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DISTRIBUTION AND ABUNDANCE OF POST-LARVAE AND JUVENILES OF THE PATAGONIAN SPRAT, *Sprattus fuegensis*, AND RELATED HYDROGRAPHIC CONDITIONS

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A large shoal of *Sprattus fuegensis* stranded in the port of Ushuaia.

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ABSTRACT

This paper reports on the first pelagic survey on the Southern Patagonian shelf. As a result of a joint Argentine-Russian cruise on board the R/V "Dmitry Stefanov" carried out in the early autumn of 1992, a major nursery ground of the *Sprattus fuegensis* was located in the coastal area off Santa Cruz and the Fireland.

Forty-nine ichthyoplankton stations along 14 transects and 7 intertransects were occupied. Biological samples were taken with and IKMT equipped with a net sounder and flowmeter for the determination of the sampler depth and distance travelled. Hydrological data were obtained in 78 CTD stations. Meteorological observations were made concurrently. Real time SST images from NOAA satellites were received on board, twice per day, cloudiness permitting. Positive stations lay mostly within the 50-m depth contour. Of all coastal stations 71% were positive for sprat post-larvae and juveniles. The density and size of the specimens collected increased southwards. Median values of the juvenile distribution varied from 23.6 mm SL to the north of the study region to 38.5 mm for stations at 54 °S. Highest biomass densities (> 2.8 t/n mi^2) were found to the south of Magellan strait, corresponding to IKMT densities of over 1000 specimens per haul. Other important components of the Isaacs-Kidd collections were the post-larval and juvenile stages of *Sebastes oculatus* and *Patagonotothen tessellata*.

In order to obtain a higher resolution view of the distribution and abundance of juvenile sprat, the area was simultaneously surveyed using an EK-400 echo-sounder with a SIORS echo integrator. A significant correlation ($r=0.95$; $\alpha<0.01$) was obtained between acoustically derived abundance estimates and those resulting from the IKMT sampling.

The large amount of post-larvae and juveniles collected and the very high values of echointegration registered particularly in the area of the strait and channels, are indicative of a major nursery ground of the species in the Patagonian coast. Post-larval and early juvenile production in the area was estimated at over 1.5 x 10^9 individuals. Differences in the diel patterns of the vertical migration of adult and early juveniles are described.

Growth increments in otoliths were used to estimate the age of sprat post-larvae and juveniles. A Laird-Gompertz model was fitted to the length-at-age data. The spawning periodicity of the species was determined by examining the temporal distribution of birthdates from otolith-aged specimens. There was indication of a major spawning peak on late December, and a secondary one on mid-January. Available information on the reproduction and early life history of the species is analyzed in view of the obtained results. The importance of the Magellan strait low-salinity water outflow for egg dispersal and larval retention is discussed.

INTRODUCTION

The Patagonian sprat, *Sprattus fuegensis*, is frequently referred to as the largest potential pelagic resource on the austral extreme of the sea shelf off Argentina. The existence of two different populations, one on the Patagonian coast and another on the coast of Malvinas, has been postulated on the basis of differences in growth parameters (Gru & Cousseau, 1982) and some morphometric characteristics (Cousseau, 1982).

Large shoals of adults of the species stranded on the Patagonian coasts or entering the coves, inlets and even the ports of Ushuaia (Frickart, 1942) and Port Stanley (Norman, 1936) have been frequently reported in the course of this century. These events seem to occur at a mesoscale spatial pattern. Lloris & Rucabado (1991) report on two recent simultaneous arrivals of several hundred tons of fish occurring at locations distant 300 km.

Notwithstanding, the occurrence of sprat in shelf waters has only occasionally been reported in the exploratory cruises carried out in the area, mostly directed to the detection and assessment of demersal resources [see Cousseau (1982) for a review]. Additional information is given by Gru & Cousseau (1982) who refer to some samples collected in the coastal region of the Patagonian Province of Santa Cruz, by small purse seiners of the artisanal coastal fleet.

In contrast with the erratic presence of adults in our surveys, planktonic collections show that larvae of the species are a major component of the icthyoplankton assemblage of the austral extreme of the Argentine sea during summer (Ciechomski et al., 1973, 1981).

This paper reports on the first pelagic survey on the Southern Patagonian shelf, a joint Argentine-Russian cruise on board the R/V "Dmitry Stefanov" carried out in the early autumn of 1992, with the general objective of assessing the population of sprat inhabiting the coasts off Patagonia.

The study region.

The Argentine shelf is the largest in the southern hemisphere with a total area of about 1,000,000 km^2 and a very smooth depth gradient (00°02'30" on the average) in contrast with a very steep continental slope of up to 4°. The width and mean depth of the continental shelf increase southwards. The average distance from shore to the 180m-depth reaches 800 km in the southern Patagonian region. Mean depth off the Rio de la Plata is less than 18m, gradually increasing to 90m to the south of 45°S.

Waters over the Argentine Shelf are predominantly of Subantarctic origin. South of 45°S (Fig. 1) shelf waters are formed as a result of mixing between Subantarctic waters of the Malvinas (=Falkland) Current flowing northwards along the continental slope and of the Magellan Strait run-off, a lower salinity water tongue (Southern Coastal Water) flowing along the Patagonian coast to the San Jorge Gulf (Bianchi et al., 1982). The three water masses are recognized by their salinity ranges. Malvinas waters are more haline with ranges between 33.8-34.2 ppt. Coastal waters show values below 33.2 ppt. Shelf waters salinity values range between those two extremes. Water circulation in the Argentine Shelf has been estimated several times by means of theoretical models based on surface wind stress and horizontal density gradients (Zyryanov & Severov, 1979; Lusquiños & Schrott, 1983; Forbes & Garrafo, 1988). Surface velocities show in all cases a NNE orientation and magnitudes ranging between 10 and 20 cm/s. The progression of bimonthly distributions of surface Ekman transport presented by Bakun and Parrish (1990), show that near the coast of Patagonia the ocean surface layer transport responding to the seasonal variability of wind stress is generally directed toward shore, with a northernly orientation.

Mesoscale frontal zones are extremely important features of Argentine shelf, having very strong localized effect on hydrography and fish spawning distributions. In the Patagonian region they include: a) a permanent shelf break front near the 200 isobath in the boundary between outer shelf and slope; b) tidal fronts of varying intensities occurring off Valdés Peninsula and southwards from early spring to autumn; c) a thermo-haline front associated with intrusion of southern coastal water to the south of San Jorge Gulf; and d) the presence of anticyclonic ring current around the Malvinas Islands (Severov, 1990).

Fig. 1-A.

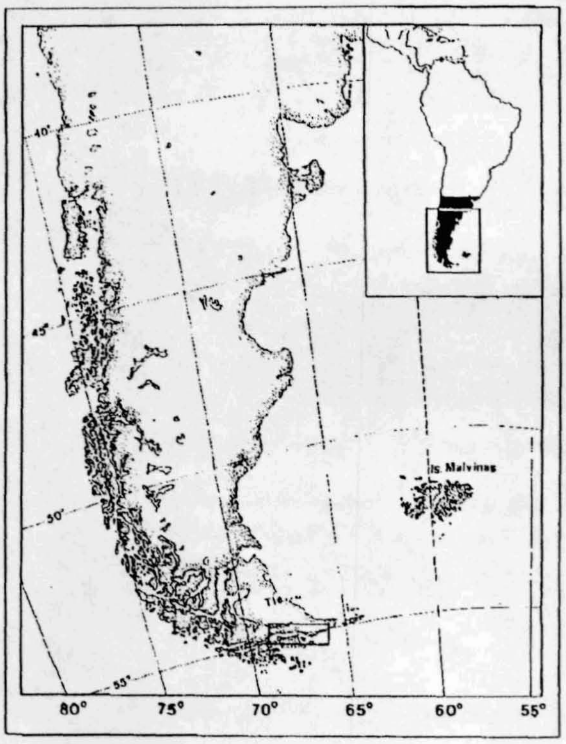


Fig. 1-B.

Fig. 1-C.

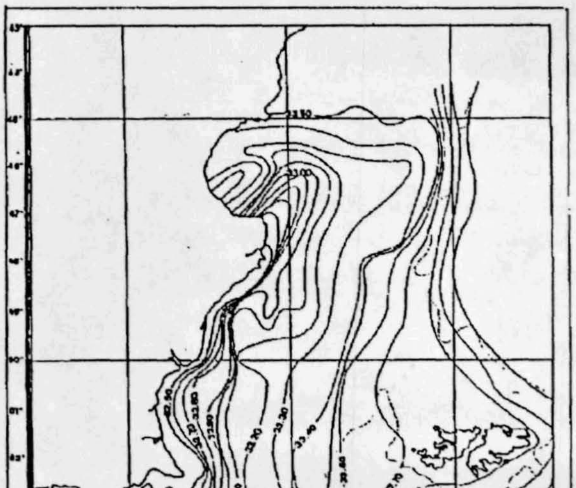


Fig. 1. A. Location of the study area.
B. Water masses and circulation patterns on the southern Patagonian shelf (From Hart, 1946).
C. Surface salinity distribution in early autumn (From Krepper & Rivas, 1979)

Relatively high values of nitrates and chlorophyll-a are found throughout the year. A peak in nitrates concentration (2.5-14.5 μM) is followed by a single phytoplankton maximum in spring and summer (2.3 - 2.7 mg/m3). As regards primary production values attained in the region around Malvinas Islands (1.3gC/m^2/day) are among the highest reported for the Argentine Sea (Angelescu & Prenski, 1987). High values of zooplankton biomass are attained during summer time with densities between 101-1000 mm3/m3 over most of the continental shelf to the south of 48°S with density maxima to the north of Malvinas Islands (Ciechomski & Sánchez, 1983).

Reproduction and early life history of the Patagonian sprat.

Early developmental stages of the species have been described by Ciechomski (1971) and Cassia & Lasta (unpubl. manusc.).

Available information on the spawning activity of the Patagonian sprat is at present fragmentary as neither the coastal regions off Patagonia nor those off Malvinas have been adequately sampled during spring. Ripe females have been collected off the North and West coasts of Malvinas during late September. Shirokova (1978) studied the maturity cycle of sprat adults off Malvinas. Her results show that the species is a partial spawner, with a 4-month reproductive season from September to December. Planktonic eggs of the sprat have been collected over a much shorter time span, (12 - 29 October) during the spawning seasons of 1969 and 1978. In both cases higher concentrations (about 1000 eggs/10 m^2) were obtained in an area to the North of Malvinas Islands (Ciechomski, 1971; Ciechomski et al., 1981).

Conversely, sprat larvae are abundant through out the summer showing and extended spatial distribution over the Patagonian shelf. According to Ciechomski et al. (1981) sprat larvae comprise 57% of all larvae collected in the area in summer. The distribution and abundance of sprat larvae, sizes and month combined, have been mapped by Ciechomski et al. (1975 and 1981).

In addition to these reports, an examination of the icthyoplankton collections of the INIDEP, carried out during the preparatory stages of this project, showed that sprat larvae and juveniles have been obtained in all exploratory cruises surveying the area during late spring, summer and early autumn (April, 1969; October-November 1969; January, 1970; December-January 1973/4; December/March 1978/9; January 1987; February 1992). These surveys covered the shelf from the coast to the 200-m depth contour extending southwards to Burdwood's Bank, some 100 Km to the south of Malvinas. A chronological arrangement of this information is presented in Figures 2.

