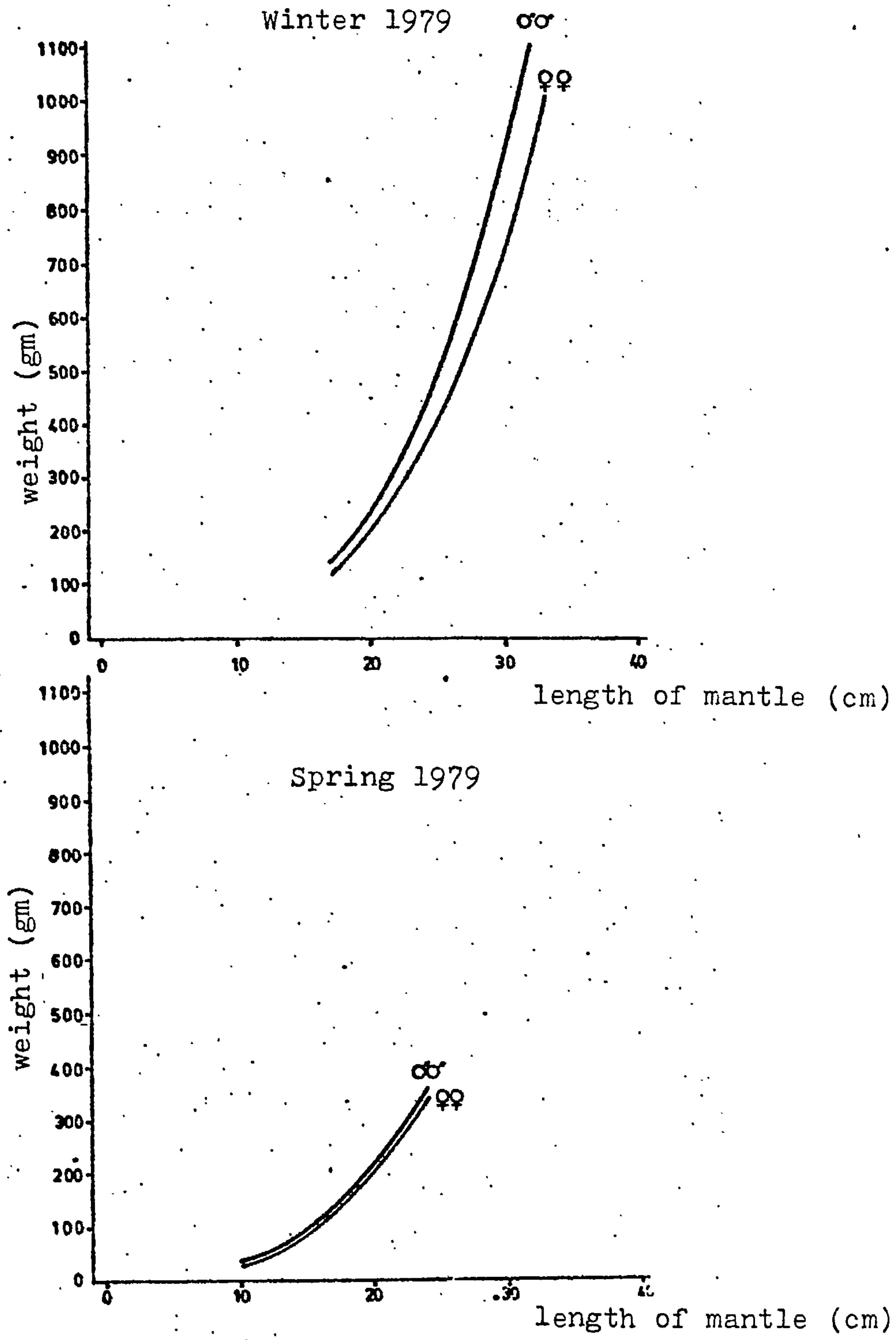
The parameters determined for males and females for each season considered are shown in the following chart:

SEASON	MALES		FEMALES	
	a	b	a	b
Winter	0.00817	3.38146	0.00728	3.35682
Spring	0.02987	2.91660	0.01782	3.06422

The curve of the function (Fig. 12) was plotted for each sex by season.

FIGURE 12

Relationship between mantle length and weight in *Illex argentinus*



The values calculated and the corresponding curves indicate that males are heavier than females of equal length. This has been reported in Illex illecebrosus (Le Sueur) by Squires (1957).

The difference in weight favouring males having a mantle of the same length can be explained by the fact that they reach sexual maturity before females (heavier gonads) and that they have more powerful and heavier arms and tentacles. This difference is more noticeable in winter when both sexes record maximum sizes and weights.

From the results obtained it may be concluded that males of equal length increase more rapidly in weight than do females, whereas the latter reach a larger size than males.

3.4 Reproduction

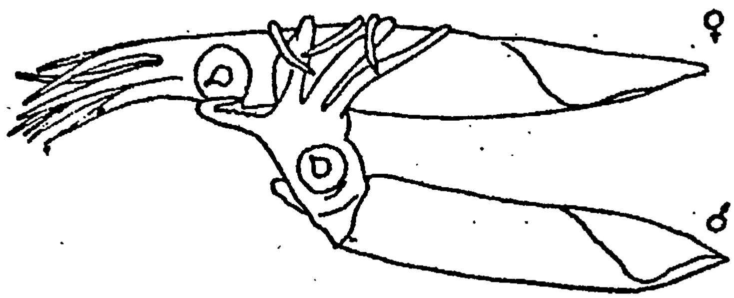
The squid Illex argentinus has separate sexes and shows sexual dimorphism. The external sexual difference lies in the ectocotylization on the fourth left arm of the male. This may be easily distinguished owing to the loss of the suckers on the arm leaving only the peduncles. It has been noted in field work that this ectocotylization may also occur on the fourth right arm (Leta, 1980).

On the other hand, the body of the male is generally narrower and softer than that of the female. The female can be easily identified in maturation periods by the greater diameter and hardness of the body.

Fertilization is internal and occurs when the male takes the spermatophores with the ectocotye and deposits them in the paleal cavity of the female through the siphon (Castellanos, 1964) as shown in Fig. 13 for the I. i. coindetii (Mangold-wirz, 1963)

FIGURE 13

Sexual intercourse in the squid
Illex Illecebrosus coindetii



3.4.1 Period and area of spawning

According to data obtained from reference sources and observations made on field trips, this species spawns twice a year, in the summer and winter. The summer spawning begins in December and extends to February (Castellanos, 1964). On the other hand, the winter spawning begins towards the end of June and extends to September. Larvae with mantle lengths of approximately 6 mm and eggs with a diameter of 1.4 mm near hatching obtained on icthyoplankton cruises made by the B/I LAMATRA in March and August 1980 seem to corroborate the dates mentioned above.

In each season considered, the spawning areas and the depths where it occurs differ. Summer spawning takes place over the Patagonian continental shelf (outside of the Common Fishing Zone) between 39°00 and 42°00 S, whereas winter spawning takes place on the slope and also at greater depths in the Argentinian - Uruguayan common fishing zone, between 36°00 and 39°00 S.

3.4.2 Type of Spawning

Spawning does not occur simultaneously throughout the whole population. It is initiated by the males who reach sexual maturity before the females. It is then continued by the latter.

The squid die after spawning. This is observed in other species, such as *Lolligo opalescens*. This possibility is suggest for *Illex argentinus* because after winter spawning no specimens were found in a state of post-evacuation. Furthermore, in the months following, no individuals were found of equal or greater size than those recorded during spawning, in the entire area of the common fishing zone.

