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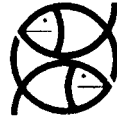
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Agosto 1999

REPRODUCTIVE HABITAT, BIOLOGY AND ACOUSTIC BIOMASS ESTIMATES OF THE SOUTHERN BLUE WHITING (*Micromesistius australis*) IN THE SEA OFF SOUTHERN PATAGONIA

Edited by Ramiro P. Sánchez

Secretaría de Agricultura, Ganadería, Pesca y Alimentación
Instituto Nacional de Investigación y Desarrollo Pesquero - INIDEP
Mar del Plata, R. ARGENTINA



República Argentina

**Instituto Nacional de Investigación y Desarrollo Pesquero
INIDEP**

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COMENTARIO PRELIMINAR

Si bien en forma ocasional la plataforma patagónica austral había sido explorada por campañas de investigación oceanográfico-pesqueras durante de los sesenta, no fue sino hasta fines de la década siguiente, y como resultado de sendos programas de cooperación internacional con los gobiernos de la República Federal de Alemania y Japón, que pudo alcanzarse una cobertura completa del área, estacionalmente repetida. El valor de estos estudios sobre recursos que, a la sazón, podían considerarse vírgenes, adquirió significativa importancia, ante la desmedida intensificación de la actividad extractiva en los ochenta, la cual no fue lamentablemente acompañada por programas de investigación que permitieran monitorear la evolución de las poblaciones ante el incremento del esfuerzo pesquero sobre ellas aplicado.

En el curso de los años recientes el INIDEP ha incrementado notablemente, la asignación de recursos económicos y humanos al estudio de dos de los recursos pesqueros más importantes de la región: la polaca (*Micromesistius australis*) y la merluza de cola (*Macruronus magellanicus*). En la actualidad, tres proyectos de la institución y un proyecto de cooperación técnica con Japón, tienen como objetivo el estudio de diferentes aspectos de la dinámica poblacional, evaluación y biología de esas especies. La creciente cantidad de información obtenida como resultado de la adecuada cobertura espacio-temporal del área de estudio, mediante buques de investigación y observadores a bordo de la flota comercial, nos ha permitido profundizar en nuestro conocimiento sobre el estado de estos recursos y comparar la situación actual con la que se observaba veinte años atrás.

Ha sido nuestra intención, al preparar este documento, reunir y sintetizar los conocimientos disponibles sobre la biología reproductiva de la polaca en la región austral del Mar Argentino. Se incluyen en el mismo tres trabajos en los que se hace referencia a las características ambientales que prevalecen en las áreas de puesta de la especie, un trabajo sobre su biología reproductiva y una caracterización acústica de la estructura de los cardúmenes y evaluación de las concentraciones reproductivas que corresponden a la región malvinense. Algunos de estos estudios se han iniciado recientemente en el INIDEP, otros tienen ya una cierta tradición institucional. En consecuencia, el alcance y profundidad del análisis difiere, en cada caso, según la disponibilidad de información actual y referencias históricas.

Los estudios oceanográficos se centraron en el análisis de las condiciones termo-halinas prevalecientes en invierno en la región sud-oriental de la plataforma continental y talud argentinos. Las masas de agua en el área derivan del estrato superior del Agua Intermedia Antártica, modificada por interacción con las aguas diluídas de plataforma. Se observaron variaciones interanuales en los campos térmicos. El invierno de 1995 fue el más frío en el

período analizado. Pudo definirse un intenso frente de talud en el borde oeste del canal situado entre la Isla de los Estados y el Banco Burdwood, el cual parece presentar un impacto biológicamente significativo sobre el comportamiento reproductivo de la especie.

Sabatini *et al.* describen en forma sinóptica la distribución de las biomásas zooplanctónicas durante el pico de desove invernal, a partir del análisis de dos campañas de investigación recientes, y comparan estos datos con informes previos de la abundancia zooplanctónica en la región malvinense durante el invierno y en la plataforma patagónica austral durante la primavera y el otoño. Los autores concluyen que, a pesar de ciertas diferencias, atribuibles a los métodos de muestreo empleados en cada caso, no existen evidencias que permitan suponer la existencia de cambios de relevancia en la composición específica o en la abundancia del zooplancton durante los últimos veinte años.

Por el contrario, la distribución y composición del ictioplancton en la región, tal como se observan en la actualidad, contrastan marcadamente con las descritas en trabajos previos. Se observa en particular una retracción del hábitat reproductivo de la polaca, y una ausencia total de formas embrionarias y larvales de *Salilota australis*, de ocurrencia frecuente en el pasado. La incorporación de nuevos sistemas de muestreo y el progreso alcanzado en el reconocimiento de los componentes del ictioplancton han permitido reseñar por primera vez, la presencia y distribución de larvas de varias especies de mictófidios, estudiar mediante análisis de clasificación jerárquica la existencia de asociaciones entre distintos niveles de la comunidad ictioplanctónica y su relación con las características del ambiente físico, y describir la estructura de tallas de las poblaciones de post-larvas y juveniles primarios de polaca y sardina fueguina.

Los estudios sobre la biología reproductiva de la especie, ponen de manifiesto que se trata de un desovante parcial, con fecundidad determinada. Se analiza asimismo la estacionalidad de la actividad de puesta y se propone una escala de madurez específica. Si bien los estimadores preliminares de la fecundidad caen dentro del rango de valores previamente calculados para la especie, la talla de primera madurez parece haber decrecido en relación con los valores calculados veinte años atrás.