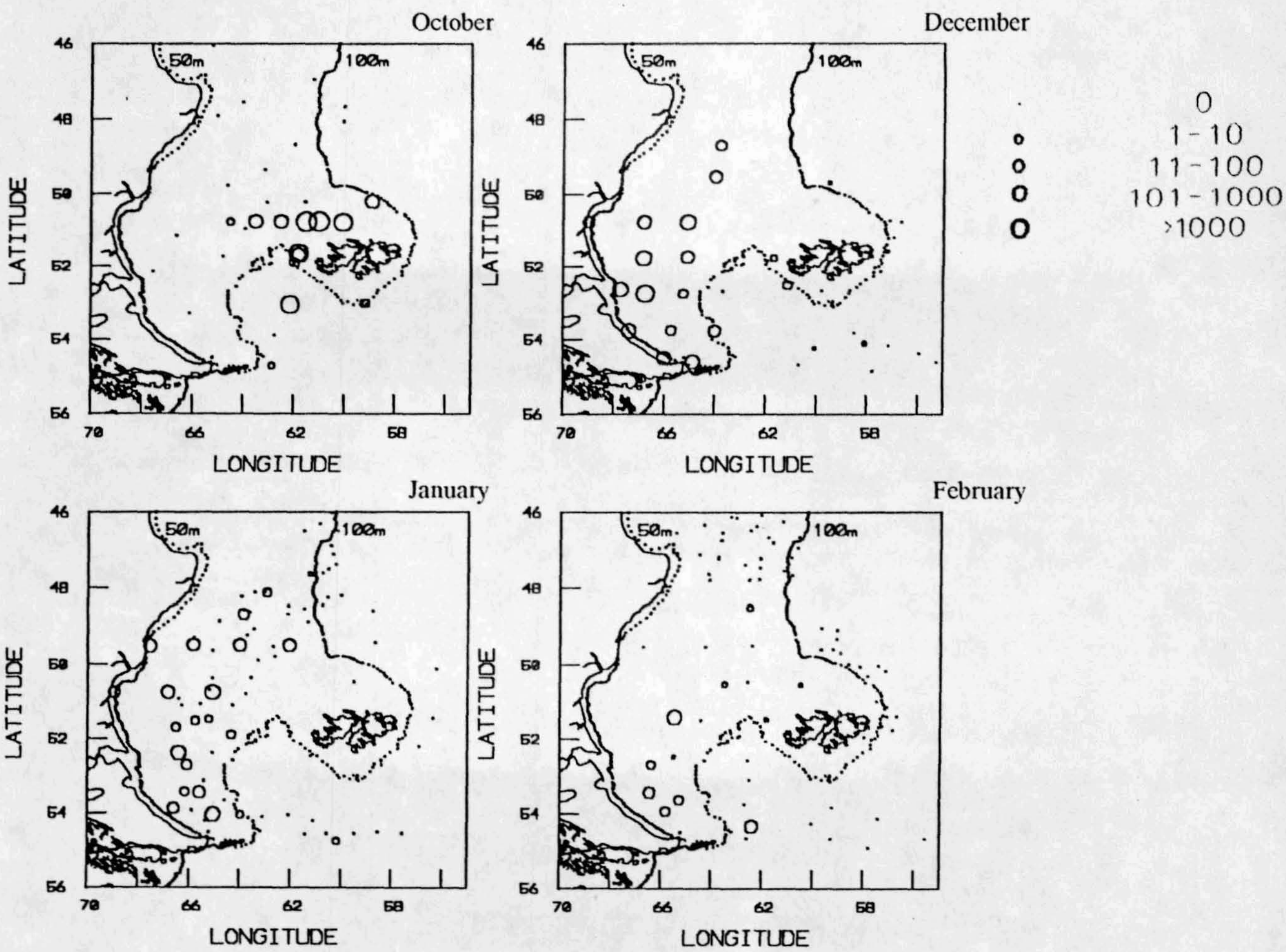


Fig. 2. Spatial and temporal distributions of Patagonian sprat (*Sprattus fuegensis*) eggs, larvae and juveniles (all sizes combined), on the southern Patagonian shelf. All values are in numbers per 10 m^2 of water surface.

Sprat larvae were particularly abundant in December and January. Positive stations were observed in the straits and channels and such distant locations as Burdwood's Bank. *Sprattus fuegensis* larvae were collected between 47-55°S; the main concentrations were situated between 50-54.30°S, with an imaginary axis along the 100-m isobath off the Argentine coast. In February larger densities are observed to the south of 52° S also along the 100-m depth contour, although no coastal sampling off Malvinas or Patagonia was carried out during this month.

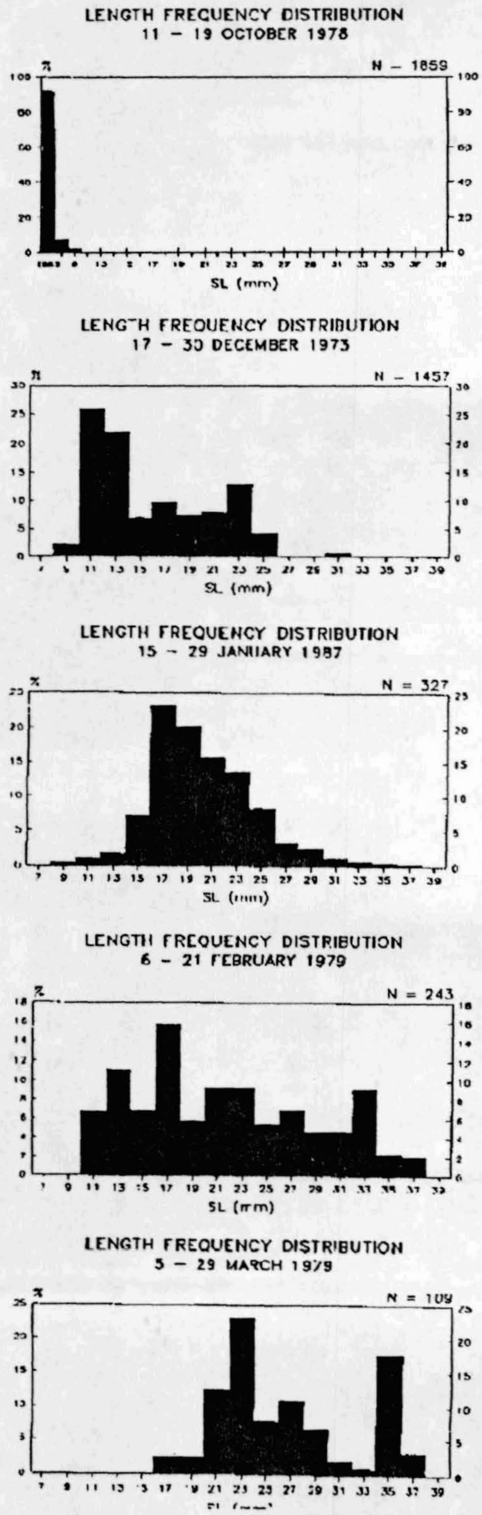


Fig.3. Length frequency histograms of Patagonian sprat larvae and juveniles, grouped by month. Data derived from 5 exploratory cruises carried out from 1973 to 1987.

The length frequency distributions of the specimens collected is presented in Figure 3. Larvae collected in October were in all cases smaller than 10 mm SL. Very few larvae were collected in November, with sizes ranging from 7-16 mm SL. In December the sizes of collected larvae ranged mostly from 8 to 26 mm SL, with peak in 11 mm. In January larvae 9 to 37 mm have been obtained, over 23% of which were 17 mm SL. Larvae from the February collections ranged from 11 to 37 mm SL with peak also in 17 mm SL. In March, the range is also very wide, from 16 to 38 mm SL, but the distribution shows a marked peak (>22%) in the 23 mm size category.

Smaller larvae (6-9 mm SL) were present from October to January. The 10-14 mm SL size range was found from November to February. Larger size groups were found from December to March. Metamorphosing juveniles (>35mm SL) were first observed in the January collections, and were present throughout the summer till April. The presence of these larger-sized specimens in our samples must be considered incidental, as collections were made with Bongo and Nackthai samplers, which are not efficient for larvae larger than 20 mm SL.

On the basis of this background information, and taking into consideration the date of the cruise, our specific objective was to locate and assess the nursery grounds of the sprat in the coasts off Patagonia. The wide larval size-ranges encountered during the summer months, may be indicative of a more protracted spawning season than could be deduced from reports on planktonic eggs and seemed to be in closer agreement with the period reported by Shirokova (1978). To check this hypothesis we planned to obtain estimates of the daily growth of post-larvae and juveniles in the field, and back-calculate the duration of the reproductive period, from the frequency distribution of birthdates during the spawning season. Other objectives of this study were to gain information on the transport routes of sprat post-larvae in the area, on their distribution in the water column and on their diel patterns of migration.

MATERIAL AND METHODS

The survey was conducted between 23 March and 10 April 1992, in the coastal area off Patagonia from 47°20'S to 54°30'S. Before delimiting the eastern border of the sampling area, an acoustic survey was conducted along the shelf from Ushuaia to the southern extreme of Gulf San Jorge.

Hydrological data were obtained in 78 CTD stations distributed along 14 transects. Distance between adjacent stations was 25 miles. Meteorological observations were made concurrently. Real time SST images from NOAA satellites were received on board, twice per day, cloudiness permitting, with a SU-8 FURUNO receiver. Maximum resolving ability accounted for was 2 Km2.

In order to obtain a higher resolution view of the distribution and abundance of juvenile sprat, the area was simultaneously surveyed using an EK-400 echo-sounder with a SIORS echo integrator.

Table 1. Parameters of the acoustic system used during the cruise.

Echosounder	:	SIMRAD EK400 (ES400 transmitter).
Echointegrator	:	SIORS
Transducer	:	ES38
Frequency	:	38kHz
Pulse length	:	1ms
Attenuator	:	10dB
Band-width	:	3.3kHz
SL+VR	:	131.5dB
Instrument constant (CI)	:	-57.6dB

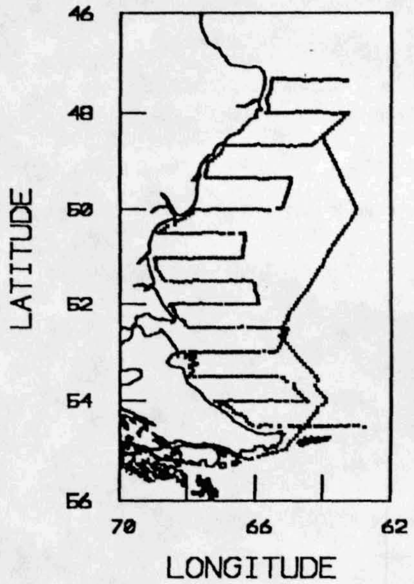


Fig. 4. Survey acoustic trackline followed during the cruise of R/V Dmitry Stefanov, 21 March - 14 April 1992.