As for the incubation time of the eggs, this is presumed to be from two to three weeks, based on the eggs and larvae collected. This time may vary depending on the temperature and the size of the egg (Mangold-Wirz, 1963).

3.4.3 Sexual Maturity

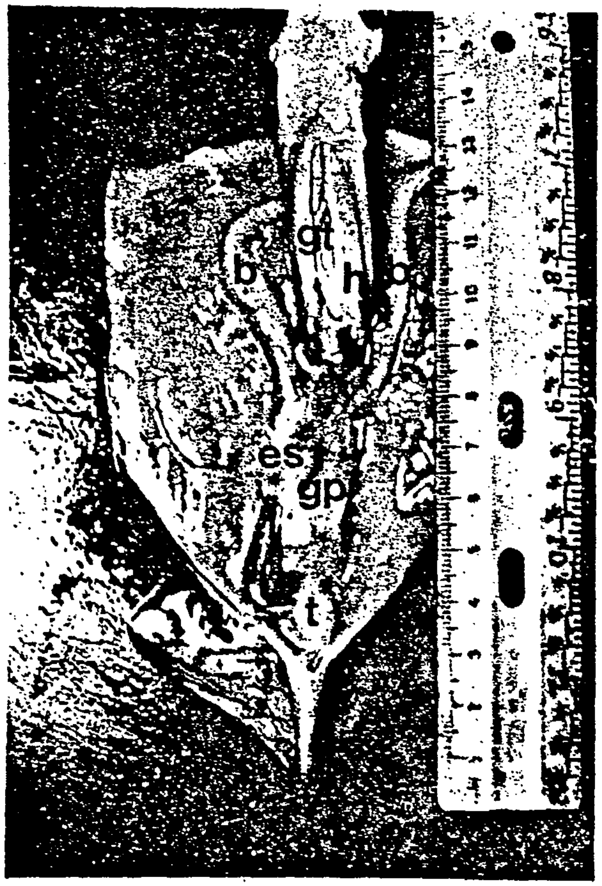
Degrees of sexual maturity were established so as to facilitate their recognition by the field observer. The following scale was prepared for this purpose:

MALES	FEMALES
LEVEL I - IMMATURE	
Translucent, transparent testicles; translucent prostate gland with a thin clear border on the mid lateral line; thin and translucent vas deferens; no spermatophores in the spermatophore sac which appears transparent (Fig. 14A).	Transparent ovary; nidamental glands are translucent and small. The oviduct glands were not observed. (FIG. 16A)
LEVEL II - BEGINNING OF MATURITY	
Testicle a little larger, whitish opalescent; prostate gland more developed and whitish; vas deferens thicker and whitish. It is sometimes possible to observe white particles in the spermatophore sac (Fig. 14B)	Whitish, opalescent, glandular ovary; nidamental glands more developed and whitish; oviduct glands are clear. (Fig. 16B)

MALES	FEMALES
LEVEL III - MATURING	
White testicle, white prostate gland; white, thick vas deferens; spermatophore sac with some spermatophores. (Fig. 15A)	Yellowish white glandular ovary; polyhedral ovules, the majority adhering to the womb, oviducts in formation; white nidamental glands, occupying almost half of the visceral cavity. Oviduct glands in formation (Fig. 17A)
LEVEL IV - SPAWNING -MATURE	
White, well developed testicle; whitish prostate gland; white vas deferens, spermatophore sac full of well-formed spermatophores, they can also sometimes be seen loose in the paleal cavity (Fig. 15B)	Yellowish ovary, oviducts with walls very distended because of the quantity of lodged ovules; the oviduct glands are white and well-formed; the ovules can be removed from them at the slightest pressure; large, globulous ovules clearly visible; large white nidamental glands occupying almost the entire visceral cavity (Fig. 17B).

FIGURE 14

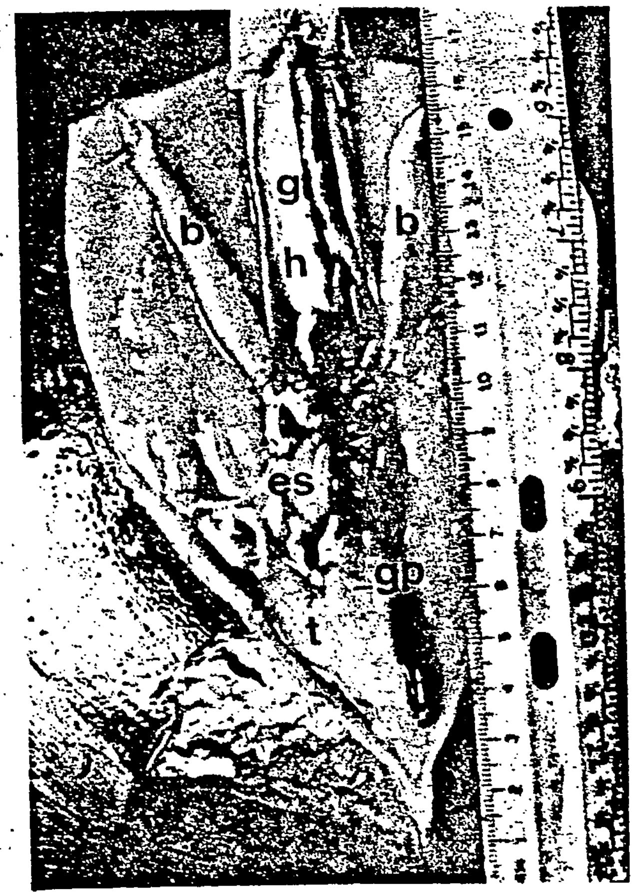
Levels of sexual maturity in the squid I. argentinus



a.-Male Level 1. t,testicle;
gp, prostate gland; es, stomach
h, liver; gt,ink gland; b,gills

FIGURE 14

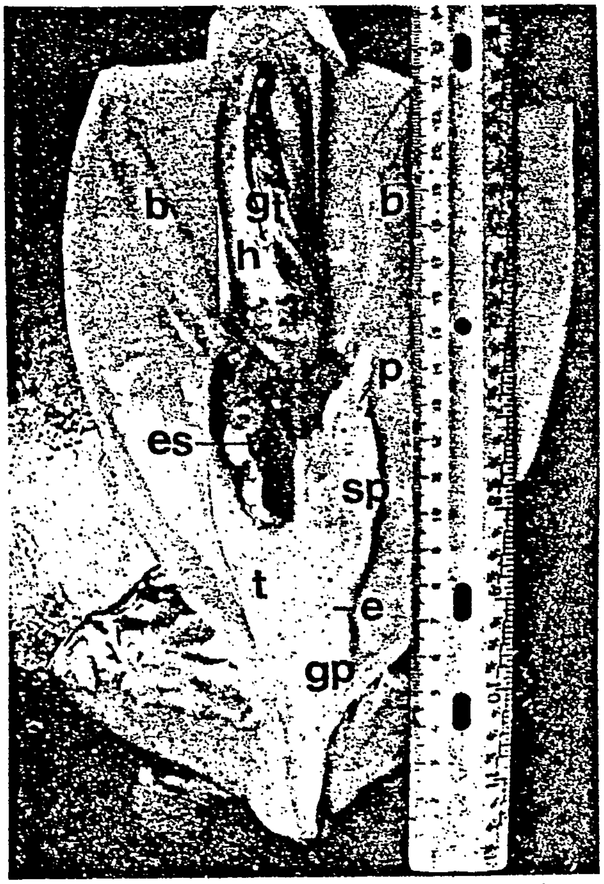
(cont.)



b.-Male Level 11. Symbols used are the same as given in a.

