ACOUSTIC SURVEYS ON THE SOUTHERN BLUE WHITING (*Micromesistius australis*)*

by

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RESUMEN

Investigaciones acústicas sobre la polaca (*Micromesistius australis*). Durante la primavera de 1994 y 1995 se llevaron a cabo dos cruceros acústicos conjuntos Argentino-Británicos para el estudio de la polaca (*Micromesistius australis*). Los cruceros confirmaron la existencia de una concentración reproductiva de polaca localizada hacia el sur del Estrecho de San Carlos. Las estimaciones puntuales de abundancia correspondientes a ambos cruceros fueron 84801 t y 140953 t, para 1994 y 1995 respectivamente. Los cruceros aportaron además información sobre la estructura y comportamiento de los cardúmenes de polaca como así también algunas pautas acerca del complejo patrón migratorio de la especie.

SUMMARY

Two joint Argentine-British acoustic surveys specifically targeted on the southern blue whiting (*Micromesistius australis*) were carried out during September 1994 and 1995. The surveys confirmed the existence of a spawning concentration area located south from San Carlos Strait. The obtained point estimates of blue whiting abundance were 84801 t for the 1994 survey and 140953 t for the 1995 survey. The surveys also provided information on the school structure and behavior as well as some clues about the complex migration pattern of the species.

Key words: *Micromesistius australis*, acoustic surveys.
Palabras claves: *Micromesistius australis*, cruceros acústicos.

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INTRODUCTION

Since 1992 INIDEP has carried out several acoustic surveys aimed at gathering information on abundance and geographic distribution of the southern blue whiting. Two joint Argentine-British acoustic surveys specifically targeted on blue whiting were carried out during September 1994 and 1995 and most of the information presented here corresponds to them.

The joint surveys were designed to obtain estimates of the biomass of blue whiting during the spawning season, assuming that during September-October most of the adult components of the stock concentrate in the western side of Malvinas Channel. This assumption is based on scientific data collected during previous surveys carried out in the seventies and early eighties (Perrotta, 1982; Sánchez and Ciechomski, 1995).

MATERIALS AND METHODS

Acoustic instrumentation

The survey platform was R/V Cap. Oca Balda, a 66 m length stern trawler run by the INIDEP. The acoustic instrumentation consisted of a SIMRAD EK-500. In 1994 the echo sounder was interfaced to a 486 based PC computer for dataloging through an asynchronic port. In 1995 the EK-500 echo sounder was interfaced to a risk processor based Graphical Work Station via an Ethernet port and the SIMRAD BI500 software for dataloging and post processing (Foote et. al., 1991). The operating frequency was 38 KHz for both surveys and the processing method was echointegration.

The echointegration method (Forbes and Nakken, 1974) is based on measurements of the sound volume scattering caused by the targets that are insonified during the pass of a ship equipped with a calibrated echo sounder. The ship trackline is decided in advance and a given sampling strategy is chosen according to the characteristics of the area and the expected distribution of the species (Simmonds *et al.*, 1991; MacLennan and Simmonds, 1992).

For each survey the scientific sounder was calibrated according to ICES recommendations for calibration with standard targets (Foote *et al.*, 1987). Sounder calibration was accomplished during the survey in 1994 and just before the survey in 1995. Calibration reports and other related information are included in the corresponding survey activities reports.

Definition of the physical parameters involved in the biomass density calculation follow the definitions given in Clay and Medwin (1977). Equivalencies with definitions from other sources are given in Bodholt (1990) and in Foote (1991). The formulae utilized for conversion from sound scattering measurements to fish density values are as follows:

$$\sigma_{bs} = 10^{(TS/10)} \; ; \; \sigma_{bs} = \sigma / (4\pi) \; ; \; \sigma_{bs\text{-}kg} = \sigma_{bs} / W$$

$$s_a = 4\pi \cdot (1852^2) \cdot s_V \cdot \Delta R$$

$$\rho = s_a \cdot (1/10^3) \cdot (1/4\pi) \cdot (\sigma_{bs\text{-}kg})^{-1}$$

where:

s_a: column or area scattering coefficient normalized per squared nautical mile (Clay and Medwin, 1977), in units of m^2/nm^2 and as calculated internally by the SIMRAD EK-500 (Bodholt, 1990).

s_V: volume scattering coefficient, in units of m^2/m^3.

ΔR: depth interval, in units of m.

TS: fish acoustic target strength (Clay and Medwin, 1977), in units of dB.

σ_{bs} : fish equivalent back scattering cross sec-

tion, in units of m^2.

σ : fish equivalent scattering cross section, in units of m^2.

W : individual fish mean weight, in units of Kg.

ρ : fish biomass density, in units of t/nm2.