Acoustic sampling was carried out along the trackline shown in Figure 4. The echosignal from the calibrated output of a 38 kHz scientific echosounder, was processed in real time with a digital echointegrator. The echointegration averaging interval was 5 n mi. Echosounder calibration was performed before cruise and according to the centered sphere method with standard targets (Foote and MacLennan, 1983; Foote el al., 1987). The scaling factor of the echointegrator was included together with the echosounder parameters into an instrument constant (Dalen and Nakken, 1983). The characteristics of the acoustic system are given in Table 1.

In order to obtain fish densities per unit of volume and per unit of area, the echointegrator outputs were expressed in terms of volume backscattering coefficient (s_v) (Clay and Medwin, 1977) and column backscattering coefficient normalized per squared nautical mille (s_a) (Dalen and Nakken, 1983; Foote et al., 1991). Conversion of scattering coefficient values or acoustic densities to fish densities was carried out by using a target strenght model derived from clupeoids data, including *Sprattus sprattus* (Foote, 1987):

$$TS = 20 \log_{10} L - 71.9 \text{ dB}$$

where:
TS= fish acoustic target strength, in dB.
L = fish total length, in cm.

The TS values obtained from this model are also in agreement with other in situ measurements for sprat (Degnbol et al., 1985).

Forty-nine ichthyoplankton stations along 14 transects and 7 intertransects were occupied from March 28 to April 9, 1992. Distance between the three stations (coastal, central and offshore) on each transect was 50 n mi. In coastal intertransects, one station was occupied at half way between adjacent transects (Fig. 5).

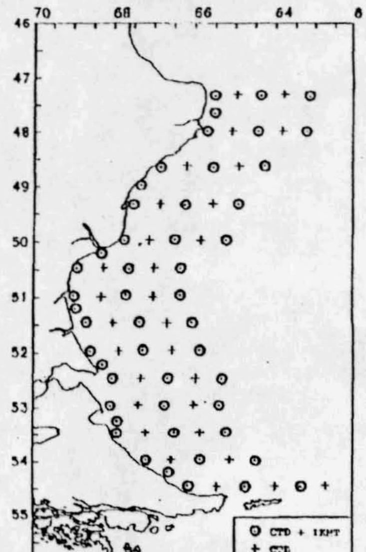


Fig. 5. Oceanographic and IKMT stations occupied during the cruise of R/V Dmitry Stefanov, 21 March - 14 April 1992.

Sampling of post-larvae and early juveniles was carried out by means of an Isaacs-Kidd midwater trawl. An echo-sounder for gear depth determination, and a flowmeter for estimation of distance travelled, were mounted on the sampler. IK tows were made obliquely through the water column from bottom to surface, except in stations where bottom depth was below 40 m. In these shallow stations IK tows were made in equal stepped intervals (distance between steps 10m, duration of the horizontal trawl 5 min.). Samples were preserved in 5% buffered formalin. Sprat specimens of the whole size-range collected were sorted out and kept in alcohol (96 % ethanol) for age determination.

In the laboratory specimens were sorted out and their standard and total lengths were measured to the lowest mm. To convert this data to real size the equation of Theilacker (1980) was used. In order to provide some adjustement of the data for daytime avoidance of the net, ratios of night to day abundances were calculated for the 1-mm length classes that were derived from the estimates of mean density. Post-larvae and juveniles (N=175) were washed in distilled water and weighed with precision of 0.1 mg.

In total 115 alcohol preserved specimens were dissected and the sagitta pair of otoliths extracted for age determination. At a first stage otoliths were read with optical microscope using transmitted light under 1000 X magnification. Otoliths were mounted in Pro-Texx mounting medium. Visibility of microstructures was enhanced after treatment with 3M polishing paper (10 μm).

Larval production at age was estimated by dividing the abundance of each size group by the time spent in the size category. Duration of each size category was the inverse of the instantaneous growth rate (IGR) for the category, which in turn was obtained from the derivative of the growth curve. The Laird Gompertz growth model (Zweifel and Lasker, 1976) was used to describe sprat post-larval and early juvenile growth. The model may be formulated as:

$$SL(t) = L_0 \exp\{G[1-\exp(-\alpha t)]\}$$

where SL is standard length and t is number of daily increments.
L_0= length at t = 0;
$G = A_0/\alpha$
A_0= specific growth rate at t=0; and
α= rate of exponential decay

Instant growth rate for size category LSi, is given by

$$IGR_{LSi} = \alpha\, LS\, [\ln (LSi/Lo) - G]$$

Duration of size class was estimated as:

$$LSi = 1/IGR_{LSi}$$

The duration of the embryonic and yolk-sac stages were estimated from results reported, respectively, by Thompson & Nichols (1980) and Alshuth (1988), for *Sprattus sprattus*.

Time at hatching was estimated by the equation:

$$t(h) = -1.259 \ln (T) + 7.509$$

where t(h) is time in hours and T is temperature (oC). Duration of the yolk sac stage was assumed to be six days.

Mean density of early juveniles caught by the IKMT was calculated applying the minimum variance unbiased estimator of the Δ-distribution (Aitchison & Brown, 1957).

The classic allometry equation was used to describe the increase in wet weight with length. Age/Length and Weight/Length models were fitted by Marquardt's algorithm for non linear least squares regression.

RESULTS

The Physical Setting.

Meteorological conditions during the surveyed period were defined by the interaction and reciprocal location of the South American pressure maximum and cyclones coming from the Drake Strait. From March 23 to April 2 the area was influenced by a crest of the South Atlantic anticyclone. As a result, moderate north and north-west winds prevailed. During this period calm weather and fog were recorded. From April 3 to April 9 cyclonic activity intensified, and storm winds were registered.

Intensity of zonal western air mass transport in the Southwest Atlantic was on the whole close to the long-time annual mean, whereas southern transport was a little below average. Air temperature and pressure ranged from 8.2-16°C and 1009.8-1027.0 mb, respectively. In all stations daily means of air temperature over the surveyed area exceeded sea surface temperature.

Fig. 6-A. Fig. 6-B.

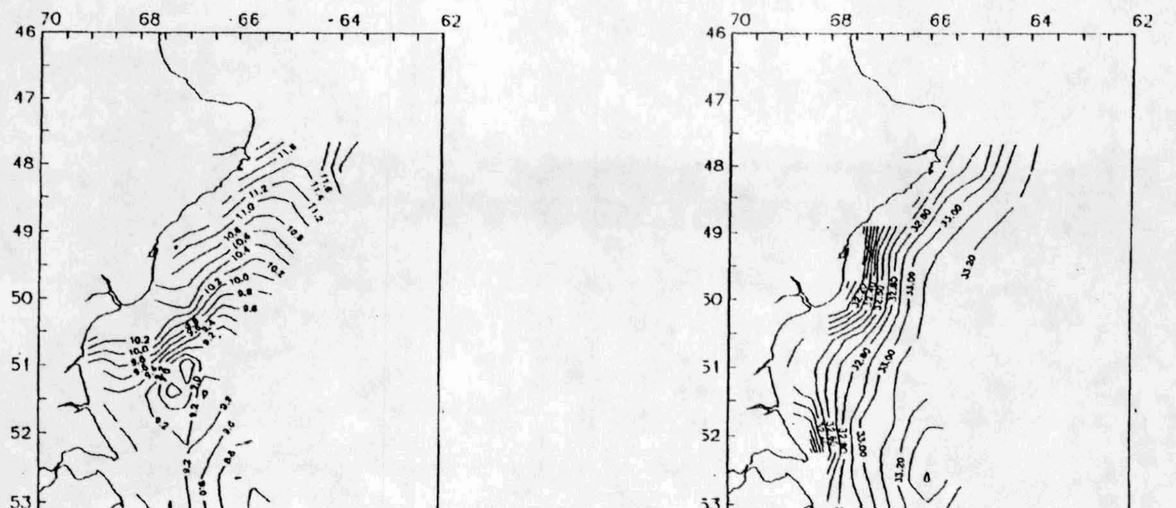


Fig. 6. Sea-surface water temperature (A) and salinity (B) distributions on the Patagonian shelf (28 March - April 4, 1992).

Fig. 7-A.   Fig. 7-B.

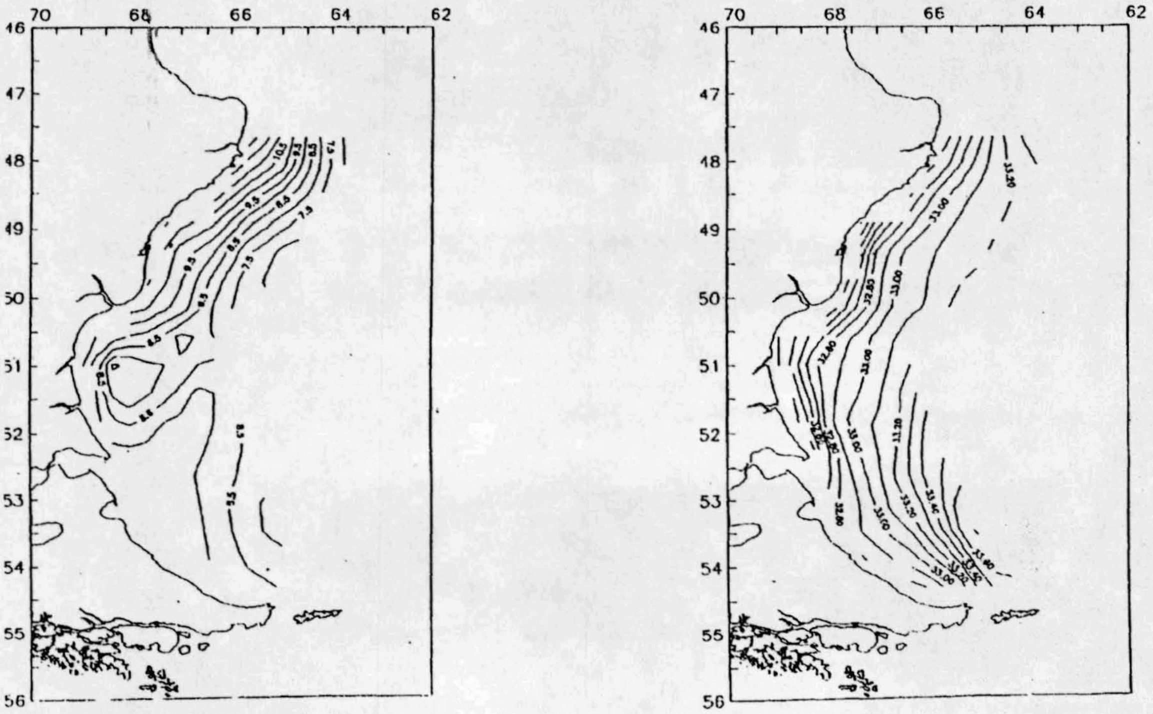


Fig. 7. Bottom water temperature (A) and salinity (B) distributions on the Patagonian shelf (28 March - April 4, 1992).

Differences in the basic hydrographical parameters were largely defined in the meridional direction. Temperature decreased from north to south, from the coastline to the open sea and from surface to bottom. Similarly, salinity increased with depth and distance from shore (Figs. 6-& 7).

Maximum sea surface temperature values (>12°C) were found in the northern part of the surveyed area. Minimum temperature (<6.5 °C) was recorded to the NE of Staten Island in waters of the continental slope of depth below 450m. The areas adjacent to the Magellan Strait showed more homogeneous water temperature distributions, both in the vertical plane and in the off-shore direction. Values observed ranged from 9.2°C in surface coastal waters to 8.0°C in off-shore bottom waters.