Finalmente, el relevamiento acústico ha permitido describir la distribución en el plano geográfico y en la columna de agua y estimar las biomásas de las concentraciones reproductivas. El tema de la fuerza de blanco, una cuestión metodológica importante en este tipo de análisis, es tratado en detalle. Se discute también sobre la dificultad de obtener anualmente un estimador instantáneo de la población en puesta a partir de este tipo de metodología.

Confiamos que el material aquí presentado pueda servir como base para futuras investigaciones. Nuestra intención al presentar este documento ha sido poner de relieve los aportes de algunas líneas de investigación que merecen continuarse e intensificarse. Recién entonces estaremos en condiciones de encarar cuestiones fundamentales que nos lleven a comprender cuáles son los mecanismos biológicos que pueden permitir a la polaca equilibrar las pérdidas causadas por la actividad extractiva y de qué modo el ambiente es capaz de condicionar la distribución, abundancia y fluctuaciones de la especie.

EL EDITOR

FOREWORD

Although occasional oceanographic and fisheries surveys of the sea off southern Patagonia began in Argentina during the 60's, the first seasonal coverage of the complete area was attained only by the end of the 70's, as a result of joint international scientific programmes with the Federal Republic of Germany and Japan. The value of these studies on resources that were at the time unexploited was enhanced in view of the uncontrolled rise of fishing during the following decade, that was unfortunately not supported by research programmes aiming at monitoring the response of the stocks under increasing fishing effort.

In the course of recent years INIDEP remarkably increased the allocation of economic and human means to the study of the major finfish of the region: the southern blue whiting (*Micromesistius australis*) and the hoki (*Macruronus magellanicus*). Three INIDEP's projects, and one technical co-operation programme with Japan target on different aspects of the population dynamics, assessment and biology of these species. The large amount of information derived from the enhanced time-space coverage of the area has widened the scope of our understanding of these resources, and allows comparison of recent results with those of the late 70's.

Our primary aim in preparing this document was to bring together and summarize what is known about the spawning activity of the southern blue whiting in the southern region of the Argentine Sea. It comprises three scientific contributions referring to environmental characteristics which prevail in the spawning habitat of the species, a paper on its reproductive biology, and an acoustical description and assessment of spawning concentrations of the southern blue whiting around Malvinas Islands. Some of these studies have been recently undertaken, others have a certain tradition in INIDEP. Consequently the scope and extent of each analysis differ in relation to the availability of previous and present information.

Oceanographic studies were focused on the analysis of winter thermo-haline conditions in the SE region of the Argentine continental shelf and slope. Water masses in the area are derived from the lighter upper stratum of the Antarctic Intermediate Water, after being modified by interaction with shelf diluted waters. Inter-annual variations were observed in the temperature fields. Winter 1995 was the coldest over the period analysed. A sharp shelf break front was defined at the west border of the channel between Staten Island and Burdwood Bank, which has a significant biological impact on the reproductive behaviour of the species.

Sabatini *et al.* report on the synoptic distribution of zooplankton biomass during the winter spawning peak based on the analysis of two recent surveys, and compare these data with previous reports on zooplankton abundance around the Islands in winter, and on the southern Patagonian shelf in autumn and spring. The authors conclude that in spite of some differences which may be attributed to sampling methods, there is no evidence to suspect major changes in specific composition or abundance of zooplankton in the last 20 years.

Conversely, the regional ichthyoplankton distribution and composition presents some striking con-

trasts with those of previous reports, particularly in relation with a contraction of the spawning grounds of the southern blue whiting and the total absence of *Salilota australis*, commonly observed in the past. The incorporation of new sampling devices and the progress in the identification of the main ichthyoplankton components allowed to report for the first time on the occurrence and distribution of larvae of several myctophiid species, describe through hierarchical classification the relationship between larval group and physical characteristics, and present length frequency distributions of post-larvae and early juveniles of sprat and blue whiting.

Results on the reproductive biology reveal that the species is a partial spawner with a determinate fecundity. Based on histological and macroscopical analysis the seasonality of spawning activity is discussed, and a maturity scale is proposed. A preliminary fecundity estimate fell in the range of values previously reported. On the other hand the size at first maturity seems to have decrease as compared to that reported for the late 70's.

Finally, the paper on acoustic focuses on the geographical occurrence, spatial distribution and biomass estimates of spawning concentrations. Target strength, an important methodological issue to this type of analysis, is addressed in detail. The difficulty of obtaining accurate point estimates of spawning biomass through a single acoustic survey is discussed.

We hope that the material discussed herein may serve as a basis for future scientific activities. Our intention in presenting this document was to point out some fields of research that deserve to be continued and intensified. We may then be in a position to address such fundamental questions as the biological mechanisms that may allow the southern blue whiting stocks to compensate for losses due to fishing and the possible linkages between the environmental forces that control the species distribution, abundance and fluctuations.