Target strength of the southern blue whiting

A target strength (TS) vs. fish length relationship for the particular species, is a key factor in the process of biomass estimation from sound scattering measurements. Different methods have been established to obtain this relationship (Foote, 1991), being the *in situ* measurements of single fish echoes or direct method generally recognized as the best approach to a solution for this problem. However, conditions suited to obtain reliable in situ TS measurements are rather uncommon in practice. For the present case, deep and high density blue whiting schools constitute serious limitations for the application of the direct method.

Before a TS relationship for the southern blue whiting can be obtained, models for other species has to be utilized. Fish target strength is a rather complex parameter and is determined by both, physiological and behavioral factors. As a first approach, given that southern blue whiting is a physoclist fish, the following general model for physoclist fish (Foote, 1987) can be considered:

$$TS = 20 \log (L) - 67.4 \text{ dB}$$

where L is the fish mean length, in units of cm.

In the 1994 survey very few TS data could be collected using split beam transducers and the general target strength model developed for physoclist fish was employed to obtain a biomass estimate. The acoustic instrumentation in the 1995 survey was significantly improved by the inclusion of a graphical work station, allowing further post-processing of acoustic data. The analysis of TS data collected in 1995 showed lower TS values than those obtained in the previous survey, indicating that due to the mentioned constraints, the obtained frequency distributions of blue whiting target strength may be affected by multiple echoes. Consequently it is believed that the general model for physoclist fish, employed for the 1994 survey, could represent an overestimation of the target strength of the southern blue whiting.

Data employed in the physoclist model corresponded to gadoid fish, mainly cod and haddock, for which the model has shown good agreement with *in situ* measurements. Nakken and Olsen (1977) performed a series of experiments to compare maximum dorsal aspect target strength of several fish species, including the northern blue whiting and showed that this species exhibits a lower TS in the dorsal aspect compared to other gadoids as cod.

Acoustic surveys on the northern blue whiting (*Micromesistius poutassou*) have been carried out inside the ICES programs for several years and the following TS/fish length relationship (Anon., 1985) is currently applied for biomass estimation:

$$TS = 21.8 \log (L) - 72.7 \text{ dB}$$

where L is the fish mean length, in units of cm.

The last target strength model agree with the lower TS compared to gadoids shown in the Nakken and Olsen experiments. Considering that both species, northern and southern blue whiting, are very similar in their physiology and school behavior and that the 1995 *in situ* measurements supports the validity of lower TS values than those of other gadoid fish, it is recommended that the TS relationship developed for the northern blue whiting (*Micromesistius poutassou*) be adopted also for the biomass estimates of southern blue whiting (*Micromesistius australis*), until a specific TS rela-