The encounter of the cold runoff from the Strait of Magellan and warmer waters from the Grande Bight in the southern coast of Santa Cruz province, originate a gradient zone, that may be clearly seen in SST satellite images. The trasport of Magellan strait water is also evident from the temperature distribution of bottom water shown in Figure 7. The front is located between 50°30'S and 51°30'S. Divergence and subsequent upwelling originated a local area of low temperature centered at 51°15'S and 66°30'W (Figs. 6-A & 7-A).

A more pronounced decrease of water temperatures with depth and distance from shore was observed to the north of 51° latitude, where values ranged uniformly between 12°C and 7°C from surface coastal to off-shore bottom waters.

The distributions of surface and bottom water salinities are quite similar (Figs. 6-B & 7-B). The position of the 33.0 ppt isohaline coincides with the configuration of the 100-m depth contour. Less haline waters (<32.0 ppt at surface and <32.45 ppt on the bottom) are found along a narrow strip along the 50-m depth contour between 49°00'S and 51°15'S. Minimum salinity values (31.16 and 32.38 ppt, at surface and bottom, respectively) were recorded at 50°00'S in relation with the outflow of the Santa Cruz River. Coastal Waters (salinity <33.2 ppt) covered most of the study region from the southern extreme of San Jorge's Gulf to the tip of

Tierra del Fuego. The core of this water mass could be identified at a temperature of 8.9°C and salinity of 32.7 ppt.

While moving away from the Magellan strait, coastal waters gradually modify their characteristics and transform into shelf waters. This water mass was observed in the NE part of the study area, with temperatures over 12°C and salinities ranging between 33.3-33.6 ppt, and a well marked thermocline. To the south of 52°S shelf waters were characterized by similar salinities (33.3-33.7 ppt) and lower temperatures (7.8-8.8°C).

Highest salinity registers (>33.8 ppt) were obtained in an area to the NE of Staten Island over the slope, where waters of Malvinas Current could be identified. On the surface temperatures ranged between 6.4-7.8°C and salinities between 33.8-34.0 ppt. At 490 m depth temperature decreased to 4.3°C whereas salinity increased to 34.2 ppt.

Temperature and salinity profiles along transects made in the northern, central, and southern parts of the surveyed area are presented in Figure 8. In the northern part of the study region the mean horizontal salinity gradient (ppt/km) observed was 4.6×10^{-3} for surface waters and 4.4×10^{-3} for bottom waters. Minimal gradients were observed in the area adjacent to the Magellan Strait (3.3×10^{-3} and 3.6×10^{-3}, at surface and bottom, respectively) whereas maximum gradients where observed at the south of the study area reaching values of 5.9 x 10-3 both on the surface and bottom layers. The intense horizontal salinity gradient observed on both layers is the result of the interaction between Western Malvinas Waters and Shelf Waters. The 33.8 ppt isoline, which delimits both water masses, is located on the bottom at 250 m depth rising sharply to the surface as bottom depth increases (Fig. 8-F).

Temperature and salinity vertical distributions were largely independent of depth in the region off the Strait of Magellan (Fig 8- E), where similar structures could be traced from the coast to mid- shelf at bottom depth of about 100m. To the north of the strait, small variations in temperature and salinity are observed particularly along the coast within the 50-m depth contour. However in some cases, within the narrow range of values, temperature and salinity inversions could be observed. On the other hand, temperature and particularly salinity inversions were typical for stations located outside de 100-m contour.

Fig. 8-A.

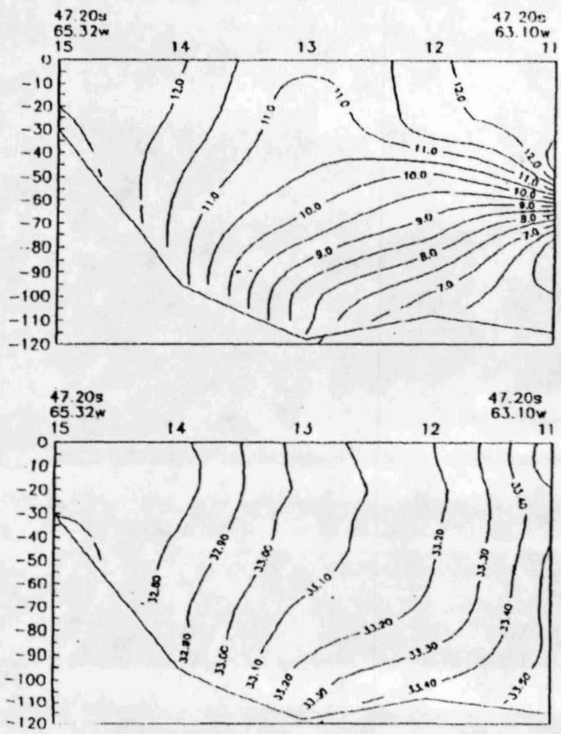


Fig.8-B.

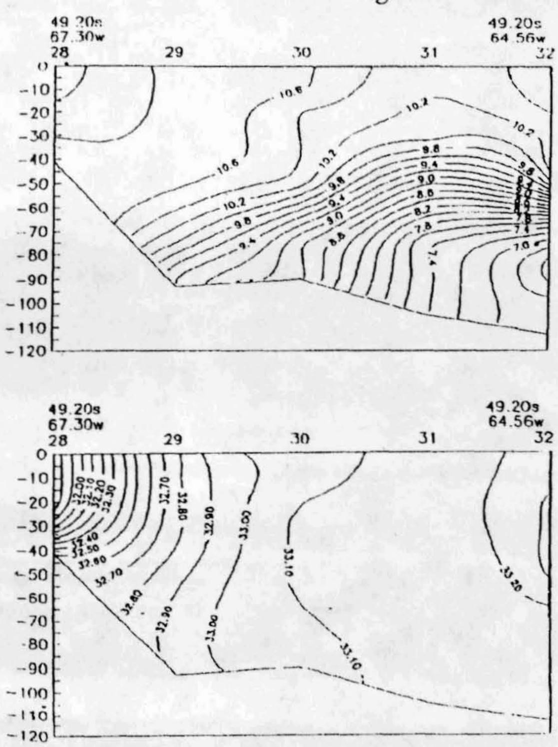


Fig. 8-C.

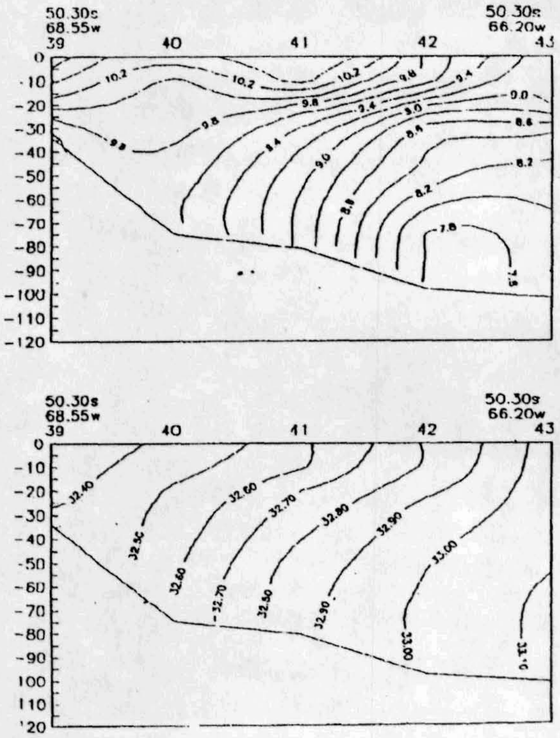


Fig. 8-D

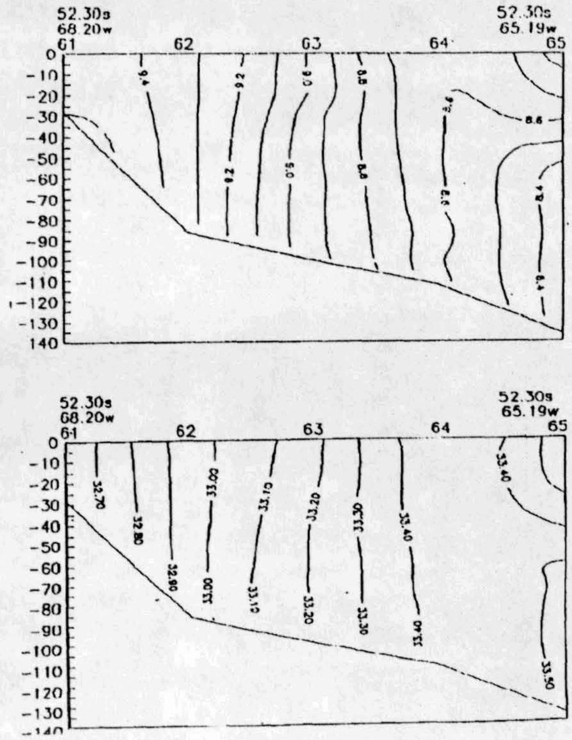


Fig. 8-E.

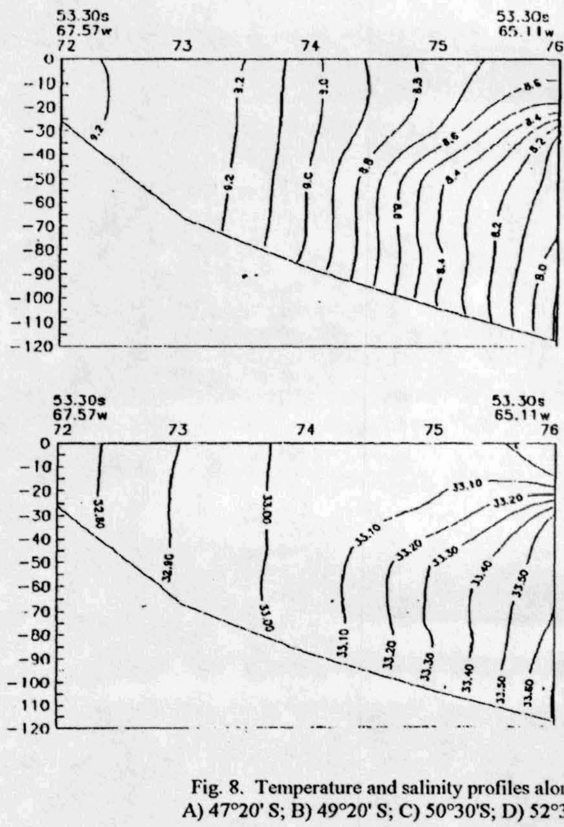


Fig. 8-F.