FIGURE 15

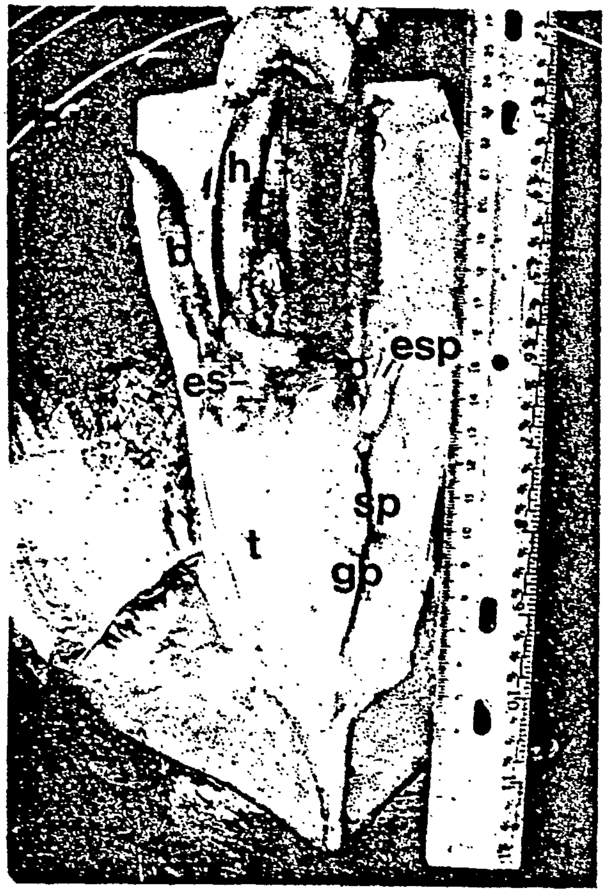
Levels of sexual maturity in the squid I. argentinus



a.- Male Level III. e, efferent;
sp, spermatophore sac.

FIGURE 15

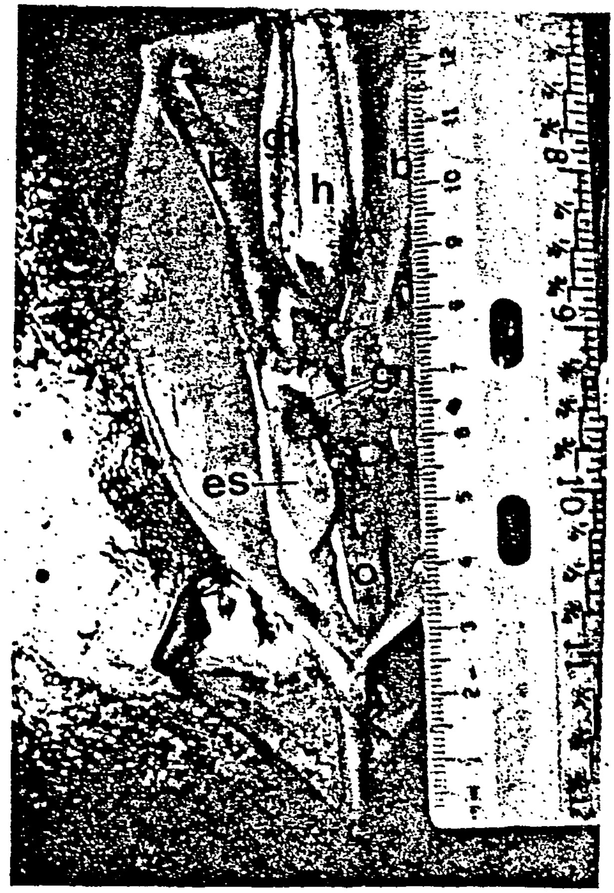
(cont.)



b.-Male Level IV. Bunches of spermatophores loose in the mantle

FIGURE 16

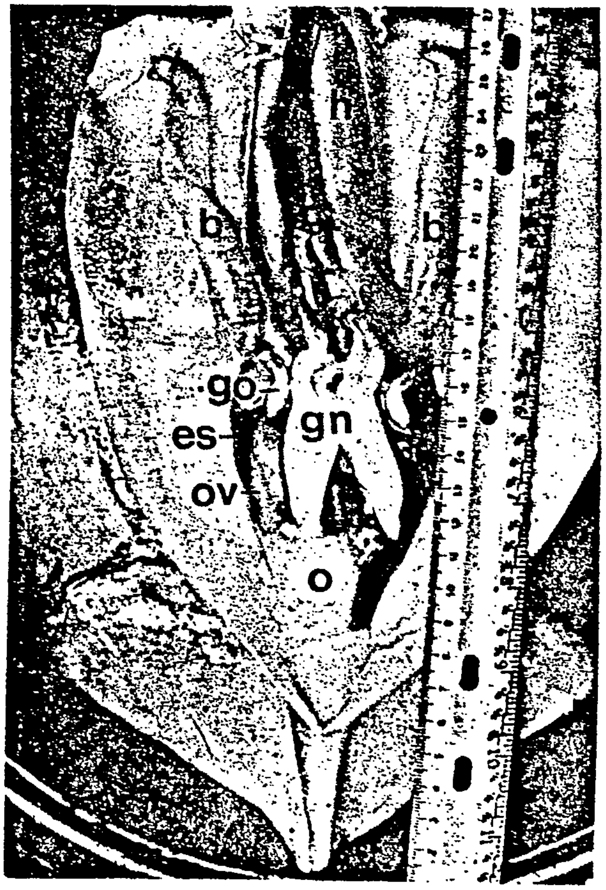
Levels of sexual maturity in the squid I. argentinus



a.-Female Level I. o,ovary; es,stomach; gn,nidamental glands; h,liver; gt,ink gland; b,gills.

FIGURE 16

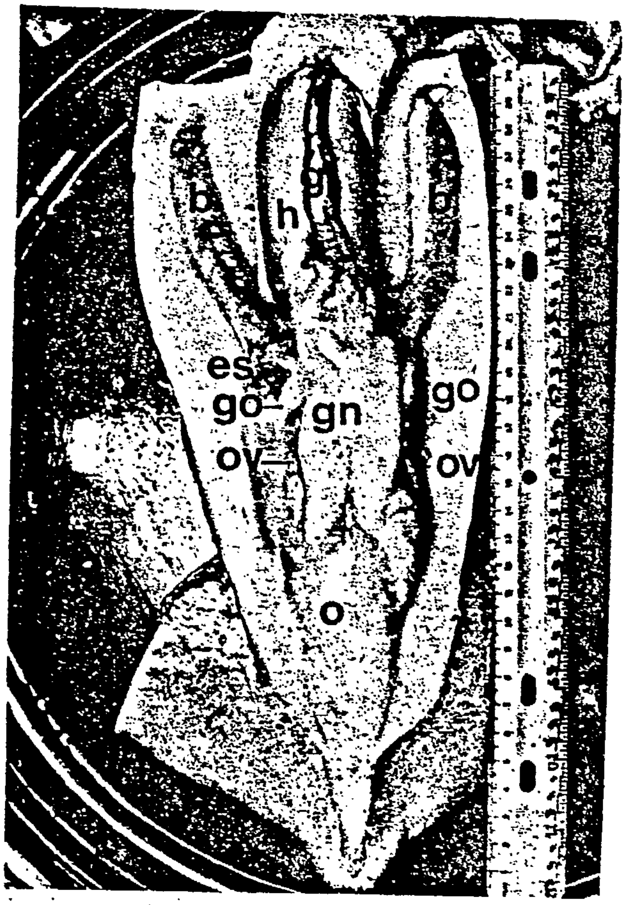
(cont.)



b.-Female Level 11. go,oviduct gland ov,oviduct; all other symbols are the same as in 16 a.