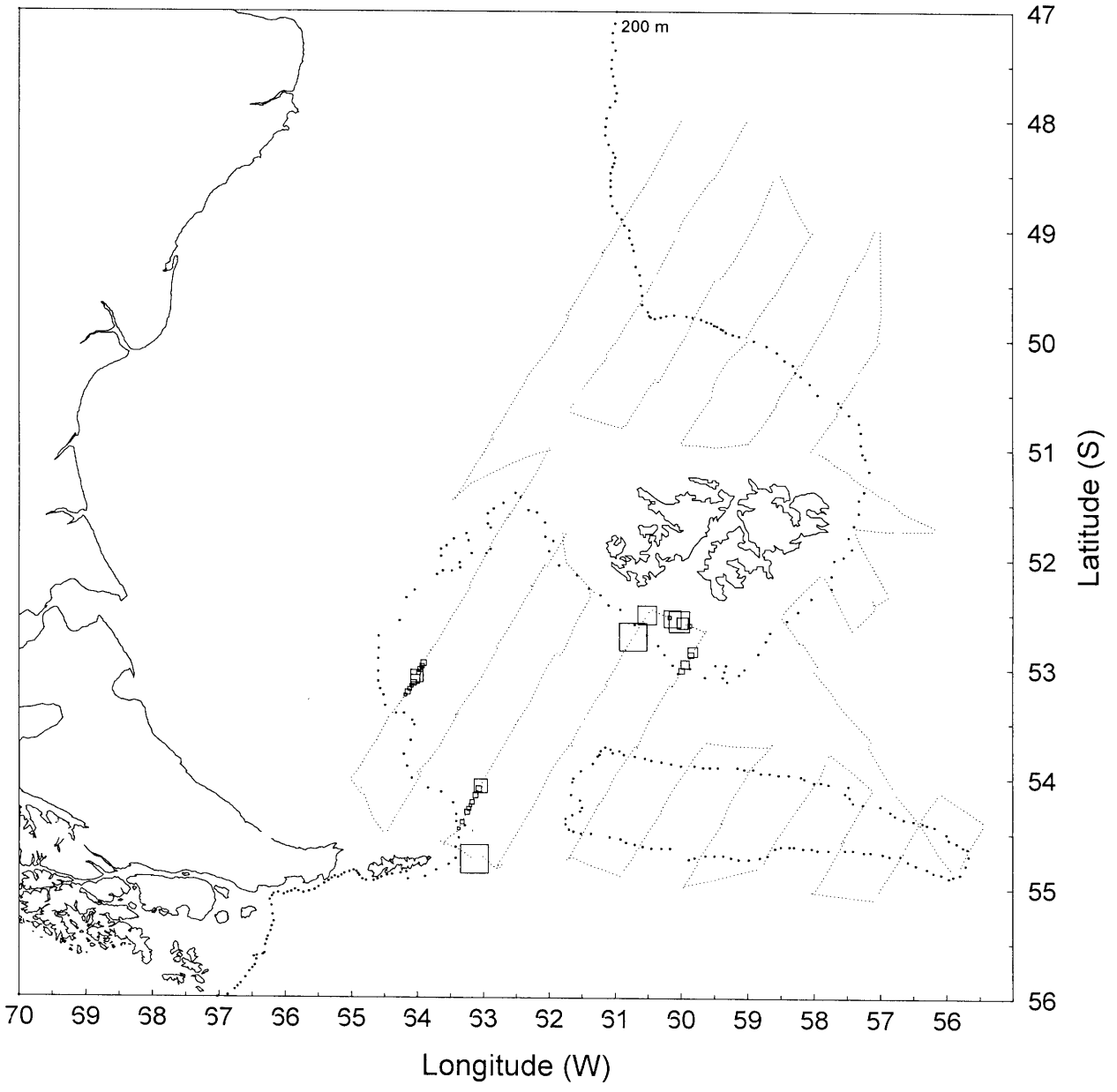

Figure 1 (A). Geographical distribution of blue whiting biomass density (OB-07/94). (Size of square symbols are proportional to square root of biomass density).

Figura 1 (A). Distribución geográfica de la densidad de biomasa de la polaca en la campaña OB-07/94. (tamaño de los símbolos proporcional a la raíz cuadrada de la densidad de biomasa)

Figure 1. (cont.)