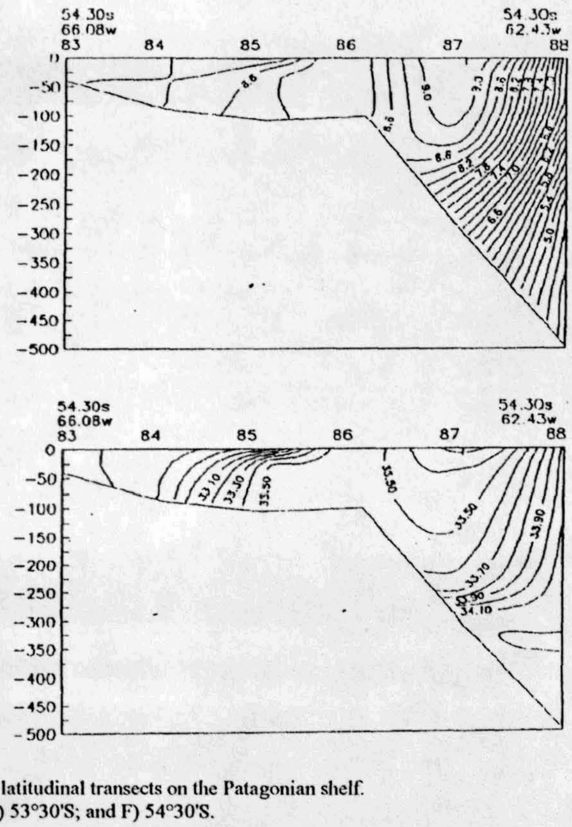


Fig. 8. Temperature and salinity profiles along five latitudinal transects on the Patagonian shelf. A) 47°20' S; B) 49°20' S; C) 50°30'S; D) 52°30'S; E) 53°30'S; and F) 54°30'S.

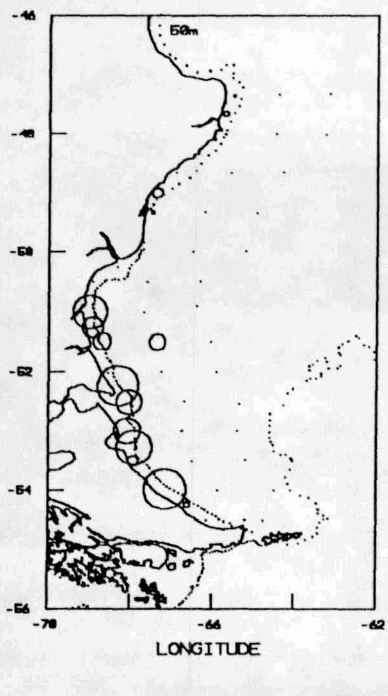
The seasonal thermocline was more clearly seen in the northwestern part of the surveyed area. The upper limit of the thermocline marked by a temperature gradient of 0.05/0.06°C/m, generally occurred between 40 and 60 m depth. In the central part of the study region a rise in the thermocline was observed, with upper limit at about 10-15 m depth. In the southeastern region the thermocline could be found at depths between 16 and 40m. In general terms the width of the gradient layer did not exceed 20 m.

The characteristics of the water dynamics in the surveyed area can be studied through the distributions of temperature and salinity. As illustrated by Figure 8 B-C, leaking of warmer, less haline, and consequently less dense waters on a more dense subsurface water mass could be observed almost throughout the study area. The high-gradient zone on the continental slope may be regarded as a high velocity indicator or the Western Malvinas Current (Fig. 8-F). Impinging of comparatively colder water from the south may be traced through the characteristic bend of surface layer isotherms (Fig. 8-C), and by a rise of isotherms to the surface at bottom depths below 100 m (Fig. 8 A-B).

IKMT sampling.

A total of 3209 sprat post-larvae, pre and post-metamorphosis juveniles (size range 18-48 mm SL) were collected in 17 IKMT stations (Fig.9-A). Positive stations lay mostly within the 50-m depth contour. Of all coastal stations 71% were positive for sprat post- larvae and juveniles. Over 95% of all specimens collected were caught to the south of 51° latitude. Peak densities (>1000 specimens per haul) were obtained in the vecinity of Magellan strait and in the coast off Tierra del Fuego.

Other important components of the Isaacs-Kidd collections were the post-larval and juvenile stages of *Sebastes oculatus* (7 off-shore and central stations), *Patagonotothen tessellata* (15 stations, peak densities in coastal stations) and *Ramnogaster arcuata* in 6 coastal stations. Occurrence of these three species is presented in Figure 9-B.



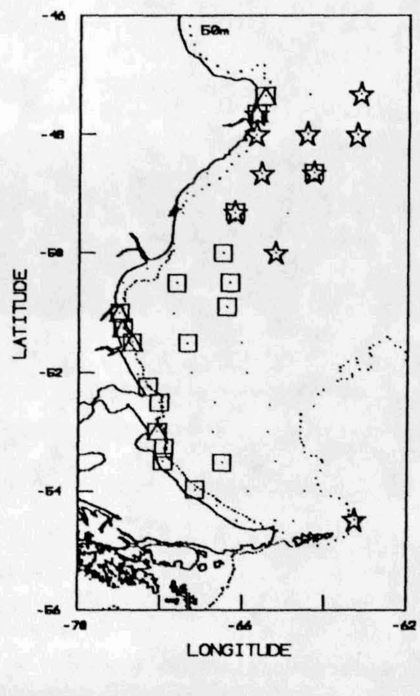


Fig.9. A. Distribution and abundance (N/10^3 m^3) of Patagonian sprat post-larvae and juveniles collected with IKMT during the cruise of R/V Dmitry Stefanov, 21 March-14 April 1992.
B. Occurrence of (Δ) *Ramnogaster arcuata*, (□) *Pataganotothen tessellata and* (☆) *Sebastes oculatus* in the IKMT samples.

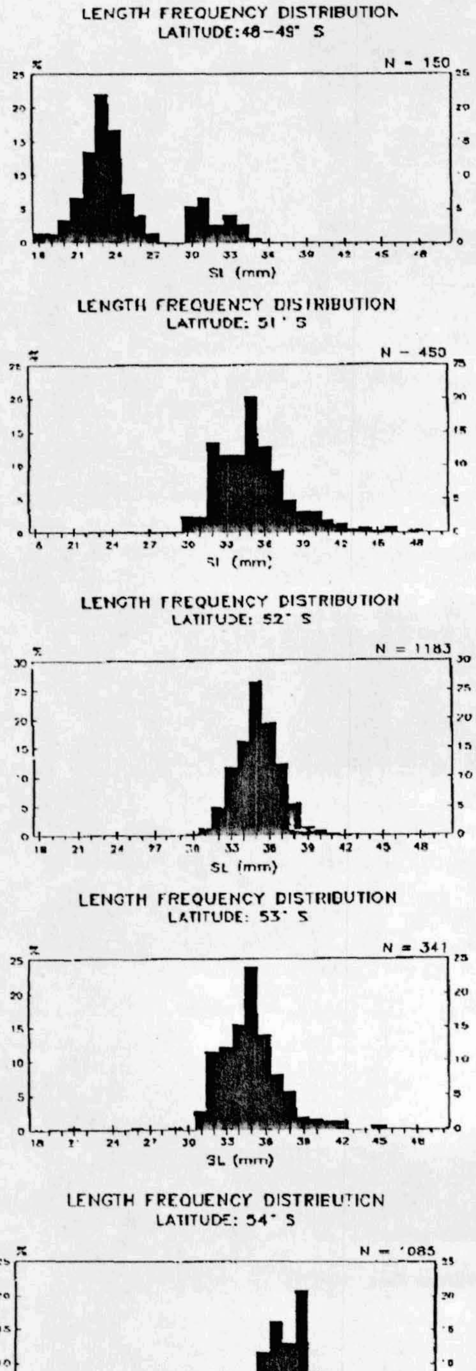


Fig. 10. Latitudinal variation in the length frequency distributions of Patagonian sprat post-larvae and juveniles during the cruise of R/V Dmitry Stefanov, 24 March - 9 April 1992.

Sprat post-larvae and early juveniles were collected within a narrow range of temperatures (9.0-12.0°C, 64% between 9.0 and 9.2°C) and salinities (32.5-33.0 ppt). Temparatures in the stations where post-larvae were collected were in the upper extreme of the range observed (11.2-12.0°C). All positive stations for sprat were located within the same water mass (southern coastal water). No specimen was collected at bottom depths over 100m, almost 98% were caught at depths below 60m, and 66% in shallow waters, at depths under 40 m.

Length frequencies distributions of post-larval and juvenile sprat arranged by latitude are presented in Figure 10. The size of specimens collected increased southwards. Post-larvae (preserved sizes: 18-27 mm SL) were collected only in the northern part of the surveyed region. The length of individuals caught between 48°-49°S ranged from 18 to 35 mm SL (median= 23.6 mm). In the rest of the study area specimens within a similar size-range (mostly 31-45 mm SL) were obtained. Median lengths calculated for specimens collected between 51° and 53° S were quite similar (34.5 mm, 34.7 mm, and 34.6mm), but increased significantly (38.5 mm SL) for specimens collected in the southernmost transects.

Isaacs-Kidd stations were mostly (65%) carried out during night hours, 23% of the stations were occupied during daytime, and 12% either at dusk or dawn. Catch ratios calculated from mean values for night stations against all others, for each size category, gave values around 1 for specimens between 24 and 36 mm SL (Fig. 11). Smaller specimens were mostly caught at dusk or dawn, whereas for large sized specimens the gear seemed to operate more efficiently during night hours.

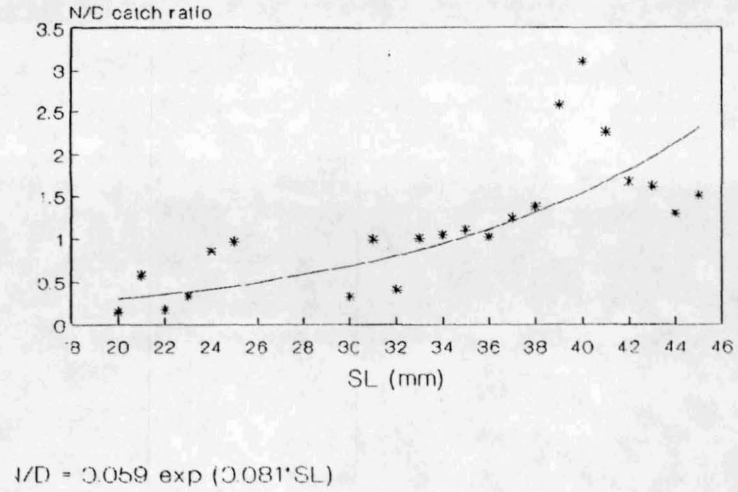


Fig. 11. Catch ratios based on mean abundance of night and day IKMT samples of post-larval and juvenile Patagonian sprat by size groups.

Acoustic survey.

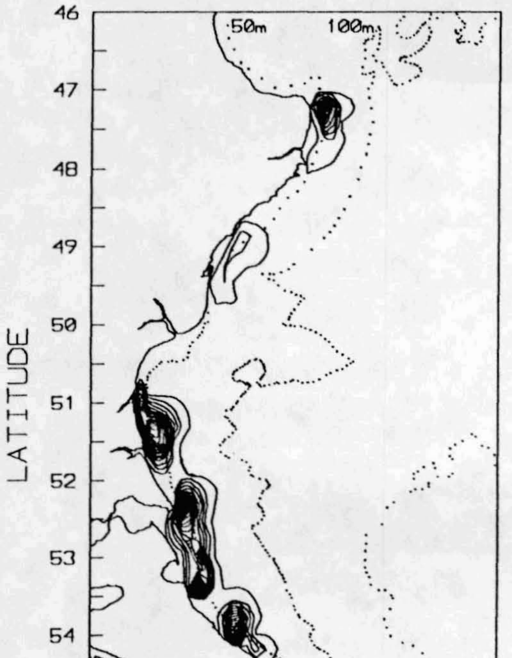


Fig. 12. Abundance distribution of post-larvaeand juvenile Patagonian sprat, obtained from the echointegrator readings. References: minimum contour = 10^4 fish/m^3 maximum contour = 10^6 fish/m^3.