FIGURE 17

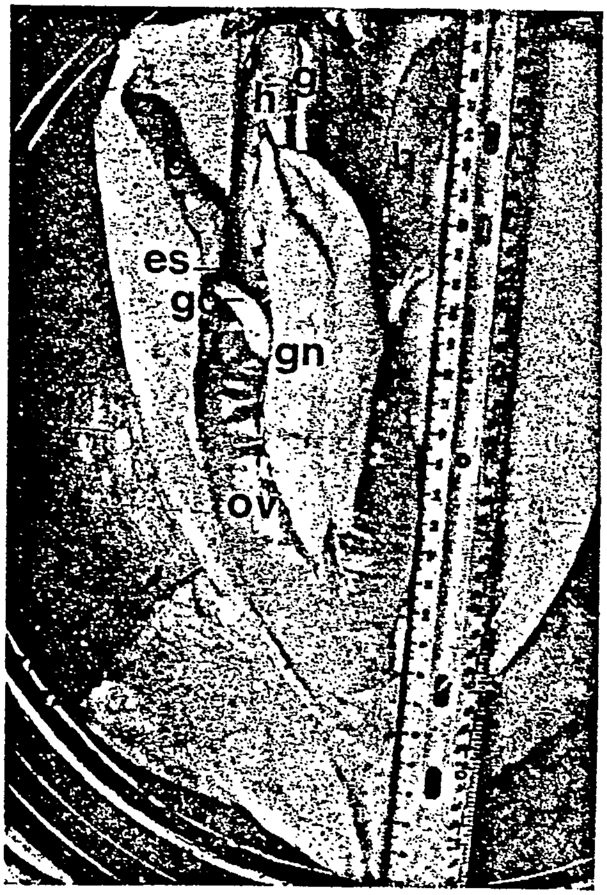
Levels of sexual maturity in the squid I. argentinus



a.- Female Level 111. Nidamental glands are more developed and there are eggs in the oviducts.

FIGURE 17

(cont.)



b.- Female Level IV. Note high development of the nidamental glands and dilated oviducts full of mature eggs.

The samples studied were composed as follows:

SEASON	MALES	FEMALES
	(N)	(N)
Winter	242	431
Spring	298	91

From this we may conclude the following:

In winter (Fig. 18) most males are maturing and a lesser proportion are ready for spawning. The females are different in this respect; they have begun maturation or are in the process of maturing. In other words, they are following behind (Fig. 19)

Towards the end of spring, many mature males ready for spawning are also found; while most of the females are still immature or beginning maturation (Figs. 20 and 21).

As for size (mantle length) at first maturation, the following figures were obtained:

SEASON	MALES	FEMALES
	cm	cm
Winter	18	19
Spring	14	17

Although 18 cm has been determined as the size at first maturation for males in winter, there is also the possibility that they begin maturation earlier than expected. The absence of immature males in these samples is probably due to problems of selectivity of the gear used, which does not allow us to be exact in this regard.