The Editor

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ZOOPLANKTON BIOMASS IN THE REPRODUCTIVE AREA OF THE SOUTHERN BLUE WHITING (*Micromesistius australis*)

by

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RESUMEN

Biomasa del zooplancton en el área reproductiva de la polaca (*Micromesistius australis*). Se analizó la biomasa zooplanctónica total y por fracciones (mayor y menor de 5 mm) durante dos campañas de investigación realizadas en inmediaciones de las Islas Malvinas en invierno tardío (septiembre 1994 y 1995), cuando normalmente se produce el desove masivo de polaca. La distribución de biomasa en el área fue casi uniforme y estuvo dominada por la fracción mayor de 5 mm, donde euphausiidos, y en segundo término chaetognatos, predominaron tanto en peso como en número. La fracción menor estuvo mayormente constituida por copépodos. A partir de la predominancia de euphausiidos y de la abundancia estacional de varias especies de copépodos comunes en el área, se especuló que en momentos del desove invernal, los requerimientos alimenticios de todos los estadios de desarrollo de la polaca estarían satisfechos. Los datos fueron asimismo examinados en el contexto de los valores de biomasa zooplanctónica obtenidos en aguas de plataforma surpatagónica durante otoño y primavera.

SUMMARY

Total and size-fractioned zooplankton biomass (larger and smaller than 5 mm) were analysed over two cruises conducted in the late austral winter (September 1994 and 1995) in the area surrounding Malvinas Islands at the time that massive spawning of southern blue whiting was expected to take place. Biomass was rather uniformly distributed in the area and dominated by the fraction larger than 5 mm in which euphausiids and secondarily chaetognaths were dominating in terms of both weight and number. The smaller fraction was mostly made up of copepods. From the high occurrence of euphausiids and seasonal abundance of the several species of copepods normally present within the

area it was hypothesised that the feeding requirements of juvenile and adult blue whiting as well as those of larvae and post-larvae may be met during the winter spawning season. The data were also examined in conjunction with the general pattern of zooplankton biomass occurring in autumn and spring in the Southern Patagonian shelf.

Key words: Zooplankton biomass, Malvinas Islands, Southern Patagonian shelf, southern blue whiting, *Micromesistius australis*.

Palabras claves: Biomasa zooplanctónica, Islas Malvinas, plataforma surpatagónica, polaca, *Micromesistius australis*.

INTRODUCTION

Understanding plankton-fish linkages has always been a major issue in fisheries ecology. In recent years more attention has been driven to zooplankton, along with the increasing awareness of the pivotal role that zooplankton might have -directly coupled with ocean physics- in controlling both the magnitude and fate of primary production and the inter-annual variability of important fish stock (e.g. Kiørboe, 1991; Banse, 1995). It is known that the fisheries potential of a region is ultimately determined not only by the magnitude of primary production but also by the length of the food chain, which in turn will affect the fraction of primary production that is available to zooplankton and to planktivorous fish (Cushing, 1989; Kiørboe, 1993). Therefore, long-term variations in the year class success of many fish stocks might be largely explained from the predictive knowledge of the relationships between fish and their zooplankton food, linked to the changing physics of the environment.

It was just in the late 70's that research surveys started to be carried out systematically in the Argentinian shelf and adjacent waters to the south of 45°S in coincidence with the increasing fishing levels of the southern Patagonian resources which, up to then, had been almost unexploited (Ehrlich and Sánchez, 1990 and Angelescu and Sánchez, 1995).

The most complete environmental sampling regarding the basic hydrography and plankton of the entire region was provided by the 'Walther Herwig' and 'Shinkai Maru' surveys (1978-1979). Although

they were primarily addressed to fisheries assessment, the resulting data set was exceptional in covering extensively all seasons and allowed to outline by the first time the seasonal pattern of zooplankton biomass related to the nutrient dynamics and phytoplankton cycle (Carreto *et al.*, 1981a, b) as well as to the abundance of fish eggs and larvae (Ciechomski and Sánchez, 1983). The distribution and abundance of the dominating copepod species were also reported in detail (Ramírez, 1981). Up to then, only occasional references to zooplankton topics were available for the Southern Patagonia (e.g. Montú, 1977; Ramírez, 1971; 1973; Ramírez and Dato, 1983).

Surveys to the south of 50° S were disrupted in 1982 as a consequence of the Malvinas War. Fisheries assessment cruises, and thus plankton sampling, were restarted only in 1992. Unfortunately, this situation left behind an about ten years gap of information between the formerly gathered data series and the most recent collections.

Two joint Argentina-United Kingdom cruises were conducted in the late austral winter (September 1994 and 1995) with the overall aim of assessing the spawning stock biomass of the southern blue whiting *Micromesistius australis*. Reproduction of the species appeared to take place around the Malvinas Islands (Perrotta, 1982; Sánchez *et al.*, 1986) where besides most of the fishing stock is concentrated (Sánchez and Ciechomski, 1995). This paper focuses on the pattern of zooplankton biomass occurring at that time in the Southern Patagonian shelf and adjacent waters. These data are brought into the perspective of the current background on the production cycle in the region. The ecological implications for

the southern blue whiting fishery and their possible management significance are examined hereof.

MATERIAL AND METHODS

Field data presented in this study were collected on cruises with the R.V. 'Capitán Oca Balda' (National Institute for Fisheries Research and Development, Argentina). Data obtained in the area around the Malvinas Islands and neighbouring waters were gathered through two acoustic surveys carried out in September 1994 (R.V. 'Cap. Oca Balda' 07/94) and 1995 (R.V. 'Cap. Oca Balda' 10/95) which were specifically aimed to assess the spawning stock of southern blue whiting in the area.

In order to better depict the overall zooplankton pattern in the region the results of the above surveys were examined in conjunction with those of two fisheries oceanographic cruises conducted in the austral autumn (April, R.V. 'Cap. Oca Balda' 04/94) and spring (November, R.V. 'Cap. Oca Balda' 09/94) 1994 on the Argentinian continental shelf between 47° and 55° S. In any case zooplankton sampling fitted the general sampling design of the cruises primary focused on stock biomass assessment. A transect sampling strategy designed for basic hydrography (CTD) and plankton was additionally carried out at 47° and 51° S on the autumn and spring cruises. The samples obtained along those transects were used to analyze the latitudinal and longitudinal variation of zooplankton biomass and composition on a temporal scale.