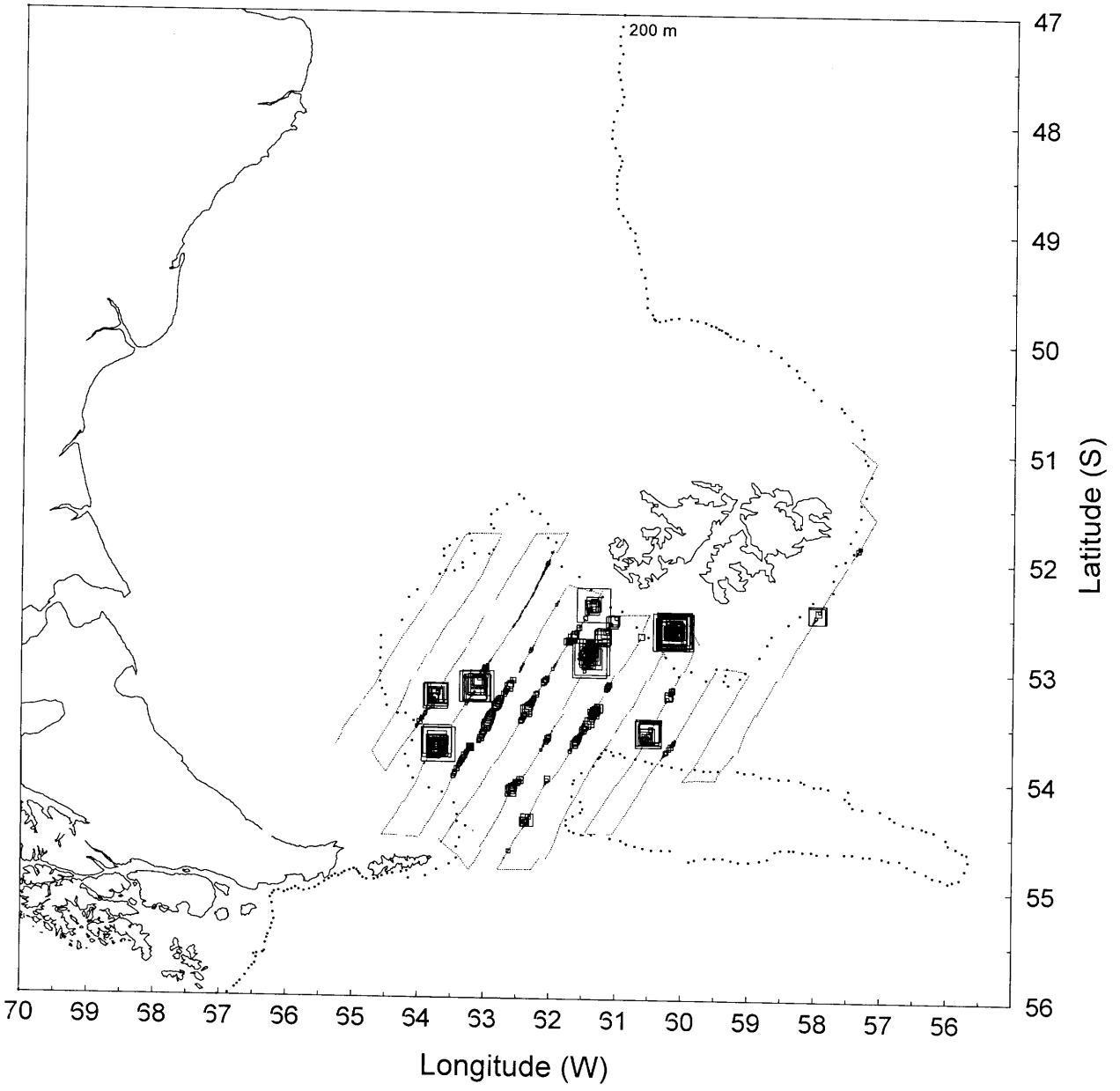

Figure 1 (B). Geographical distribution of blue whiting biomass density (OB-10/95). (Size of square symbols are proportiona to square root of biomass density).

Figura 1. (B). Distribución geográfica de la densidad de biomasa de la polaca en la campaña OB-10/95. (tamaño de los símbolos proporcional a la raíz cuadrada de la densidad de biomasa).

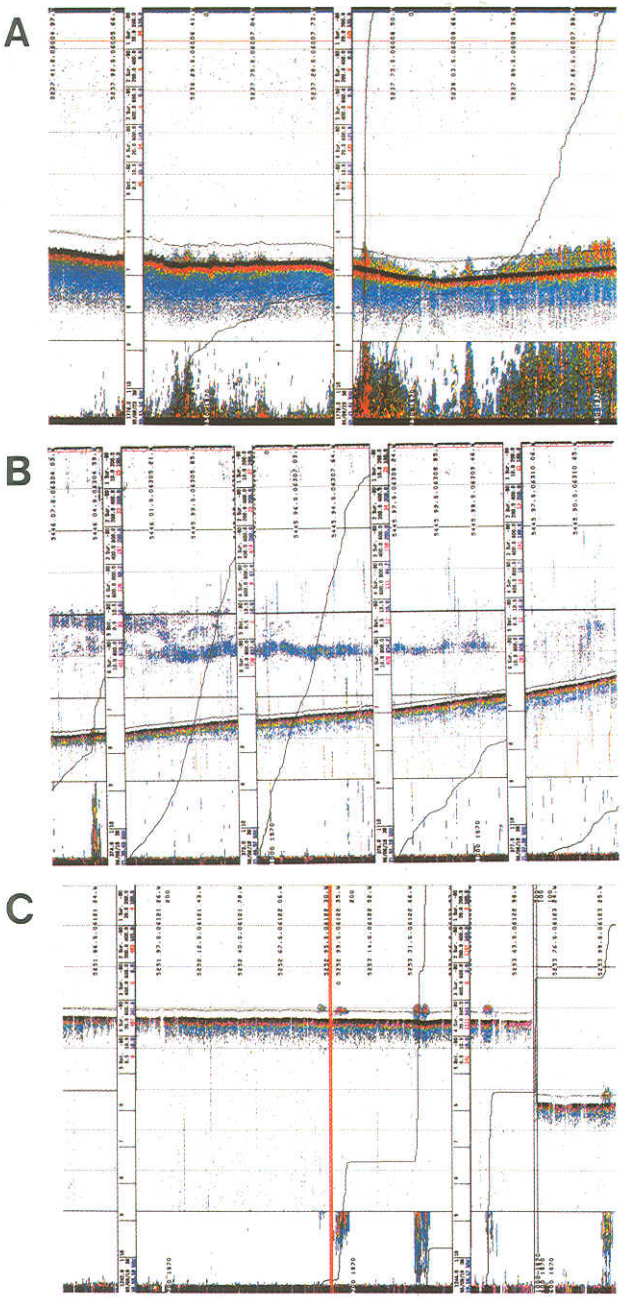

Figure 2 (A). Examples of echorecordings of southern blue whiting. Spawning fish concentration located south of San Carlos Strait. (05:00 GMT ; bot. Depth 170 m) *Ejemplos de registro ecoico de polaca. Concentración reproductiva de peces localizada al sur del Estrecho San Carlos. (05:00 GMT ; prof. fondo 170 m).* (B). Examples of echorecordings of southern blue whiting. School of adult fish located near Isla de los Estados. (22:00 GMT ; bot. Depth 600 m)