FIGURE 18

Squid *Illex argentinus*

Levels of sexual maturity
WINTER 1979
MALES

N = 242

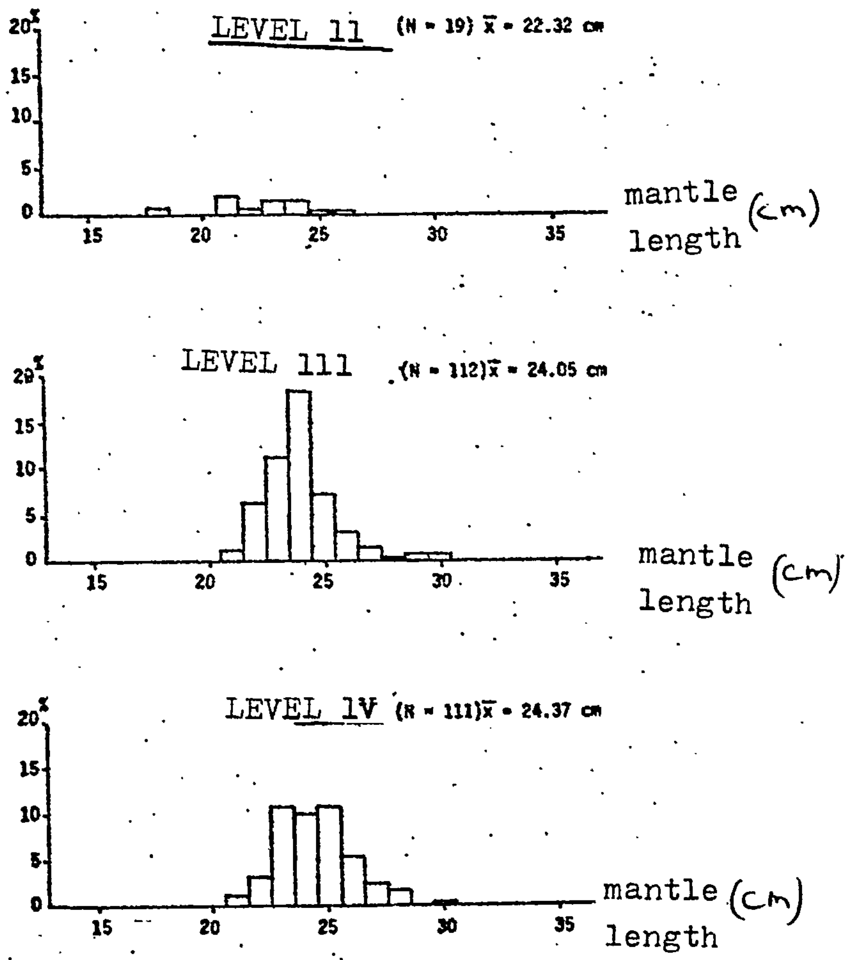


FIGURE 19

Squid *Illex argentinus*

Levels of sexual maturity

WINTER

FEMALES

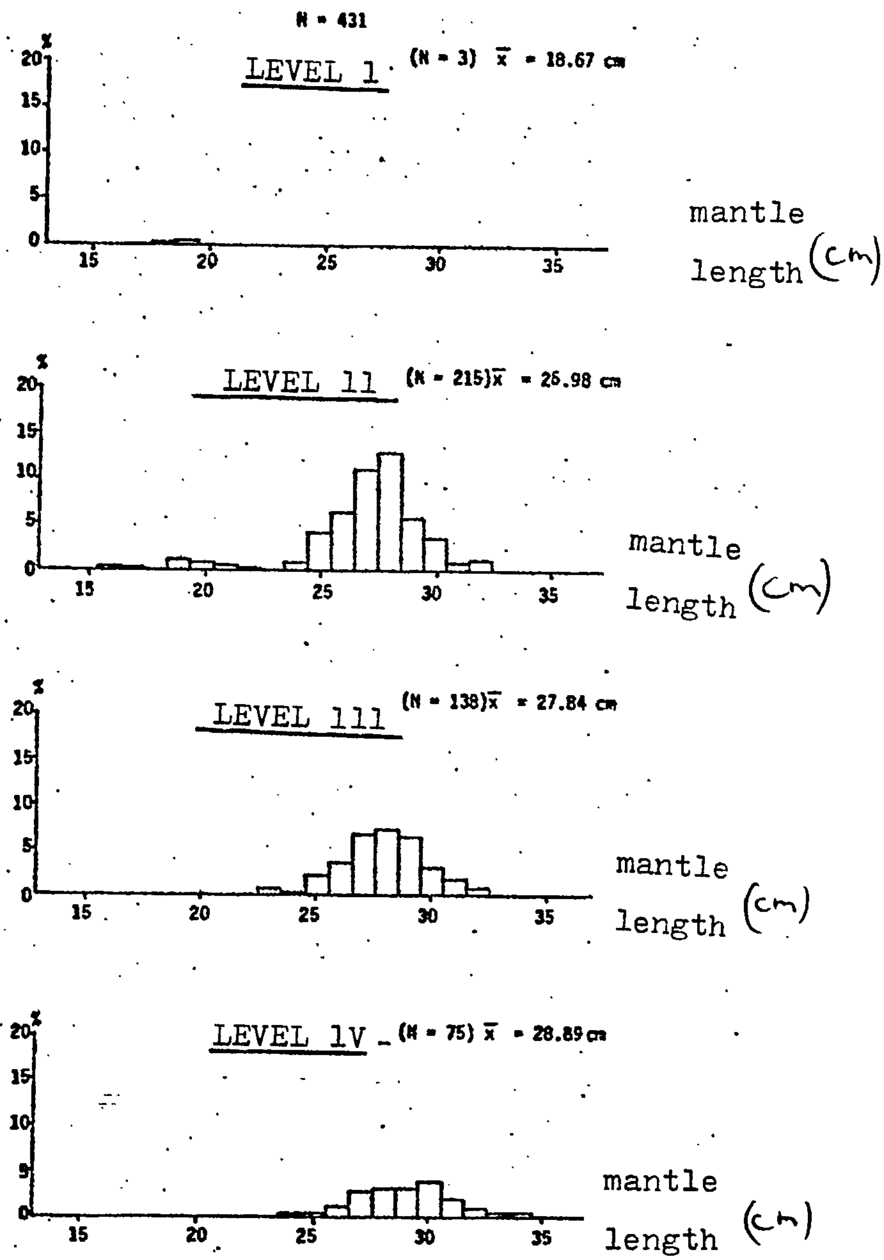


FIGURE 20

Squid *Illex argentinus*
Levels of sexual maturity
SPRING 1979 MALES

N = 298

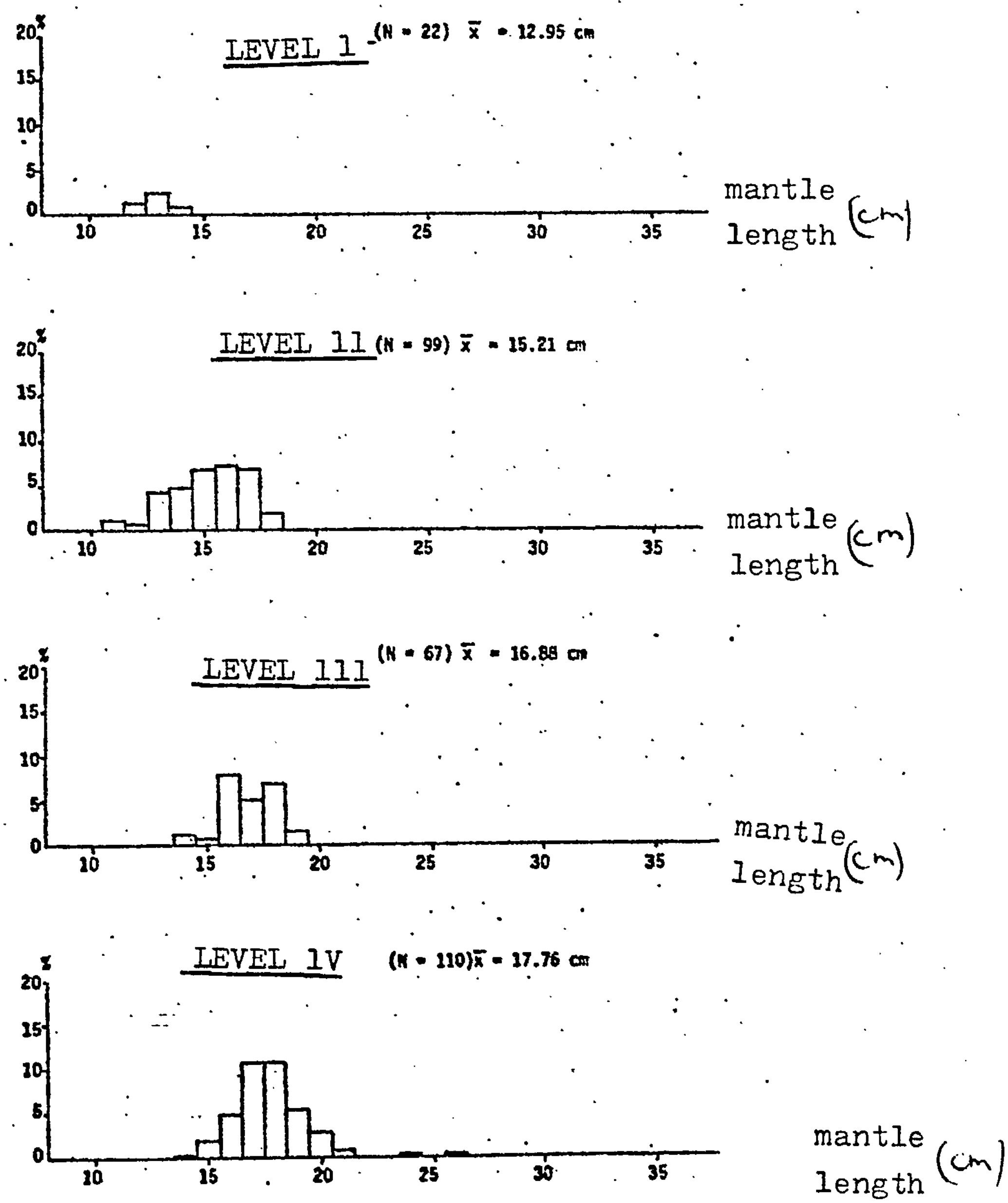


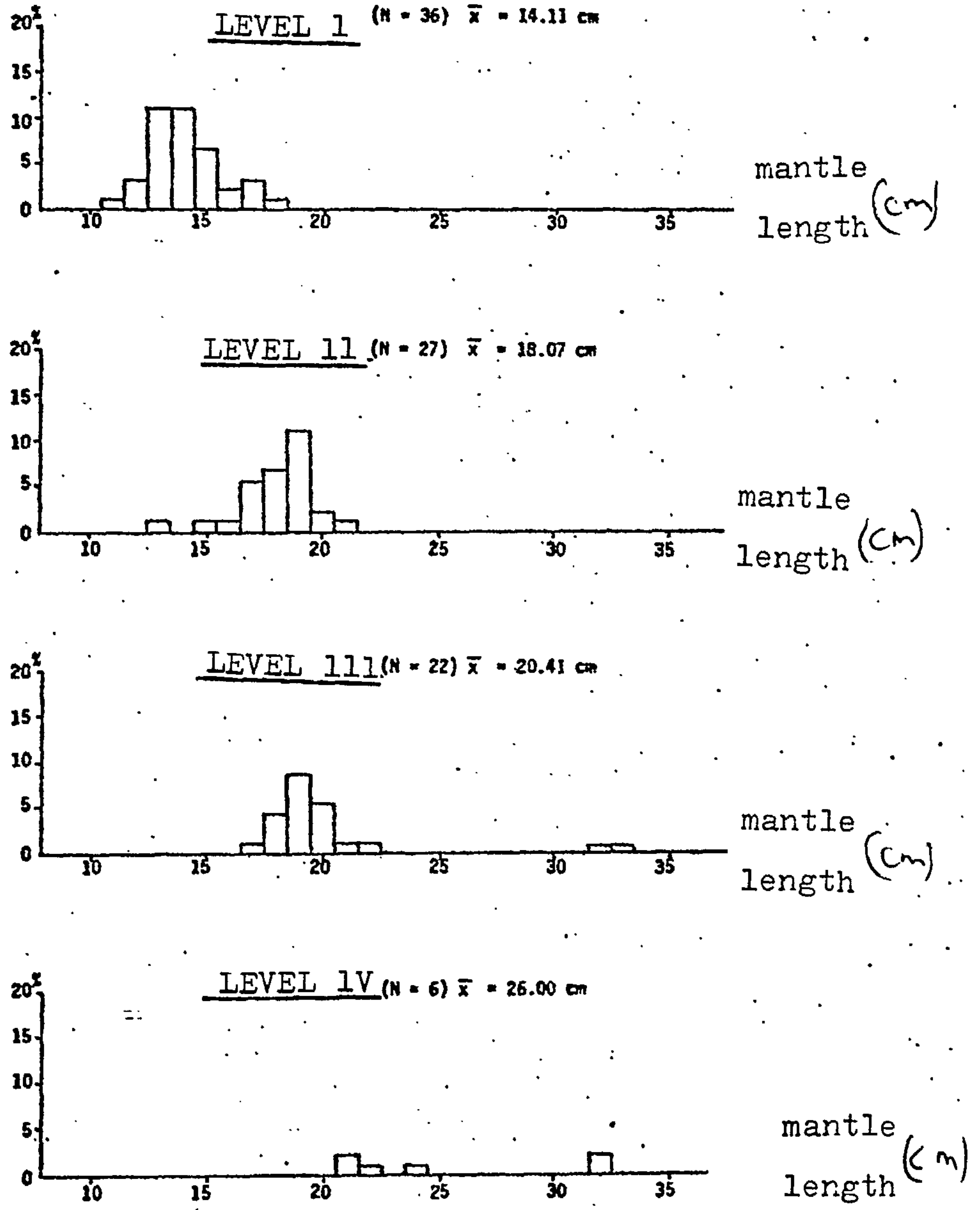
FIGURE 21

Squid Illex argentinus

Levels of sexual maturity

SPRING 1979

FEMALES



The sizes at spawning in each season are as follows:

SEASON	MALES cm	FEMALES cm
Winter	26	31
Spring	18	22

3.4.4 Factors Influencing Reproduction

The reproductive cycle in most marine species generally lasts no longer than normal, if external conditions are kept optimal.

Certain external factors can influence this cycle, for example, by triggering a response at the physiological level.

For squid the main external factors considered are light and temperature. Although both factors are interrelated so that they produce the same effect, they can, however, act separately under certain conditions.

The importance of light in the process of sexual maturity was proven by Wells and Wells (1959) for the octopus Octopus vulgaris. These authors showed that gonad maturation is determined by the secretion of the optic glands, which is controlled by a centre of the basal lobule of the brain. This is directly affected by the optic lobules and light.

On the other hand, Baggerman (1957) showed that a reduction in the duration of illumination from 16 to 8 hours immediately interrupts sexual activity during the spawning period.

As regards temperature, Mangold-Wirz (1963) found that the late maturation of Atlantic cephalopods is probably due to higher winter temperatures (compared with those in the Mediterranean). Richard (1966 - 67) indicates that growth and sexual maturity are accelerated by higher temperatures. According to this author, the effect of the length of illumination is as follows:

- Photoperiod of long nights favours ovary maturation in females. Males are relatively insensitive to this.
- Photoperiod of long days and/or high light intensity inhibits ovary maturation but induces spawning in mature females.