Zooplankton samples were collected with a Nackthai sampler (400-500 µm mesh size) towed obliquely through the water column from near the bottom to surface or from a maximum depth of 500 m at deeper stations. Depth and towing speed were monitored by means of a depth sensor outfitted to the gear. A flowmeter was used to estimate the water volumes.

Wet weights were determined either on board immediately after collection or samples were preserved in 5% buffered formalin for the subsequent analysis in the laboratory. Macrozooplankton was sorted into two size fractions (larger and smaller than 5 mm) by sorting individually the animals with tweezers. The remaining smaller fraction as well as the sorted groups (euphausiids, hyperiid amphipods and chaetognaths) were weighted separately by using a small manual scale (± 0.2 g) after removing as much water as possible. The smaller fraction was mostly made up of copepods, though occasionally ostracods, euphausiids, other crustacean larvae and fish eggs were also present. Group dominance (%) in the larger fraction was also estimated. The sum of the two fractions is referred to as 'total' zooplankton biomass herein, although it quite clearly omits the small copepods and microzooplankton. Yet, major trends in copepod abundance can be presumed from the signal provided by the larger copepod species which were effectively retained by the mesh (400 - 500 µm).

In view of the general pattern of aggregation and vertical migration of the dominant groups (e.g. Greene *et al.*, 1989) only data obtained at dusk-, dawn- or night-time were included in this study.

RESULTS

Total zooplankton biomass and size composition measured in the spawning area of *M. australis* in late winter are shown in Fig. 1. Since no significant differences were found between biomass concentrations occurring in September 1994 and 1995, all the data were pooled together. Maximum biomasses (ca. 300 - 500 mg m⁻³) were found over the continental shelf, and at stations deeper than 200 m located to the NE and SW of the Malvinas Islands and towards the eastern part of the Burdwood Bank (ca. 200 mg m⁻³). Minimum values (< 30 mg m⁻³)

were found to the south of Tierra del Fuego and in the vicinity of the Staten Island. Biomass was quite dominated by the fraction larger than 5 mm, the smaller one showing values lower than 10 mg m^{-3} in the 70 % of the catches. Euphausiids and secondarily chaetognaths were dominating in terms of both weight and number over the entire area (Fig. 2).

While euphausiids were numerically more abundant over the continental shelf, chaetognaths were located in deeper areas, mainly over the slope (Fig. 3).

The autumn data (April, Fig. 4) available for the southwestern Malvinas area indicate no changes either in the average magnitude or size composition of zooplankton biomass in comparison with the situ-