Figura 2 (A). *Ejemplos de registro ecoico de polaca.Cardumen de peces adultos ubicado cerca de la Isla de Los Estados. (22:00 GMT ; prof. fondo 600 m)* (C). Examples of echorecordings of southern blue whiting. Juvenile fish schools located south-west from Malvinas Islands. (19:00 GMT ; bot. Depth 370 m) *Ejemplos de registro ecoico de polaca. Cardúmenes de peces juveniles localizados hacia el sud-oeste de las Islas Malvinas. (19:00 GMT ; prof. fondo 370 m)*

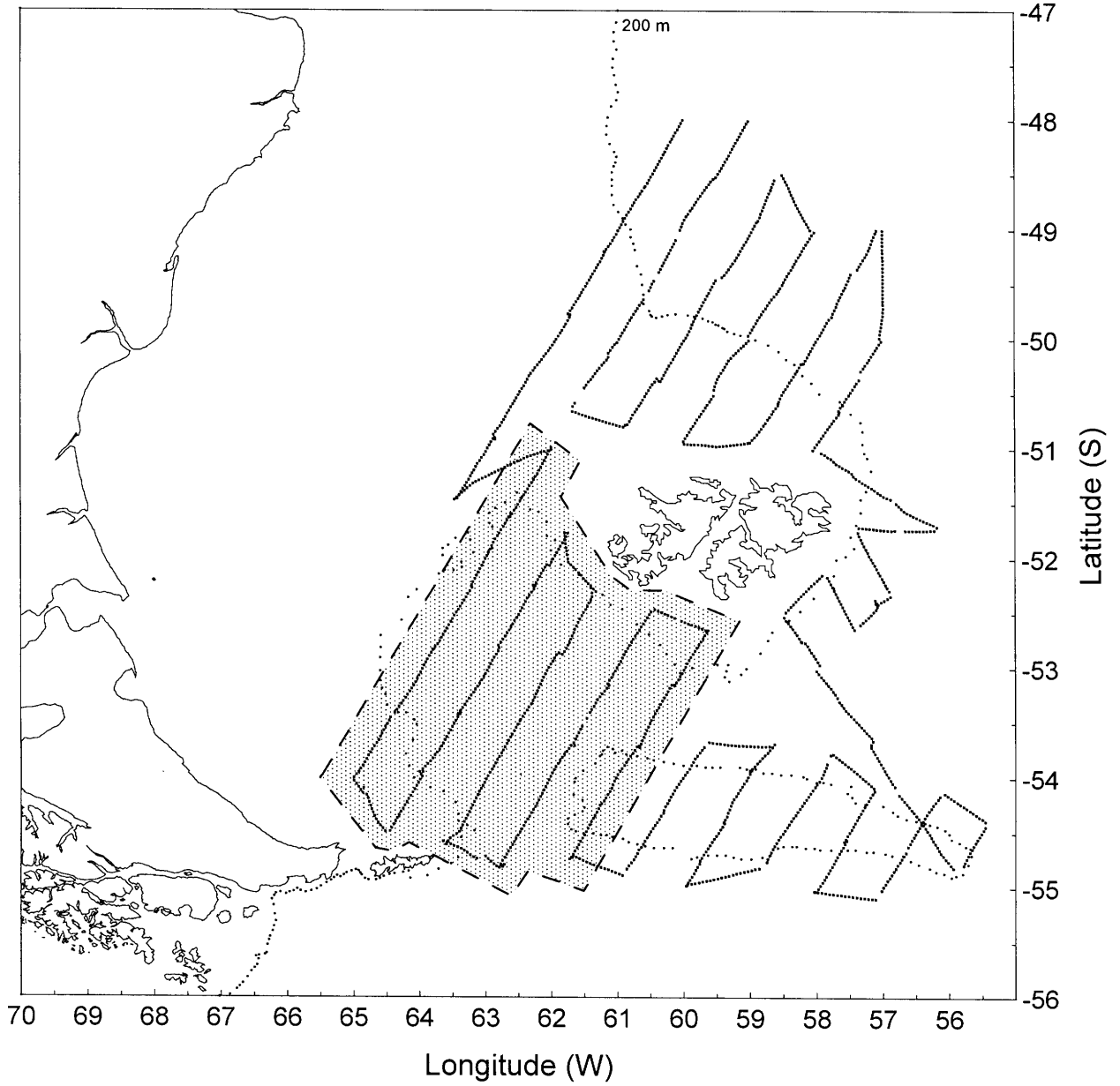

Figure 3 (A). Definition of the area for the biomass estimations (OB-07/94).
Figura 3 (A). Definición del área para la estimación de la biomasa (OB-07/94).

Figure 3. (cont.)