The photoperiod of long nights is characteristic of winter. It is in this season that female maturation occurs. This was reported by Mesnil (1976) for I. illecebrosus, and by the author for I. argentinus.

The photoperiod of long days is characteristic of summer, so that spawning in mature females can be observed in this season, as noted by Castellanos (1964) for the waters of Patagonia (Argentina).

3.5 Life Cycle of the I. argentinus

The following chart gives a summary of data on its distribution, size and sexual maturity for the seasons considered:

SEASON	GEOGRAPHICAL DISTRIBUTION Lat. to Lat.	ZONING	SIZE $\bar{X}$ (cm) males	SIZE $\bar{X}$ (cm) females	SEXUAL MATURITY males	SEXUAL MATURITY females
Winter	35°30'-38°30'S	Slope	24.00	28.89	III IV	II III
Spring	36°15'-39°00'S	Continental shelf	17.76	20.41	III	II

As may be seen, we find ourselves with two groups well defined in terms of their geographical distribution, zoning, size and sexual maturity. The differences observed can be explained in the following manner:

Large winter squid could remain in the deepest zones to complete their maturation, reproduce at the end of this season and at the beginning of spring. Maturation seems to be induced by the long night photoperiod.

Smaller sized squid (medium) at the end of spring are found in shallow waters with higher temperatures, where conditions for feeding and growth are more favourable. With the beginning of summer, the long day photoperiod stimulates spawning by mature female.

Based on the above considerations, the cycle suggest for I. argentinus is illustrated in figure 22.

3.6 Feeding of the Squid I. argentinus

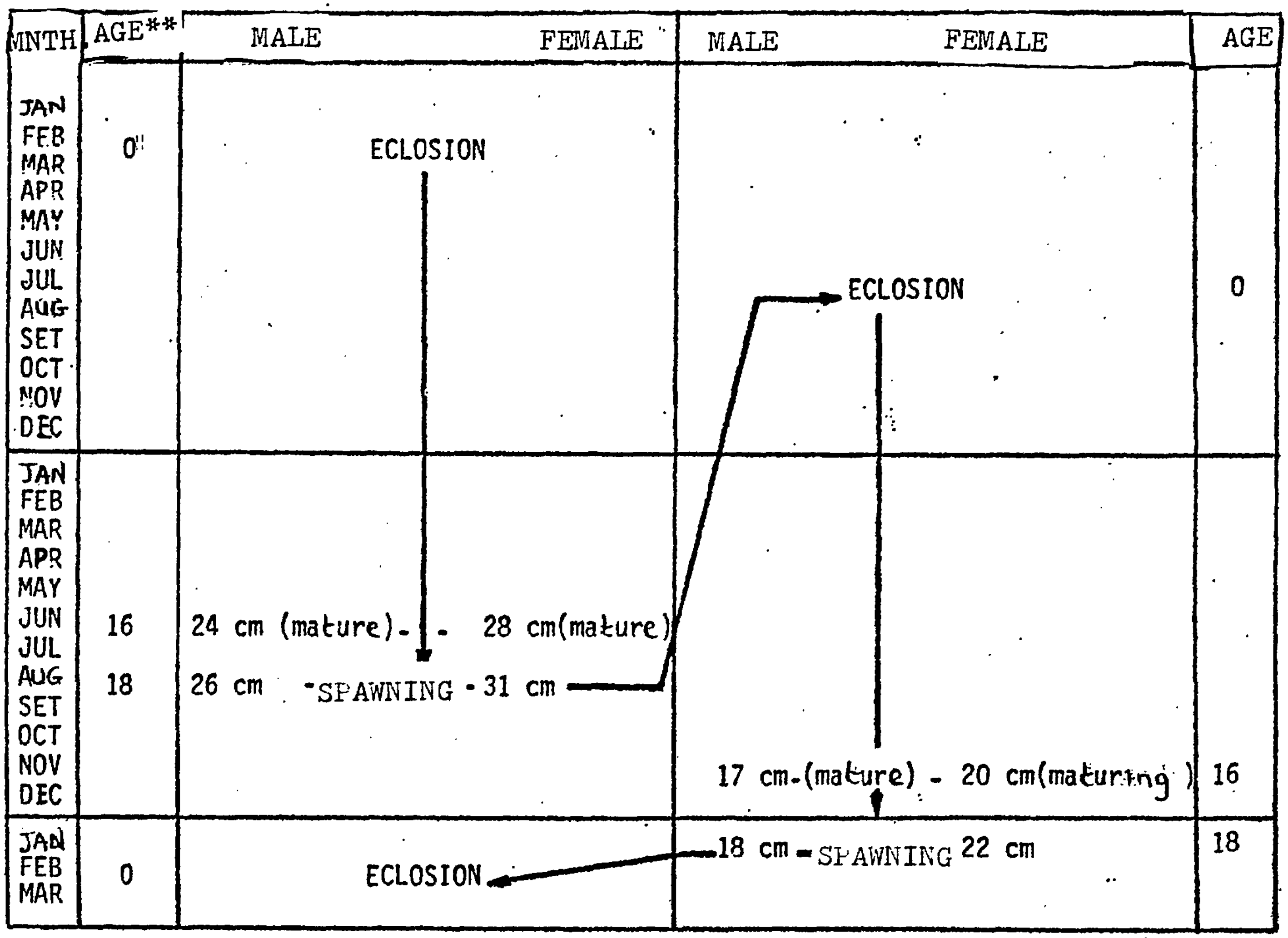
The squid I. argentinus is mainly carnivorous. The functional adaptations related to this diet are as follows: 8 arms and 2 tentacles armed with suckers which are used for catching and holding the prey; a digestive apparatus consisting of two jaws for grinding, in the form of a beak housed in a muscular buccal vestibule, a thin gullet and a stomach which has three parts: a smooth front part, a middle part for grinding with thick, muscular walls and a piloric rear part. The intestine ends anteriorly at the ink gland.