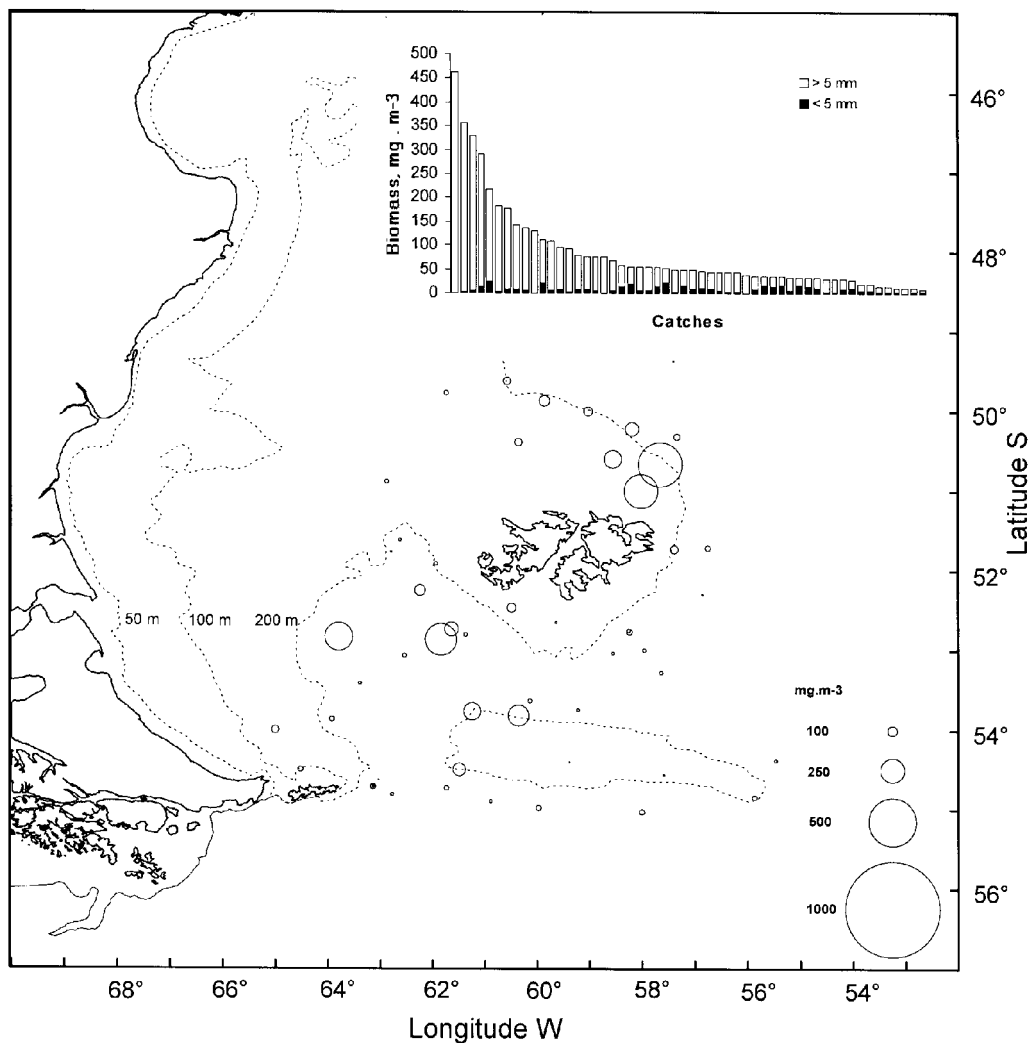


Figure 1. Total and size-fractionated zooplankton biomass (wet weight) occurring on the Argentinian continental shelf around the Malvinas Islands and adjacent waters in the late austral winter. Data collected during September 1994 and 1995 were pooled together.

Figura 1. Biomasa zooplanctónica total y por fracciones (en peso húmedo) registradas en la plataforma continental argentina alrededor de las Islas Malvinas y aguas adyacentes en invierno tardío. Los datos colectados en septiembre 1994 y 1995 fueron graficados juntos.

ation found in late winter (September). Instead, the bulk of biomass in neritic and mid-shelf waters was quite different between ca. 50° and 52° S where concentrations ranging ~500 - 1500 mg m⁻³ were found in contrast with the low values occurring in >200 m depth waters.

Later in spring (November, Fig. 5), the total biomass occurring on the remainder adjacent shelf between 47° and 55°S was overall the same as that found around the Malvinas Islands, except for the maximum values (>1000 mg m⁻³) measured in neritic waters and to the northeast, approaching the shelf-

break. Contrastingly, the fraction smaller than 5 mm dominated over the continental shelf while within the area surrounding the Malvinas Islands the larger one did.

Some broad spatial and seasonal trends in zooplankton biomass were drawn by examining the patterns found along the transects performed at 47° and 51° S. The most complete series of data to analyze the latitudinal and longitudinal distribution of biomass was gathered in spring (November, Fig. 5). At this time the highest concentrations (~1300 mg m⁻³) were measured in the mid continental shelf at 47°S

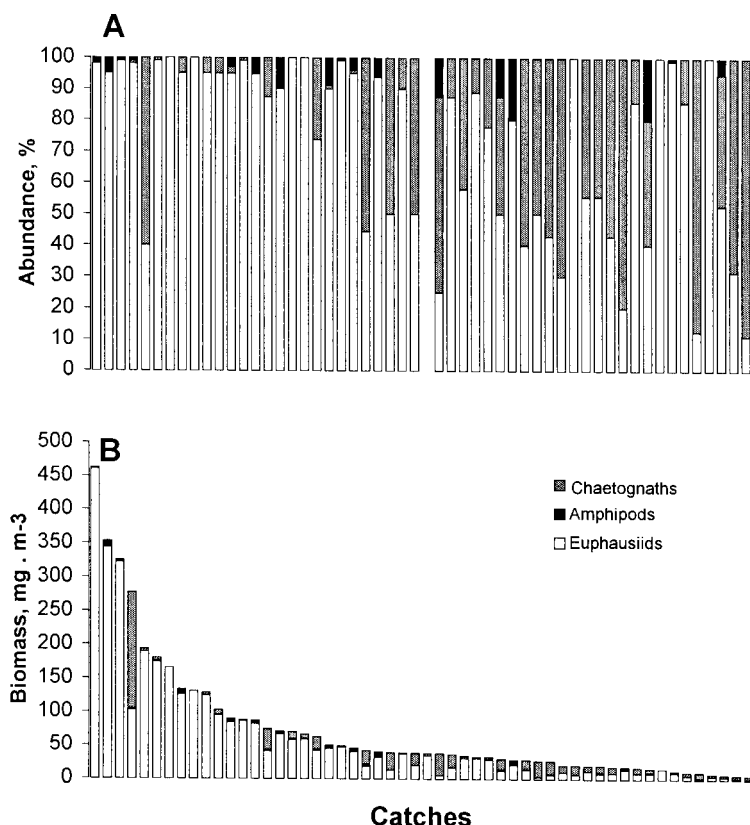


Figure 2. Contribution of major taxonomic groups to the larger fraction (> 5 mm) of zooplankton abundance (A) and biomass (B) in the Nackthai catches obtained in the area surrounding the Malvinas Islands and adjacent waters. Data collected during September 1994 and 1995 were pooled together.

Figura 2. Composición por grandes grupos taxonómicos de la fracción > 5 mm del zooplankton colectado en el área de Islas Malvinas y aguas adyacentes; A, Abundancia . B, Biomasa. Los datos colectados en septiembre 1994 y 1995 fueron graficados juntos.