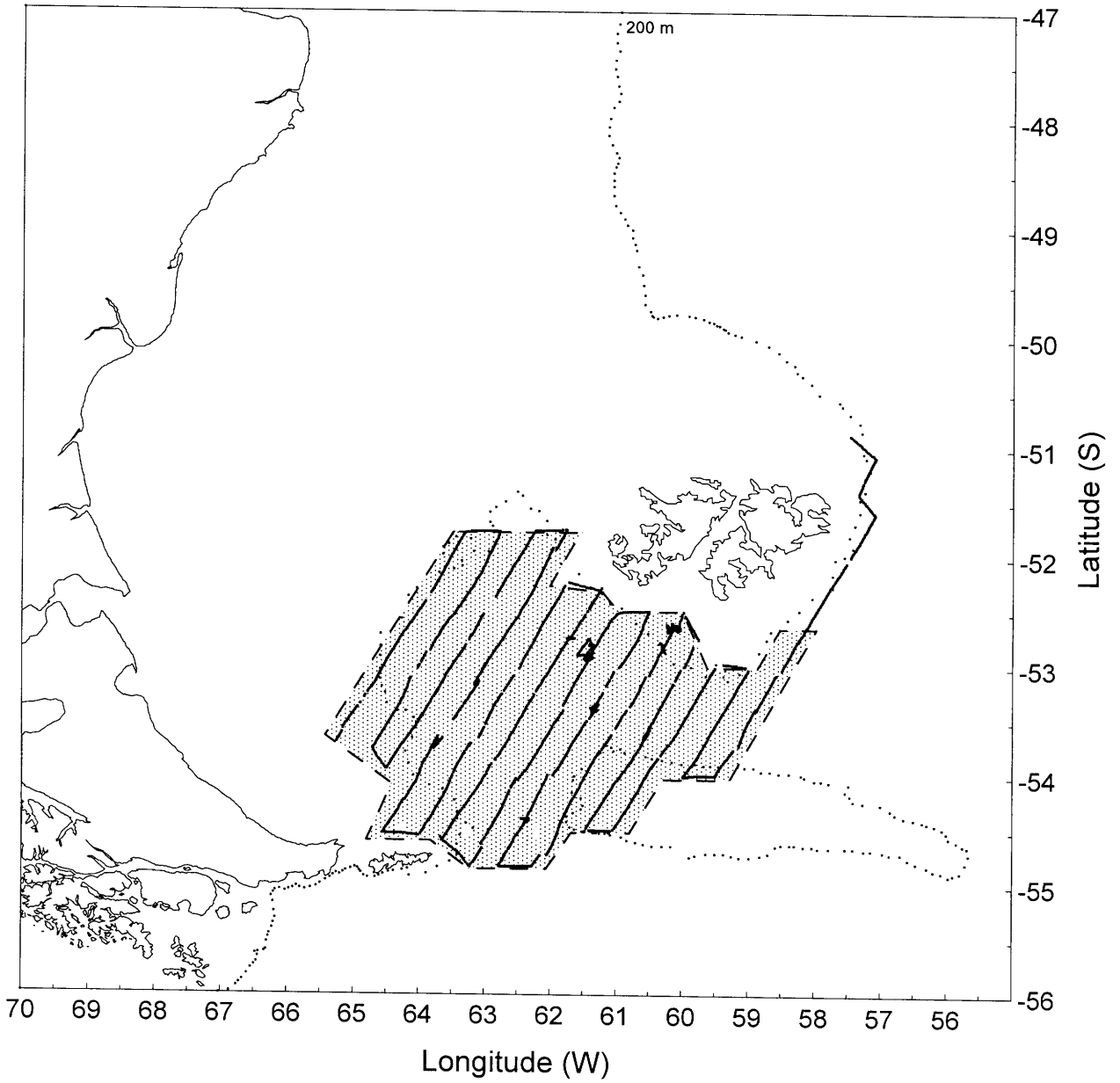

Figure 3 (B). Definition of the area for the biomass estimations (OB-10/95).
Figura 3 (B). Definición del área para la estimación de la biomasa (OB-10/95).

tionship could be developed and in order to maintain consistency between successive survey results.

Survey design

A scheme of parallel equally spaced transect was chosen as the sampling design for both surveys. The area established for the 1994 survey was based on historical catch data and ichthyoplankton samples, resulting in an extended area around Malvinas Islands. The survey design for 1995 was based on catch data only from recent years and consequently the survey area was restricted to the southern sector of the area covered in 1994. This allowed a better survey design with closer transects an thus an increased sampling effort compared to 1994. The sailed acoustic trackline were 3342 nm and 2380 nm for 1994 and 1995 surveys respectively.