This species feeds on planktonic crustaceans: misidaceae, euphausiaceae, hiperidae, and peneidae; bony fish: Engraulidae (Castellanos, 1964), Mictophidae, Sciaenidae and Macrouridae (Klyuchnik and Zasypkina, 1972). Both report having observed cases of cannibalism which has been corroborated by this author on various occasions. According to Ennis and Collins (1978) the high incidence of cannibalism in I. Illecebrosus could be related to unfavourable feeding conditions.

As may be seen, the squid I. argentinus acts as a secondary,

FIGURE 22

Life cycle of *Illex argentinus*



** Age measured in months

tertiary and quaternary consumer. At the fourth level of the trophic chain, it acts as prey (hake, sharks, etc.) and as a competitor (with the hake) for the anchovy Engraulis anchoita).

3.7 Behaviour of the Squid I. argentinus

The study of certain aspects of the behaviour of this species is very important for Fisheries Biology. We refer to those which may explain phenomena related to population movement, such as shoal formation, and vertical and horizontal migrations.

3.7.1 Shoal Formation

Squid and fish are both marine animals which exhibit strong tendencies to shoal formation.

The shoal is usually structured so that each individual is found at a distance of two or three body lengths away from the next.

The specimens forming the shoal have a limited range of sizes (Fields, 1965; Hurley, 1976).

The size of the shoal may vary; in the Ommastrephes caroli, it becomes smaller as the length of the specimens increases (Clarke, 1966, in Arnold, 1979). However, during sexual intercourse and spawning in our species, we have observed that it forms large shoals which are estimated to contain between 20 and 30 tons. Similar observations have been made on Loligo opalescens; the difference being that the shoals are larger: 35 to 45 tons (Anon., 1978).

Shoal formation is also found to be related to feeding: Illex illecebrosus has been seen concentrated near large quantites of mictophidae (Milliman and Mannheim, 1968).

3.7.2 Vertical Migrations

Diurnal vertical migrations may be distinguished from seasonal vertical migrations by their size and the time of year in which they occur.

Diurnal vertical migrations are characterized by a cyclic movement which occurs at night from the bottom to the surface layers or to the surface itself.

These vertical movements may extend several hundred meters. Some species, such as Loligo vulgaris and Alloteuthis media are found on the surface itself (Mangold-Wirz, 1963), while I. argentinus, like other species of the same genus, is found at depths ranging from 20 to 30 m from the surface.

The diurnal or nychthemeral movements of this species are associated with nutrition. They are exploited commercially since the concentrations which they produce allow fishing to be carried out with squid nets or jigging machines. The use of this gear produces excellent yields; for example. 95% of squid caught in Japan (main world producer) are caught in this manner.

Seasonal vertical migrations are greater in scope; usually, the squid migrate towards coastal waters in spring and return to deeper waters in autumn. These migrations appear to be for two reasons: to reach deep water to spawn and to feed on the way down or to find their habitat.

In I. argentinus, it has been observed that during the winter individuals gradually mature and move in the Argentinian - Uruguayan common fishing zone from the continental shelf towards the slope, to depths of 450 m, so as to reproduce.

In spring, smaller immature and maturing specimens of this species have been found on the continental shelf of this zone at depths of 50 and 100 m.

3.7.3 Horizontal Migrations

Migrations in which the individuals travel large distances are horizontal or latitudinal migrations; these are generally parallel to the coast and run in both northerly and southerly directions.

Because of the location of the coasts and the continental slope in the common fishing zone, the horizontal movements of this species are from SW to NE and vice versa. These movements are related to the maintenance of the optimal environmental conditions of the species. This can be explained if we take into account that it tolerates reduced variations in salinity (stenohaline species) and in temperature (stenothermal species) and that it inhabits the cold waters of the Falklands current (Castellanos and Menni, 1968) the characteristics of which have been already established in 3.1.

3.7.4 Defensive Behaviour

As previously noted, the squid has several enemies, against which it has developed various forms of defence for its own survival. One of these consists of the ability to excrete a protective coloration. This is achieved by means of special cells which coat the surface of the body: the chromatophores.

This mechanism is controlled by the central nervous system which allows these cells to concentrate, diffuse or become superimposed at will by taking on the colour of the surrounding environment.

Another method consists of stretching a cloud of ink around its attacker, which the squid uses to enable it to escape. This product is secreted by the ink gland, the duct of which has its opening in the vicinity of the rectum (Fig. 14). The ink is expelled by the action of the musculature of the mantle and of the siphon.

In commercial fishing boats it has been possible to observe that after hauling in a large catch of squid, the deck and part of the catch remain stained with the ink expelled by these cephalopods.

BIBLIOGRAFIA

1. Abella, A., Arena, G., Nión, H. y Ríos, C. - Peces bentónicos del Río de la Plata y de la Zona Común de Pesca Argentino-Uruguaya, Mem. Semin. Ecol. Bent. y Sedim. de la Plat. Cont. Atl. Sur. UNESCO, Uruguay. :291-323, 1979.

2. Amaratunga, T. y Durward, R.D. - Standarization of data collection for the short-finned squid, Illex illecebrosus. ICNAF Selected Papers (5):37-41, 1979.

3. Ampola, V.G. - Squid - Its potential and status as a U.S. Food resource, Mar. Fish. Rev. 36 (12):28-32, 1974.

4. Anon. - Everything your wanted to know about Loligo opalescens... The Department of Fish and Game wanted to find our. Seahorse, 10 (2) 5. 1978.

5. Arnold, G.P. - Squid - A review of their biology & fisheries. Lab. Leafl., MAFF Direct. Fish. Res., Lowestoft (48) 37 pp., 1979.

6. Baggerman, B., - An experimental study on the timing of breeding and migration in the three-spined stickleback (Gasterosteus aculeatus L.). Arch. Néerl. Zool., 12(2):105-317, 21 figs. 1957.