The degree of coverage of the acoustic sampling in the coastal area prevented us from estimating accurately the juvenile production from the echointegration data. However an approximate abundance of 1.5×10^9 individuals may be obtained by multiplying the area of the nursery ground by its corresponding mean column backscattering coefficient.

Isolines of density distribution were calculated from the echointegration data and the TS model previously mentioned. Figure 12 shows the resulting abundance distribution map of post-larvae and juveniles of *Sprattus fuegensis.*

Different patterns of vertical distribution were found for individuals with size range 25-50mm and for those with sizes above 70mm. The echogram shown in Figure 13-A corresponds to night Station No. 42, where 36.6mm mean length early juvenile sprat dominated the IKMT haul. A wide spread layer covering most of the water column can be observed, representing the night vertical distribution of the smaller fish. In daytime this pattern transforms into a thinner layer and that is placed closer to the bottom. Figure 13-B corresponds to the larger fish, sampled with an ENGEL pelagic trawl. The diel pattern observed at sunrise corresponds to individuals with mean length 74.4mm. At nigth these fishes concentrate in a very shallow layer, partially above the transducer depth, at about 5m. In light hours, this surface layer moves deeper and splits into small midwater schools, constituting the daytime vertical distribution of age 0/1 group fish.

Fig. 13-A.

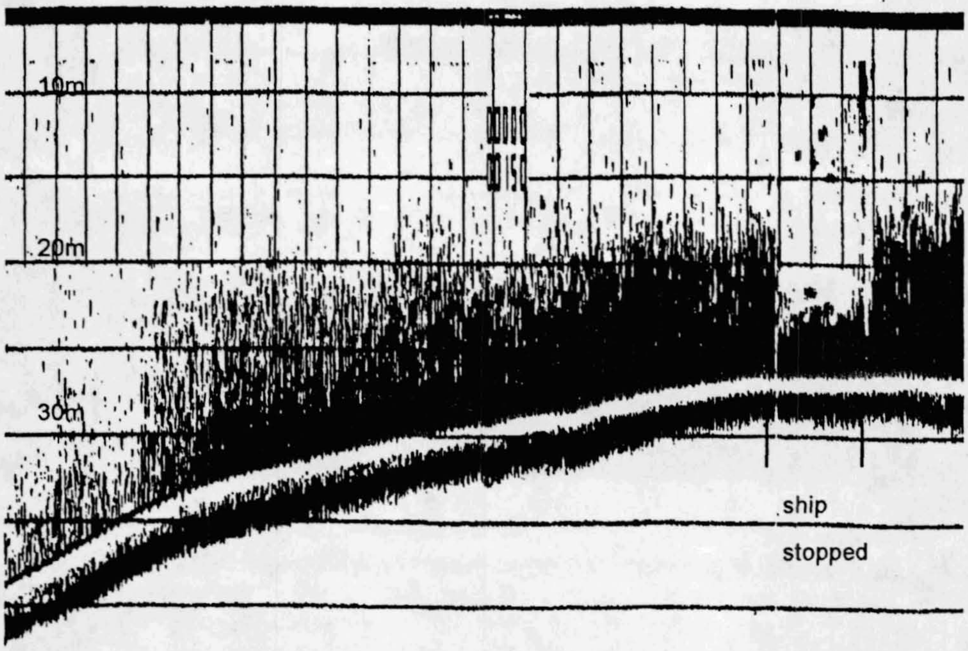


Fig. 13-B.

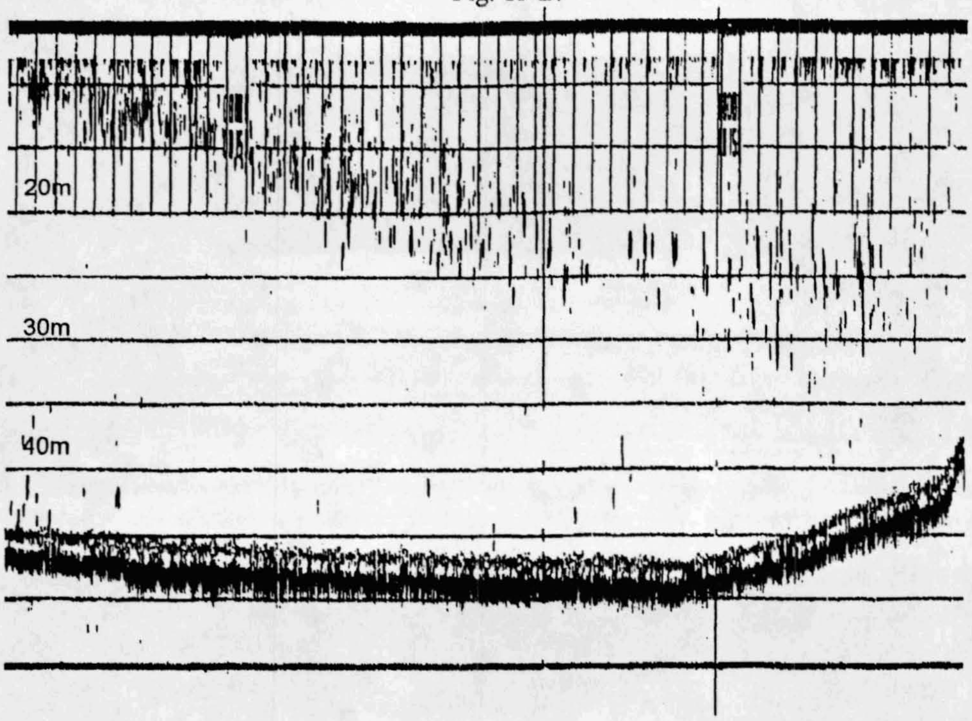


Fig. 13. Echograms showing the vertical distribution patterns of early juvenile and age 0/1 group Patagonian sprat:
A. Nightime vertical distribution pattern of the post-larvae and early juveniles (arrows indicate ship stopping for CTD station).
B. Vertical migration of the age 0/1 sprat from nightime to daytime distribution, at dawn.

It has been demonstrated that, under certain circumstances, fish may react to the presence of the research vessel (Ona & Godo, 1990; Olsen, 1990). An example of this type of reaction was observed at night during a CTD station carried out in very shallow water. The normal night-time distribution pattern for post-larvae and early juvenile sprat was clearly altered, as can be appreciated at the right end of Figure 13-A. The fish reacted soon after the ship stopped to occupy the station and concentrated in a deeper layer on the bottom. As observed from the haul transducer, mounted at approximately middle ship length, such a reaction could be stimulated by light from the ship's deck, by noise from ship's machinery or by a combination of these two sources.

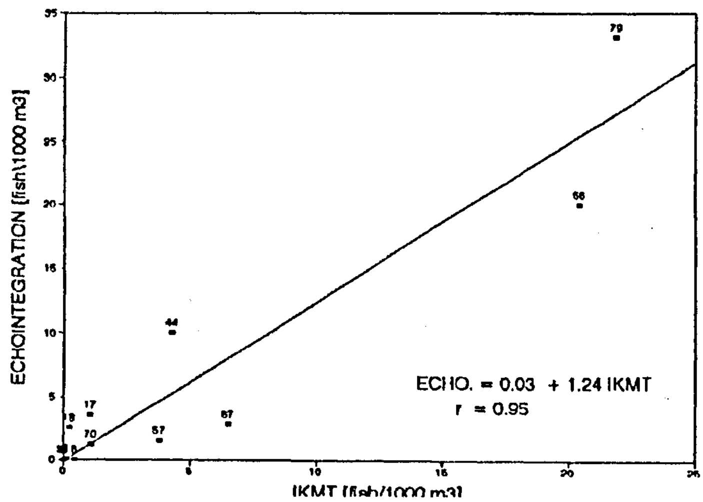


Fig. 14. Relation between fish density values, derived from IKMT collections and from the corresponding echointegrator output.

The fish density values obtained from the IKMT collections and the densities derived from the corresponding echointegrator outputs were compared. A simple regression analisys was performed over the data of the coastal stations. Those stations with significant abundances of other fish species, particularly *Rammogaster arcuata* and *Patagonotothen tessellata*, were discarded for this analysis. The scatter diagram and the regression line are shown in Figure 14.

Studies on Patagonian sprat post-larvae and juveniles.

In order to express juvenile production in terms of biomass, the growth in weight of the different size categories was calculated. As the classic allometry equation fitted data very well (Fig. 15), no other model was tried. Estimates of the parameters, confidence intervals and the ANOVA for model significance are presented in Table 2.

Table 2. Power equation and estimated parameters describing growth of *Sprattus fuegensis* post-larvae and juveniles. The growth model was fitted using nonlinear least-squares regression. ASE = asymptotic standard error of parameter estimates; CI = approximate confidence interval of parameter estimates.

WEIGHT/LENGTH GROWTH EQUATION

W =aLb

Parameter	ASE	(95%) CI
a = 0.926	0.205E-06	0,926
b = 3.562	0.0587	3.44 - 3.68

ANOVA TABLE

Source	DF	SS	MS	α
Model	2	38.05	19.02	<0.001
Residual	173	0.31	0.002	
Total	175	38.35		

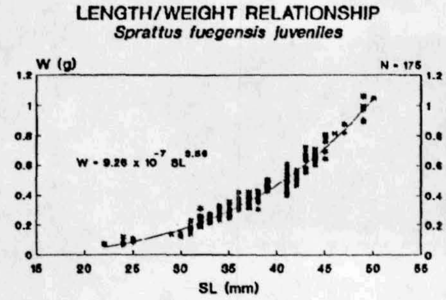


Fig. 15 . Relationship between body weight and standard length for post-larvae and juveniles of *Sprattus fuegensis*, and fitted power growth curve.

Mean density of juvenile sprat over a nursery ground of 2400 n mi^2, was estimated at 16.06 individuals/100 m2. Confidence intervals of the estimate are -31% and +43%. Hence, the total number of juveniles in the study area can be estimated at 1.32×10^9.

Expanding the length frequency distribution in the samples to the whole nursery ground, and applying the length/weight relation calculated in Fig. 15, the biomass of post-larvae and juveniles can in turn be estimated at 423.2 t (Fig. 16).

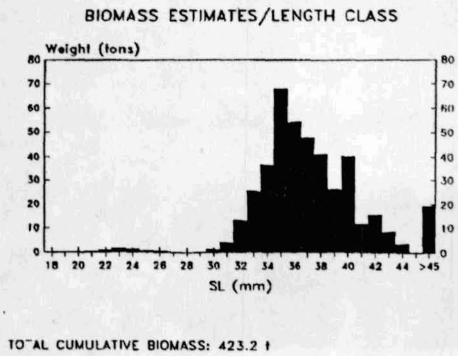


Fig. 16. Biomass of the different size-classes collected with IKMT.

Growth increments in otholits were used to estimate the age of Patagonian sprat juveniles. Daily periodocity of ring deposition, and initial increment formation at the onset of exogenous feeding were assumed. Back-calculation of daily rings has been used to determine the temporal distribution of birthdates during the spawning season.