RESULTS

Spatial distribution

Figure 1 (A and B) shows the geographical distribution of the values of blue whiting biomass density recorded in the survey area. During the 1994 survey the presence of blue whiting concentrations was extremely rare while in 1995, if still scarce, blue whiting occurrence was much frequent. Blue whiting schools were recorded only south of Malvinas Islands, in the western side of Malvinas Channel (along the circular shaped slope) and in the west channel of Burdwood Bank. Schools depth ranged from 150 to 700 m. The shallowest schools (spawning blue whiting) were found on the Malvinas shelf, south from San Carlos Strait. Schools of juvenile fish were detected only in the 1995 survey near shore and south-west from Malvinas Islands.Figure 2 shows different examples of echorecordings of southern blue whiting concentrations. School size, density and position in the water column varied. Southern blue whiting aggregates forming deep pelagic schools which may occupy an area of several squared nautical miles and extend vertically several tenths of meters. These fish layers are generally found at depths ranging from 450 m to 600 m. Exceptionally, in deep waters blue whiting schools can be found as deep as 800 m. Schools si-tuate over the slopes and when a layer riches the bottom, at depths shallower than 450 m, fish form bottom layers that generally exceeds ten meters height. A rather moderate scattering of the schools is observed at night, as it is the vertical diurnal migrations. Juvenile fish were observed forming pelagic schools of relative small size, compared to adult fish, and scattering at night was more pronounced than in adult fish schools.

Spawning concentrations are characterized by a significantly higher fish density, modifying the appearance of the bottom layers by creating very dense and high bottom schools. Other, much less dense concentrations of blue whiting can be found on the bottom, at depths shallower than 400 m. This very low density concentrations mix with other bottom fish, as grenadiers, being difficult to discriminate between the different species in the echorecordings.

Biomass estimation

Since the area covered by the 1994 survey was much larger, the trackline was splitted into blocks of transects or strata for data processing. Four strata were defined, i.e. the Burdwood Bank, north, east and south Malvinas area. Only the stratum defined south of Malvinas Islands contained non zero values. The whole survey area for 1995 was in fact approximately limited to the southern strata of 1994. No stratification was applied to the 1995 survey data. Figure 3 (A and B) shows the definition of the area corresponding to the biomass estimations. As it

can be seen in Figure 3A (1994 survey), the inter-transects containing non zero values indicated a distribution area extending beyond the ends of the transects. Consequently the values recorded along the inter-transects were utilized to estimate the abundance in that survey, and the corresponding sampling area was extended. In 1995 no schools were observed along the inter-transects and hence the area considered for the estimation of the biomass was restricted to the ends of the transects (Figure 3B).

Equally spaced transects are considered to be a systematic sampling design, having the advantage of a good coverage of the area (better representation of the geographic distribution). However, selection of the best estimator for the variance of the estimated mean fish density, has been a well known object of controversy (Aglen, 1989; Jolly and Hampton, 1990; Foote and Stefansson, 1993). In the present work the simple random sampling estimator is utilized with the only aim to facilitate a comparison between surveys.

Table 1 contains the results of the biomass estimation corresponding to the 1994 and 1995 surveys. The estimates were obtained utilizing the TS model corresponding to *Micromesistius poutassou.*

DISCUSSION AND CONCLUSIONS

Very low biomass estimations resulted from both, 1994 and 1995 surveys. It is known that annual catches of blue whiting were comparable to these figures and hence obviously none of the survey estimates accounted for the total biomass of the stock. However, it is believed that the estimates produced by the surveys agree with the fraction of the biomass that was present in the spawning area. The major catches made by the commercial fleet at the time of the surveys corresponded to the same locations where the concentrations of blue whiting were detected. The ichtyoplankton samples also confirmed that there was no spawning activity in areas other than those where the concentrations were recorded.

Migration in the NE direction of large schools of blue whiting found near Isla de los Estados was observed during the surveys. This behavior was also reported by the INIDEP observers onboard the commercial fleet. The schools probably enter the spawning area through the west channel of Burdwood Bank and move along the slope, at depths from 300 to 600 m, towards Malvinas Islands where schools are found on shallower bottoms and major spawning activity was recorded.

This notably migratory behavior could be the explanation for the low biomass point estimates.

Table 1. Abundance estimates for the 1994 and 1995 surveys.
Tabla 1. Estimaciones de abundancia para los cruceros de 1994 y 1995.

Survey ---	TS model ---	Mean Biomass Density [t/mn^2]	C. V. [%]	Area [mn^2]	Biomass [t]
OB-07/94	*Micromesistius poutassou*	3.15	34	26884	84801
OB-10/95	*Micromesistius poutassou*	5.74	13	24551	140953