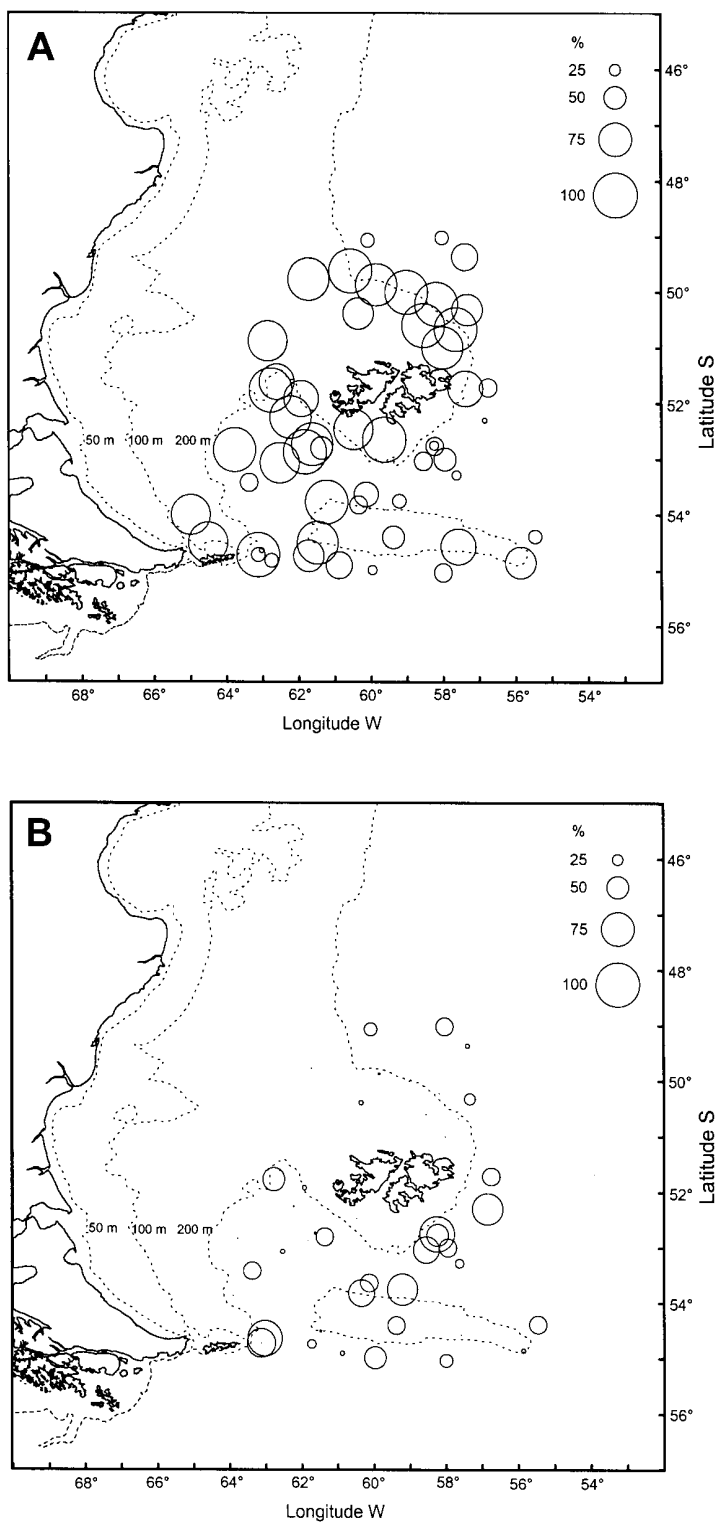


Figure 3. Abundance distribution (as percentage) of euphausiids (A) and chaetognaths (B) in the study area.
Figura 3. Distribución porcentual de la abundancia de euphausiidos (A) y chaetognatos (B) en el área de estudio.