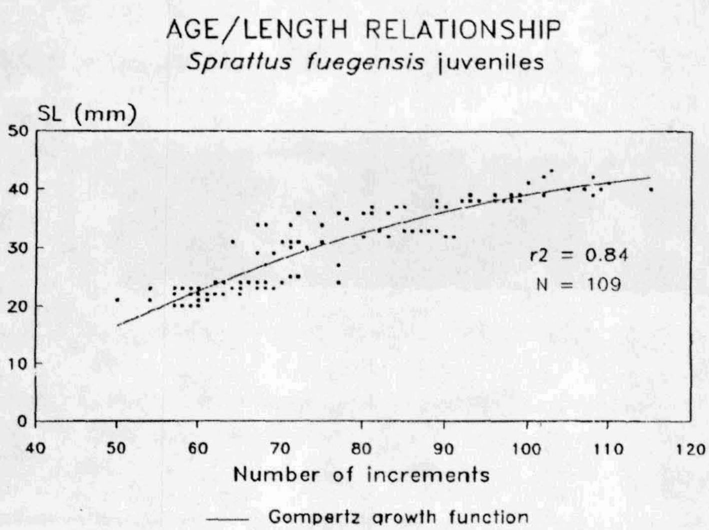


Fig. 17. Relationship between standard length and number of growth increments on sagittae for post-larvae and juveniles of *Sprattus fuegensis*, and fitted Gompertz growth curve.

Three models that had been applied to describe the post-larval growth of cold-temperature waters clupeoids were fitted to the set of data: The Laird-Gompetz (Zweifel & Lasker, 1976; Lough et al. 1982), and von Bertalanffy (Saila & Lough, 1981) growth models and the power equation (Castillo et al., 1985; Aguilera et al., 1986). The three models gave good and similar fits to the data (r^2=0.84 for the Gompertz, r^2=0.83 for the von Bertalanffy, and r^2=0.81 for the power equation), but only results on the Laird-Gompertz are presented (Fig.

17, Table 3) as the model fitted the data with a lower residual sum squares than the other regression tested (SSR=871, 887, 994, respectively).

Table 3. Laird-Gompertz equation and estimated parameter describing growth of *Sprattus fuegensis* post-larvae and juveniles. The growth model was fitted using nonlinear least-squares regression.
ASE = asymptotic standard error of parameter estimates;
CI = approximate confidence interval of parameter estimates.

AGE/LENGTH GROWTH MODEL

$$SLt = L_0 \exp\{G[1-\exp(-\alpha t)]\}$$

Parameter	ASE	(95%) CI
L_0=0.132	0.254	-0.376 - 0.640
G =5.871	1.862	2.147 - 9.595
α =0.035	0.00652	0.022 - 0.048

ANOVA TABLE

Source	DF	SS	MS	α
Model	3	106571.6	35523.9	<0.001
Residual	106	871.4	8.30	
Total	109	107443.00		

After correcting for day avoidance of the net and dividing the abundance of each size category by its duration, calculated as the inverse of the growth rate for the category, length frequencies were aged according to the age/length model described above. As number of increments was supposed to represent age since first feeding, to estimate the age from fertilization of the juveniles collected during the cruise, the number of days elapsed during the embryonic and yolk sac larvae stages were added.

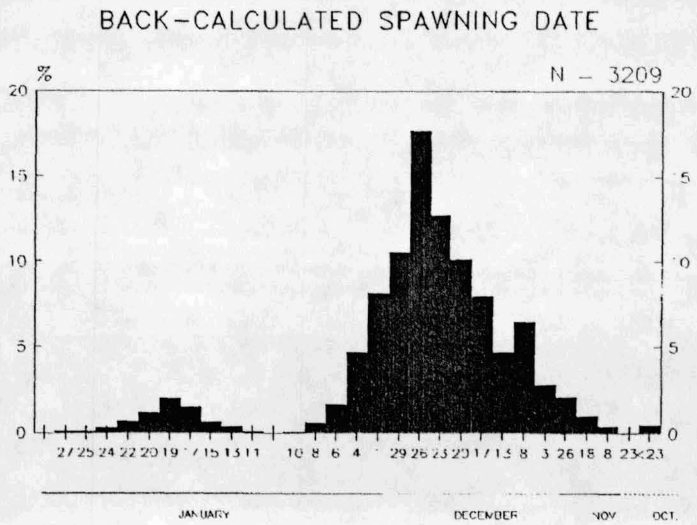


Fig. 18. Reproductive activity of the Patagonian sprat, during late spring and early summer, based on back-calculated dates of spawning. Date of initial increment formation was calculated from the number of ring countings. The duration of the embryonic and yolk-sac stages were estimated from equations given by Thompson & Nichols (1980) and Alshuth (1988).

Figure 18 shows that spawning of the Patagonian sprat, occurred over four months from October to January. A major spawning peak is estimated to have taken place around the end of December 1991, and a secondary one on 19 January 1992. The final age class of the histogram, represents the few specimens collected of sizes over 45mm SL, which are assumed to have been spawned before October 23.

DISCUSSION

Although the small and middle-sized larvae of the *Sprattus fuegensis* show an extended distribution over the southern Patagonian shelf during summer, results reported here, and those obtained from the analysis of the ENGEL net sampling (Hansen, unpub. manusc.) demonstrate that the bulk of the 0-group sprat, remains from metamorphosis onwards in the southern Patagonian shelf, in association with southern coastal waters, mostly at bottom depths below 50m. Satellite images of the study area for mid-February show the 40-mile wide cold Magellan water tongue, spreading northwards from the Strait area to San Jorge's Gulf, in good correspondance with the descriptions of Krepper (1977), Krepper & Rivas (1979) and Bianchi et al. (1982). During the cruise, however, the converse situation was observed. The coastal region was covered by warmer - and as the CTD sampling indicated lower salinity - water impinging from San Jorge's Gulf, moving southwards down to 51°S, probably as a consequence of the Magellan runoff slackening and displacing offshore. A similar warm coastal countercurrent has been referred to by Hart (1946) as "old shelf water" (Fig. 1-B).

In their analysis on the comparative climatology of reproductive habitats of neritic pelagic fishes, Bakun & Parrish (1991) point out several physical and biological configurations of spawning and nursery grounds that serve to secure larval survival. Recurrent features of these scenarios are mechanisms tending to produce (i) stability of the water column by strong vertical stratification, (ii) nutrient enrichment caused by upwelling and, (iii) retention of spawn within a favourable habitat.

The nursery ground of the Patagonian sprat shares features in common with other neritic fish reproductive habitats. Stability of the water column induced by the formation of picnoclines is a crucial mechanism for food particle accumulation. In the study area, picnoclines are mainly dependent on salinity gradients, although during the cruise temperature also contributed to the lower density of the upper water layer.

Sources of nutrient enrichment are given by the impinging of comparatively colder subantarctic water evident by the rise of bottom thermoclines to sub-surface layers, and by circulation characteristics of the encounter of the Magellan runoff and shelf waters, which during the cruise originated divergence and subsequent upwelling. These results are confirmed by the direct observations on chlorophyll-a distribution carried out by the Coastal Zone Color Scanner, a radiometer with visible and infrared spectral channels that operate on NASA's Nimbus-7 research satellite. Summer images show very high pigment concentrations in relation with the penetration of Magellan water over the shelf and in the frontal zone between the two water masses.

Retention of juveniles within the coastal habitat, may be secured by ocean surface layer transport caused by wind stress that in the area is generally directed shorewards, and by the southwards drift of coastal water from San Jorge's Gulf, that in combination with tidal circulation and migratory habits of post-larvae and juveniles may serve to counteracting the general pattern of NNE transport characteristic of the Argentine shelf.

Acoustic sampling combined with IKMT sampling proved to give very useful information on abundance and distribution of juvenile sprat. However a higher sampling effort, both acoustic and IKMT, should be allocated in the coastal area to obtain accurate estimates of juvenile production.

From the regression analysis between IKMT and echointegration data, it can be concluded that the fish densities obtained from both methods show a good correlation. Adequate sampling conditions -with a predominance of night stations, and efficient samplers for the size-ranges encountered- lead us to conclude that the IKMT catches are representative of the real abundance of early juvenile sprat. The obtained regression line (intercept close to 0 and slope close to 1), supports reasonably well the assumption of applicability of the adopted TS model. However the use of a shorter wavelength in the acoustic sampling, as for example 120 or 200kHz, should be experimented in order to account for possible unstabilities in the TS of post-larvae and early juveniles fish due to the frequency dependance of the backscattering / frequency function near or at the Rayleigh zone (Clay & Medwin, 1977; Holliday, 1983).

The fact that the schools of post-larvae and early juveniles and those of age 0/1 group sprat were in occasions distinctly sepparated, permitted to conclude that both age groups show different diel migratory patterns. Variations in the vertical distributions of young and adult stages of one species inhabiting the same area have been reported by Raid (1985) for Baltic herring, but contrary to his results our observations indicate that during the day post-larvae and early juveniles concentrate near the bottom from where they migrate to occupy the whole water column in nighttime. Older stages on the other hand, move to the surface during the night, migrating to mid-depths and breaking into small schools, at sunrise. Night distributions of post-larvae and early juveniles generally reported in the literature, describe an ascend of specimens after dusk, and a migration towards the bottom as illumination progresses (i.e. Sjöblom & Parmanne, 1978; Munk, 1988).

The avoidance reaction observed when the ship stopped to occupy the station could be due, at least partially, to the ship's illumination at the working station. Thus, the utilization of deck ligths during regular sampling (trawling or acoustic surveying) should be restricted to a minimum to avoid possible bias in the data. Taking into consideration that most of the study area lays in shallow waters, a smaller and more quiet ship should be employed in order to reduce vessel introduced perturbations.

Back-calculation of otoliths countings to determine larval birthdates during the spawning season, has been reported for several clupeoids (Towndsend & Graham, 1981; Methot, 1983; Jones, 1985; Thorrold, 1988; Alheit & Bakun 1991). Patagonian sprat seem to spawn over a period of at least 4 months, which compares well with results reported for the Malvinas population. Results presented here are limited by the fact that duration of the egg and yolk sac stages had to be calculated on the basis of values reported for *Sprattus sprattus*. The duration of the period from hatching to initial ring deposition, may be underestimated as Alshuth (1988)'s experimental values were obtained at higher temperatures than those encountered by the Patagonian sprat. Age determination with optical microscopy seemed to be adequate for specimens smaller than 40 mm SL. Larger specimens were somewhat difficult to read, and other techniques (i.e. SME) will be used in the future.

Two questions remain unanswered: (a) where does the Patagonian stock spawn?; and (b) is there a nursery ground of the type described here on the coasts of Malvinas Islands?. We believe that sprat eggs present in our historic collections correspond to the spawning of the Malvinas stock. Although not completely discarding the fact that very coastal spawnings off Patagonia could have eluded previous plankton surveys during early summer, it may be hypothesized that the reproductive activity could take place in inlets and channels, and that early developmental stages could be transported to the shelf by the Magellan strait runoff. The fact that post-larvae during summer months, appeared aggregated along the 100-m depth contour, which as stated above corresponds with the 33.0 psu isohaline, seem to indicate an association between these early stages and the frontal zone created by the meeting of less-haline Magellan waters and shelf waters. Advection towards the coast could be effected by surface Ekman transport, that during the reproductive season is generally directed toward shore (Bakun & Parrish, 1991).