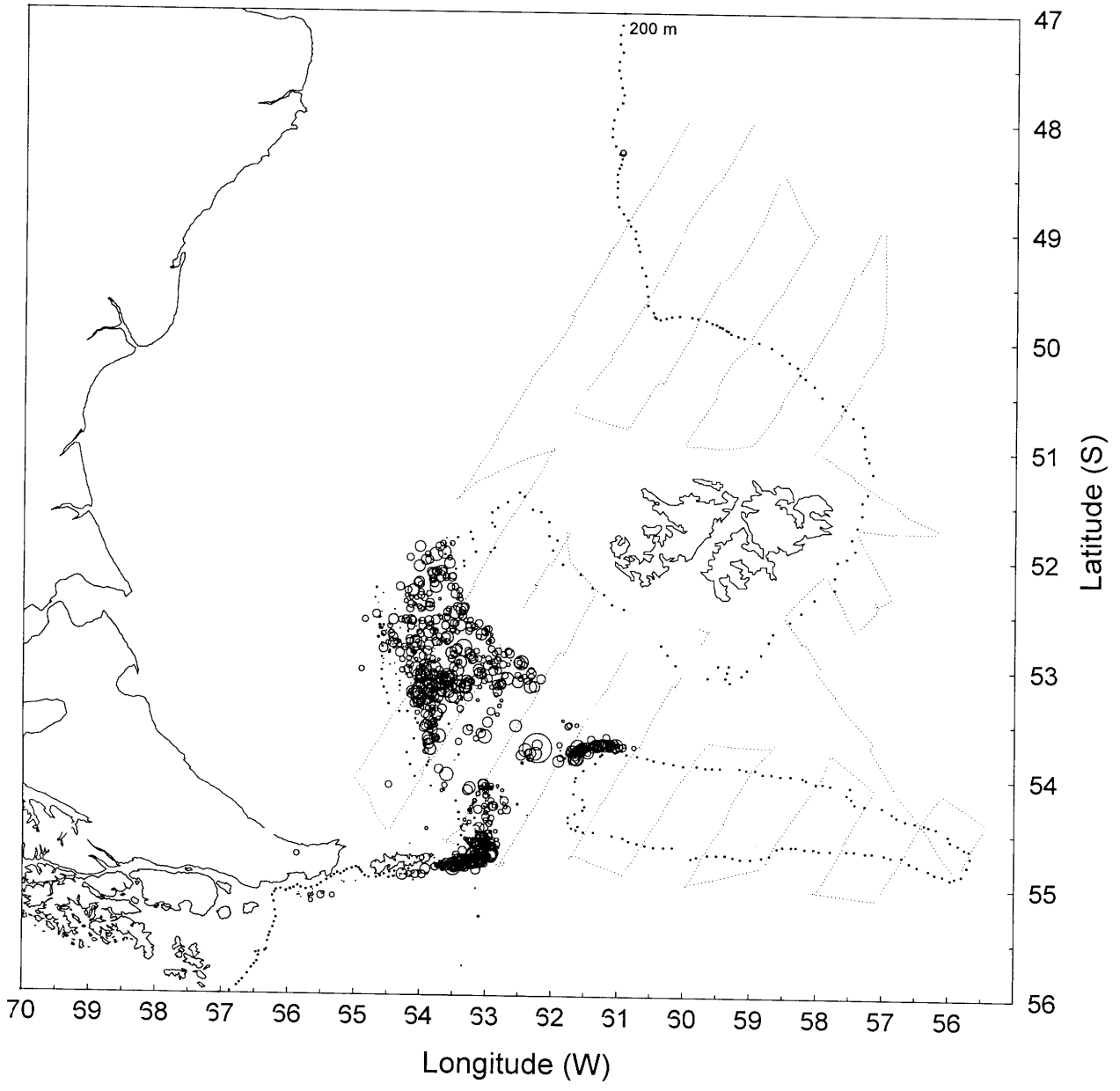

Figure 4. Positions and relative size of catches made by the commercial fleet in the period 1993 - 1996. (data from INIDEP Observers project)

Figura 4. Posiciones de las capturas de polaca realizadas por la flota comercial durante el período 1993 - 1996.

According to Macchi and Pajaro (in this volume) instead of a unique massive spawning concentration of the stock, the fish might aggregate forming different spawning concentrations. If this is the case, different schools could move in and out the spawning grounds at different times during a spawning season which continues for some months.

Methodology and equipment employed in the surveys seems to be adequate for sampling blue whiting biomass density. If a rather low sampling effort can be attained to the 1994 survey, the design for 1995 was substantially improved by limiting the area and reducing the distance between transects to approximately 22 nm, which stands for a more appropriate sampling effort. Also the survey area appears to be adequate as indicated by the operations of the commercial fleet in recent years. Data obtained from the INIDEP project *Observers on board the commercial fleet* are shown in Figure 4 for the period 1993 - 1996, where the positions and the relative size of the blue whiting catches are indicated by circles (circles made proportional to catches).

If the described behavior of the southern blue whiting is confirmed then, at least from a practical point of view, no point estimate of the total biomass of the stock would be possible from a survey alone. The validity of an annual point biomass estimate as an index and its contribution to other methods for determining the biomass of the stock (e.g. VPA) has to be analyzed.

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