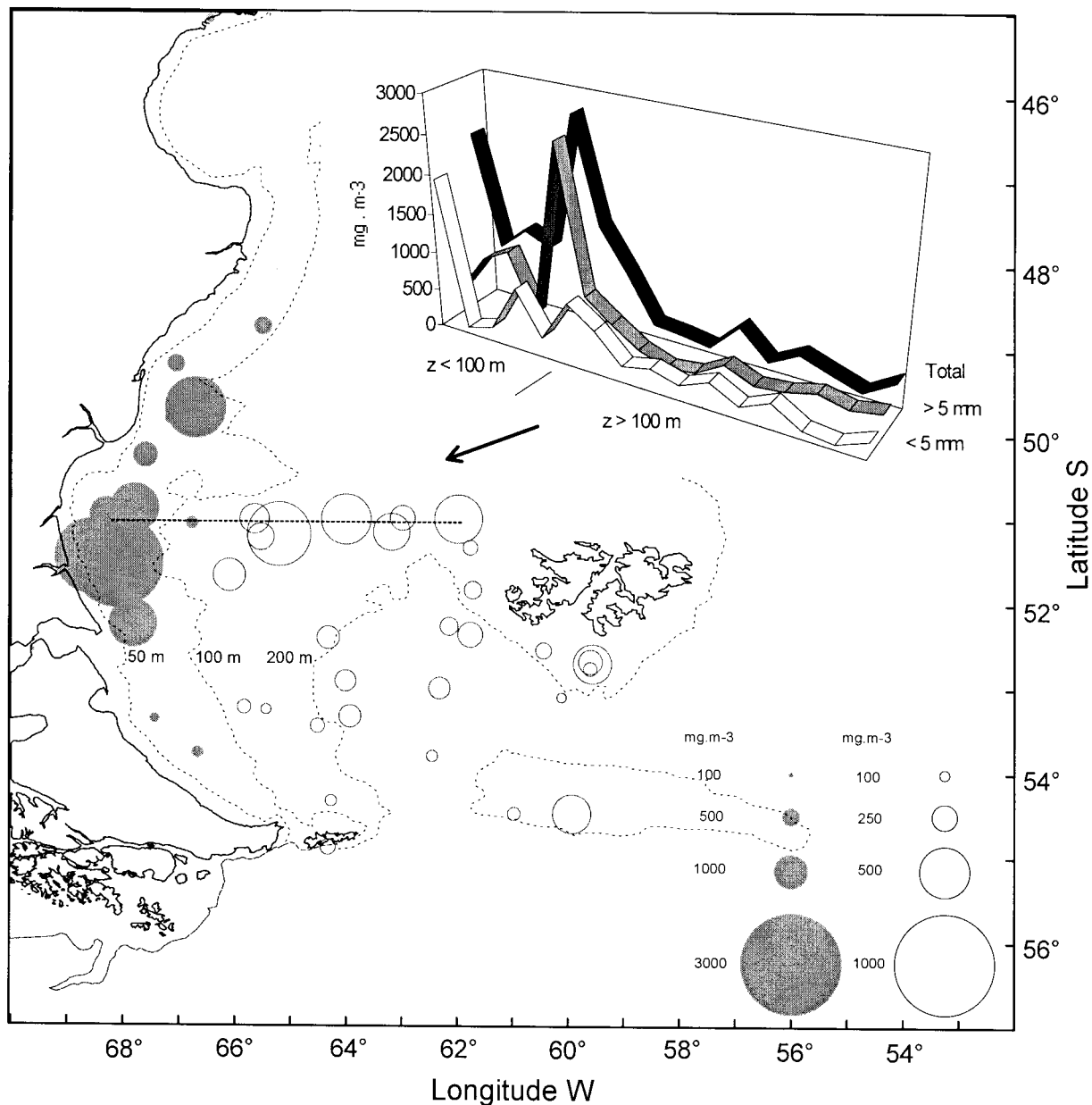


Figure 4. Total zooplankton biomass (wet weight) occurring on the shelf off Argentina and adjacent waters to the south of 45° S in the austral autumn (April 1994). Size-fractionated zooplankton biomass through the water column in shallower and deeper than 100 m depth along a transect at 51° S is shown in the upper panel.

Figura 4. Distribución de biomasa zooplanctónicas (peso húmedo) en la plataforma continental argentina y aguas adyacentes al sur de los 45° S en abril 1994. En el panel superior se muestra la variación de la concentración de las dos fracciones de tamaño desde profundidades menores de 100 m a mayores a lo largo de una sección ubicada a 51° S.