7. Boltovskoy, E. - La zona de convergencia subtropical-subantártica en el Océano Atlántico, Part. Occidental, Serv. Hid. Nav. H-640, 1966.

8.a Castellanos, Z.A. de, - Una nueva especie de calamar argentino Ommastrephes argentinus sp. nov. (Mollusca, Cephalopoda), Neotrópica 6 (20):55-59, 1960.

b ________ Contribución al conocimiento biológico del calamar argentino Illex illecebrosus argentinus. Bol. Inst. Biol. Mar. Mar del Plata, (8):4-33, 1964.

c ________ Catálogo de los moluscos marinos bonaerenses, An. Com. Inv. Cient. (8):365 pp., 1970.

9. Castellanos, Z.A. de, y Menni, R.C. - Los cefalópodos de la expedición "Walther Herwing". Notas Com. Invest. Cient. Bs.As. 6 (2):1-31, 1968.

10. Datos y resultados de las campañas "Pesquería", Proyecto de Desarrollo Pesquero Argentino-FAO, Pub. No. 10-111 a 10-X, Series Informes Técnicos, 1968-1969.

11. Durward, R.D., Amaratunga, T. y O'Dor, R.K. - Maturation index and fecundity of female squid *Illex illecebrosus* (LeSueur, 1821), ICNAF Res. Bull. (14):67-72, 1979.

12. Durward, R.D., Vessey, E., O'Dor, R.K. y Amaratunga, T. - Reproduction in the squid *Illex illecebrosus*: First observation in captivity and implications for the life cycle, ICNAF Selected Papers (6): 7-13, 1980.

13. Ennis, G.P. y Collins, P.W.- Food and feeding of the short-finned squid, *Illex illecebrosus*, and long-finned squid, *Loligo pealei*, off Nova Scotia and New England, ICNAF, Selected Papers (5):25-29, 1979.

14. a Fields, W.C. - A preliminary report on the biology of the squid, *Loligo opalescens*, Calif. Fish. Game, 36 (4):366-377, 1950.

b __________ Structure, development, food relations, reproduction and life history of the squid, *Loligo opalescens* Berry, Fish. Bull. Calif. (131):108 pp, 1965.

15. Figueiras, A. y Sicardi, O. - Catálogo de los moluscos marinos del Uruguay (parte IX) Com. Soc. Malac. del Uruguay, 3 (26): 323-360, 1974.

16. Frost, N. y Thompson, H. - The squids, Ann. Rept. Newfoundland Fish. Res. Comm, 1 (4): 25-33, 1932.

17. Gulland, J.A. - The fish resources of the ocean, Fising News (Books) Ltd., London, 255 pp. 1972.

18. Hamabe, M., Kawakami, T., Watabe, Y., Okutani, T., e Ikeda, K. - Examen de los recursos de cefalópodos y su explotación por el Japón. FIIM/R170 Supl. 1 (Es):1-3, 1975.

19. a Hurley, N.A., - Feeding behaviour, food consumption, growth, and respiration of the squid *Loligo opalescens* raised in the laboratory. Fish.Bull.U.S., 74 (1):176-182, 1976.

b __________ School structure of the squid *Loligo opalescens*. Fish. Bull., U.S. 76 (2):433-442, 1978.

20. Klyuchnik, T.S. y Zasypkina, V.A. - Some data on argentine squid *Illex argentinus* Castellanos 1960. Tr. Atl. Nauchno-Issled Inst. Rvbn. Khoz. Okeanogr. (42):190-192, 1972.

21. Le Sueur, C.A. - Description of several new species of cuttlefish. J. Acad. Nat. Sci. Phila. (2):86-101, 1821.

22. Leta, H.R. - Observaciones sobre la ectocotilización en el calamar Illex argentinus (Castellanos, 1960) (Teuthoidea-Oegopsida) Res. Jorn. C. Nat.:17-18, 1980.

23. Lipiñski, M. - The place of squids in the biological and fishery structure of the world ocean, Squid Symposium held at Gdynia (Poland), Nat. Mar. Fish. Serv.: 4-10, 1973.

24. Mangold-Wirz, K. - Biologie des céphalopodes bentiques et nectoniques de la Mer Catalane, Lab. Arago, Université de Paris, 285 pp. 1963.

25. Mesnil, B. - Growth and life cycle of squid, Loligo pealei and Illex illecebrosus from the Northwest Atlantic, ICNAF Selected papers (2):55-69, 1977.

26. Milliman, J.D. y Manheim, F.T. - Observations in deep-scattering layers off Cape Hatteras, USA. Deep-Sea Res., 15:505-507, 1968.

27.a Richard, A. - Action de la température sur l'évolution génitale de Sepia officinalis. L. C.R. Acad. Sci., Paris, 263 (Serv. D): 1998-2001, 1966.

b ——— Role de la photoperiode dans le determinisme de la maturation génitale femelle du céphalopode Sepia officinalis L., C.R. Adad. Sci. Paris. 264 (Ser. D): 1315-1318, 1967.

28. Roper, C.F., Lu, C.C. y Mangold, K. - A new species of Illex from the Western Atlantic and distributional aspects of other Illex species (Cephalopoda:Oegopsida), Proc. Biol. Soc. (82):295-322, 1969.

29. Sissenwine, M.P. y Tibbetts, A.M. - Simulating the effect of fishing on squid (Loligo and Illex) populations of the Northeastern United States. ICNAF Selected Papers (2):71-84, 1977.

30.a Squires, H.J. - Squid, Illex illecebrosus (Le Sueur), in the Newfoundland Fishing Area, J. Fish. Res. Bd. Canada, 14 (5): 693-728, 1957.

b ——— Growth and hipothetical age of the Newfoundland bait squid Illex illecebrosus, J. Fish. Res. Bd. Canada, 24 (6):1209-1217, 1967.

31. Summers, W.C. - Winter population of Loligo pealei in the Mid-Atlantic Bight. Biol. Bull., 137:202-216, 1969.

32. Thomsen, H. - Masas de agua características del Océano Atlántico, parte Sudoeste. Serv. Hid. Nav. H-632, 1962.

33. Vinogradov, V.I. y Noskov, A.S. - Feeding of short-finned squid, *Illex illecebrosus* and long-finned squid, *Loligo pealei*, off Nova Scotia and New England, ICNAF Selected Papers, (5):31-36, 1979

34. Voss, G.L. - Cephalopod resources of the world. FIRM/C149, 75 pp. 1973.

35. Wells, J.M. y Wells, J. - Hormonalcontrol in sexual maturity in Octopus Journ. Exp. Biol., 36 (1):1-33, 13 figs., 1959.

FOREIGN BIBLIOGRAPHIC ITEMS

1. Benthonic fishes of the Plate River and the Argentine - Uruguay Common Fishing Zone.

7. The subtropical-subantartic zone of covergence in the Atlantic Ocean.

8a A new species of Argentine squid Ommastrephes argentinus n. sp. (Molusca, Cephalopoda)

b Contribution to the biological knowledge of the Argentine squid Illex illecebrosus argentinus

c Catalogue of Argentine marine mollusks.

9. The cephalopods of the Walther Herwing expedition.

10. Data and results of the "Fisheries" campaign, Argentine-FAO Fisheries Development Project.

15. Catalogue of marine mollusks of Uruguay.

18. Study of cephalopod resources and their exploitation by Japan.

22. Observations on ectocotylization in the squid Illex argentinus (Castellanos 1960) (Teuthoidea-Oegopsida)

32. Water masses characteristic of the Atlantic Ocean, Southwest part.