As to the second question, there is no information available from that area about the presence of post-larvae and early juveniles resulting from spring spawning. However, assuming that this is a genetically distinct stock, as morphometrics and population attributes indicate, we can speculate, following Iles & Sinclair (1982) upon the existence of a geographically stable larval retention area. The well-delimited area around Malvinas as a result of anticyclonine current circulation and sinking of shelf waters described by Severov (1990), may be the physical feature involved in maintainig the integrity of the individual population.

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LITERATURE CITED

AGUILERA, E., HERRERA, G. & CASTILLO, G. 1986. Tasa de crecimiento larval de *Clupea benticki*, en el area de Talcahuano. Análisis de incrementos diarios en otolitos sagitta. Biota, p. 89.

ALHEIT, J. & BAKUN, A. 1991. Reproductive success of sprat (*Sprattus sprattus*) in German Bight during 1987. ICES C.M. 1991/L:44.

ANGELESCU, V. & PRENSKI, L.B. 1987. Ecología trófica de la merluza común del Mar Argentino (Merlucciidae, *Merluccius hubbsi*). Parte 2. Dinămica de la alimentación analizada sobre la base de las condiciones ambientales, la estructura y las evaluaciones de los efectivos de su área de distribución. Ser. Contrib. Inst. Nac. Invest. Des. Pesq., No. 561, 205 pp.

ALSHUTH, S. 1988a. Daily growth increments on otoliths of lagoratory-reared sprat, *Sprattus sprattus* L., larvae. Meeresforsch., 32: 23-29.

BAKUN, A., & PARRISH, R.H. 1991. Comparative studies of coastal pelagic fish reproductive habitats: the anchovy (*Engraulis anchoita*) of the Southwestern Atlantic. ICES J. mar Sci. 48: 343-361.

BIANCHI, A; MASSONNEAU, M. & OLIVERA, R.M. 1982. Análisis estadístico de las características T-S del sector austral de la Plataforma Continental Argentina. Acta Oceanogr. Arg. 3: 93-118.

CASSIA, M.C. & LASTA, C.A. Descripción de larvas de *Sprattus fuegensis* (Jenyns, 1842) (Pisces, Clupeiformes, Clupeidae). (unpubl. manusc.)

CASTILLO, G.; AGUILERA, E.; HERRERA, G.; BERNAL, P.A.; BUTLER, J.L.; CHANG., J.; GONZALEZ, H.; OYARZUN, C. & VELOSO, C. 1985. Larval growth rates of the Pacific sardine *Sardinops sagax* off central Chile, determined by daily ring count in otoliths. Biol. Pesq., 14: 3-10.

CIECHOMSKI, J.D. de. 1971. Estudios sobre los huevos y larvas de la sardina fueguina, *Sprattus fuegensis* y de *Maurolicus muelleri*, hallados en aguas adyacentes al sector patagónico argentino. Physis, Buenos Aires, vol. XXX, No. 81: 557-567.

CIECHOMSKI,J.D.;M.C.CASSIA & G.WEISS. 1975. Distribución de huevos, larvas y juveniles de peces en los sectores bonaerense, patagónico y fueguino del Mar Epicontinental Argentino, en relación con las condiciones ambientales, en noviembre 1973-enero 1974. Ecosur, Buenos Aires, 2(4): 219-248.

CIECHOMSKI,J.D.; M.D.EHRLICH; C.LASTA y R.SANCHEZ. 1981. Distribución de huevos y larvas de peces en el Mar Argentino y evaluación de los efectivos de desovantes de anchoíta y de merluza. *In*: V. Angelescu (ed.)Campañas de investigación pesquera realizadas en el Mar Argentino por los B/I"Shinkai Maru" y "Walther Herwig" y el B/P"Marburg", años 1978 y 1979.,Contrib. INIDEP 383: 59-79.

CIECHOMSKI, J.D. de & SANCHEZ, R.P. 1983. Relationship between ichthyoplankton abundance and associated zooplankton biomass in the shelff waters off Argentina. Biol. Oceanog., 3 (1): 77- 101.

CLAY, C. & MEDWIN, H. 1977. Acoustical Oceanography: Principles and Applications. N.York, Willey interscience, 544p.

COUSSEAU, M.B. (1982). Revisión taxonómica y análisis de los caracteres morfométricos y merísticos de la sardina fueguina (*Sprattus fueguensis*), Jenyns, 1842 (Pisces, Clupeidae). Rev.Inv.y Desarr.Pesq., Mar del Plata, 3: 77-94.

DALEN, J. & NAKKEN, 0. 1983. On the application of the echointegration method. ICES C. M. 1983/B:19.

DEGNBOL, P.; LASSEN, H. & STAEHR, K.J. 1985. In situ etermination of target strength of herring and sprat at 38 and 120 KHz. Dana, 5: 45-54.

FOOTE, K.G. 1987.Fish target strength for use in echointegrator surveys. J. Acoust. Soc. Am., 82(3): 981-987.

FOOTE, K.G.; KNUDSEN, H.P.; VESTNES, G.; MACLENNAN, D.N. & SIMMONDS, E.J. 1987. Calibration of acoustic instruments for fish density estimation: A practical guide. ICES Coop. Res. Rep., 144, 69pp.

FOOTE, K.G. & MacLENNAN, D.N. 1983. Use of elastic spheres as calibration targets. FAO Fish. Rep., 300: 52-58.

FORBES, C. & GARRAFO, D. 1988. A note on the mean seasonal transport on the Argentinian shelf. J. Geoph. Res., 93 (C3): 2311--2319.

FORBES S.T. & NAKKEN O. 1972. Manual of methods for fisheries resource survey and appraisal. Part 2. The use of acoustic instruments for fish detection and abundance estimation. FAO Man. Fish. Sci. 5, 1-138.

FRICKART, J. 1942. Viejos recuerdos de la Tierra del Fuego. Bol. Centro Naval, Bs.As., 60 (553): 819-833.

GRU, D.L. y M.B.COUSSEAU (1982). Estudio de edad y crecimiento de la sardina fueguina (*Sprattus fueguensis*) de las costas de la Provincia de Santa Cruz e Islas Malvinas. Rev.Inv.y Desarr. Pesq., Mar del Plata, 3: 51-58.

HANSEN, J. Fisheries Biology and Ichthyology. Final Rep. DS-01/93 (unpubl. manusc.).

HART, T.J. 1946. Report on the trawling surveys of the Patagonian continental shelf. Discovery Rep., Vol. 23: 223-408.

HOLLIDAY, D.V. 1980. Volume scattering stregth and zooplankton distributions at acoustic frecuencies between 0.5 and 3 MHz. J. Acoust. Soc. Am. 67(1): 135-146.

ILES, T.D. & SINCLAIR, M. 1982. Atlantic herring: stock discreteness and abundance. Science., 215: 627-633.

JONES, C. 1985. Within-season differences in growth of larval Atlantic herring, *Clupea harengus harengus*. Fish. Bull., U.S., 83 (3):289-298.

KNUDSEN, H.P. 1990. Bergen echo integrator: An introduction. J. Cons. Int. Explor. Mer 47: 167-174.

KREPPER, C.M. 1977. Difusión del Agua proveniente del Estrecho de Magallanes en las Aguas de la Plataforma Continental. Acta. Oceanographica Argentina, 1 (2): 49-65.

KREPPER, C.M. & RIVAS, A.L. 1979. Análisis de las características oceanográficas de las zona austral de la Plataforma Continental Argentina., 2(2): 55-82.

LLORIS, D. & RUCABADO, J. 1991. Ictiofauna del Canal Beagle (Tierra del Fuego). Aspectos ecológicos y análisis biogeográfico. Publ. Espec.Inst. Español Oceanogr., No. 8, 181 pp.

LOUGH, R.G.; PENNINGTON, M.; BOLZ, G.R. & ROSENBERG, A.A. 1982. Age and growth of larval Atlantic herring. *Clupea harengus* L., in the Gulf of Maine-Georges Bank region, based on otolith growth increments. Fish. Bull., U.S., 80: 187-199.

LUSQUIÑOS, A. & SCHROTT, A.G. 1983. Corrientes en el Mar Epicontinental Argentino en invierno. Subsecr. Cienc. Tecnol., pp. 1-74.

MacLENNAN, D.N. 1990. Acoustic measurement of fish bundance. J. Acoust. Soc. Am. 87: 1-15.

METHOT, R.D. Jr. 1983. Seasonal variation in survival of larval northern anchovy, *Engraulis mordax*, estimated from the age distribution of juveniles. Fish. Bull., U.S. 81: 741-750.

MUNK, P. 1988. Catching large herring larvae: Gear applicability and larval distribution. J. Cons. int. Explor. Mer, 45: 97-104.

OLSEN, K. 1990. Fish behaviour and acoustic sampling. *In*: W.A. Karp (ed). Developments in Fisheries Acoustics; , Rapp. P.-v. Réun. Cons. int. Explor. Mer, 189: 147-158.

ONA, E. & GODO, O.R. 1990. Fish reaction to trawling noise: The significance to trawl sampling. In: O.R. Godo, Dr. Phil. Thesis, Inst. Fish. and Mar. Biol., Univ. Bergen, Bergen, Norway.

RAID, T. 1985. The reproduction areas and ecology of Baltic herring in the early stages of development found in the Soviet zone of the Gulf of Finland. Finnish Fish. Res., 6: 20-34.

SAILA,B. & LOUGH, R.G. 1981. Mortality and growth estimation from size data An application to some Atlantic herring larvae. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 178: 7-14.

SEVEROV. D.N. 1990. Particularidades de la condición oceanográfica del Atlántico Sudoccidental sobre la base de características temporales medias procedentes de una serie de años. Frente Marit., 6: 109-120.

SHIROKOVA, E.N. 19878.Contribution to the biology of Tierra del Fuego sprat *Sprattus fuegensis* (Jenyns, 1842). Biology of the Sea, 3: 78-84 (In Russian).

SJÖBLOM, V. & PARMANNE, R. 1978. The vertical distribution of Baltic herring larvae (*Clupea harengus* L.) in the Gulf of Finland. Finnish Fish. Res., 2: 5-18.

THOMPSON, B.M.; MILLIGAN, S.P. & NICHOLS, J.H. 1981. The development rates of sprat (*Sprattus sprattus* L.) eggs over a range of temperature. ICES, Pelagic Fish Com., CM 1981/H:15.

THORROLD, S.R. 1988. Estimating some early life history parameters in a tropical clupeid *Herklotsichthys castelnaui*, from daily growth increments in otoliths. Fish. Bull., U.S., 87: 73-83.

TOWNSEND, D.W. & GRAHAM, J.J. 1981. Growth and age structure of larval Atlantic herring, *Clupea harengus harengus*, in the Sheepscot River estuary, Maine, as determined by daily growth increments in otoliths., Fish. Bull., U.S. 79: 123-130.

ZWEIFEL, J.R. & LASKER, R. 1976. Prehatch and posthatch growth of fishes ageneral model. Fish. Bull., U.S., 74: 609-621.

ZYRYANOV, V.N. & SEVEROV, D.N. 1979. Water circulation in the Falkland-Patagonia region and its seasonal variation. Oceanology, 19 (5): 518-522.