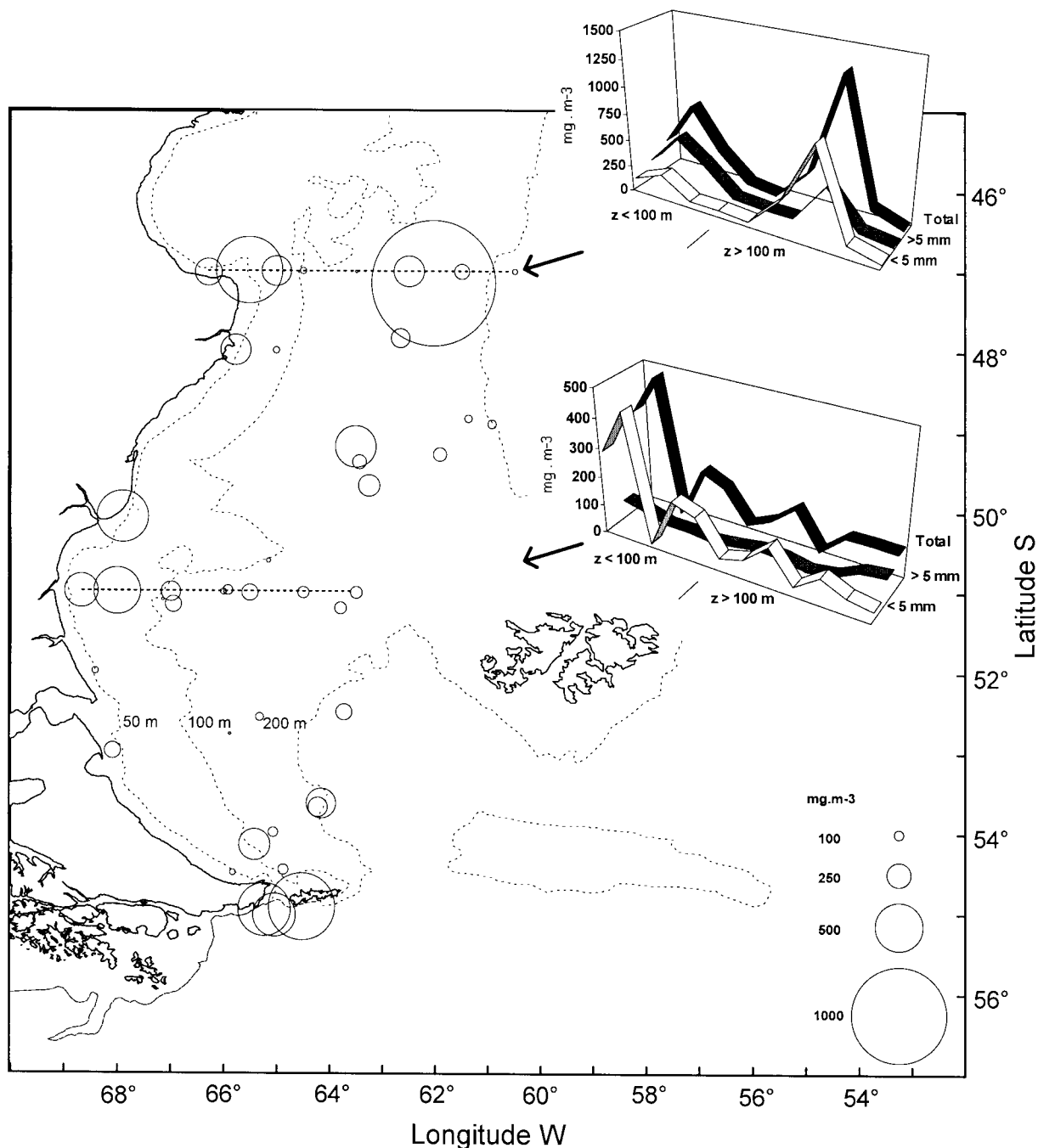


Figure 5. Total zooplankton biomass (wet weight) occurring on the shelf off Argentina and adjacent waters to the south of 45° S in the austral spring (November 1994). Size-fractioned zooplankton biomass through the water column in shallower and deeper than 100 m depth along two transects at 47° and 51° S is shown in the upper panels.

Figura 5. Distribución de biomasa zooplanctónicas (peso húmedo) en la plataforma continental argentina y aguas adyacentes al sur de los 45° S en noviembre 1994. En los paneles superiores se muestra la variación de la concentración de las dos fracciones de tamaño desde profundidades menores de 100 m a mayores a lo largo de las secciones ubicadas a 47° y 51° S.

with the smaller fraction -mainly copepods- accounting for up to 80% of total biomass. Lower values ($\sim 700 \text{ mg. m}^{-3}$), dominated by the larger fraction (mostly euphausiids and mysids), were found in $<100 \text{ m}$ depth waters. Total biomasses of about the same magnitude were also measured in neritic waters of the southern area (51° and 55° S) but the smaller fraction dominated (most of it made again of copepods representing $\sim 80\%$ of total biomass). At 51° S the larger one prevailed in the deeper area with dominance gradually changing from amphipods to euphausiids as distance offshore increased (no data available for the most southern area). It appears thus that in spring zooplankton biomass -consisting mainly of copepods- peaked offshore nearby the shelf-break in the northern area (47° S) while to the south (51° S) highest values occurred in neritic waters. In autumn (April, Fig. 4) highest biomass were located in neritic waters ($50 \text{ m} > z < 100 \text{ m}$) with values ranging $\sim 200 - 1500$, but up to 2500 mg. m^{-3} . In this area the larger fraction -mainly made up of hyperiid amphipods- was dominating. In deeper waters ($>100 \text{ m}$) both fractions contributed almost equally to total biomass (maximum values $\sim 700 \text{ mg. m}^{-3}$) but in the larger one the dominance gradually changed again from amphipods to euphausiids with increasing distance from the coast as it was observed in spring. Unfortunately there are no data available in this season for the further northern area.

On the account above, some main features - though based on quite limited data- may be outlined:

i) The outer continental shelf off Argentina surrounding the Malvinas Islands and the deeper adjacent waters located to the SW emerge as a distinct area where zooplankton biomass, primarily dominated by the fraction larger than 5 mm , is rather uniformly distributed (range $\sim 50 - 500 \text{ mg. m}^{-3}$) and likely shows a low seasonal variation, as suggested by the comparison of Fig. 1 and Fig. 4.

ii) Despite spatial fluctuations in abundance, euphausiids are most frequently present in large bio-

mass concentrations within the area around Malvinas and neighbouring waters.

iii) It appears that zooplankton biomass does not peak synchronously on the whole southern Patagonian shelf but the magnitude and size-composition shift temporally from the coast to the shelf-break and from north to south.

iv) The largest bulk of biomass, mostly made up of hyperiid amphipods, occurs in autumn in neritic waters between 51° and 52° S .

DISCUSSION

The reproductive strategy of the southern blue whiting *M. australis* is expected to be synchronized with the plankton production cycle of the area where it occurs, which in turn will be linked to the bottom topography and physical processes affecting water column stability. Spawning areas are normally fixed in time and space in order to meet the conditions leading to the occurrence of an abundant food supply for larvae and juveniles (e.g. Cushing, 1975; 1984; Bakun and Parrish, 1991). Recruitment of the northern blue whiting *Micromesistius poutaousou* in particular has been shown to be directly affected by even short changes in phyto - and/or zooplankton production cycles in waters off the west coast of Scotland (Bainbridge and Cooper, 1973) and in the Catalanian Sea (Bas and Calderón-Aguilera, 1989).

The plankton production cycle in waters off Argentina was first described by Carreto *et al.* (1981a, 1981b) from the seasonal sampling provided by the 'Walther Herwig' and 'Shinkai Maru' surveys (1978-1979), mainly for the northern region down to 46° S . The cycle follows the typical development and breakdown of the seasonal thermocline characteristic of cold-temperate seas, the main phytoplankton peak occurring in spring and the secondary one in autumn. The algal bloom starts in October-November in the inshore shallow waters of the northern shelf and gradually develops southwards

and offshore later in the season (November-December). Zooplankton biomass peaks following the spring bloom, its magnitude also shifting temporally from the coast to the shelfbreak and from north to south. Though based on too fragmentary information since nutrient and phytoplankton data are lacking, the main trends found in zooplankton biomass from the data collected through the more recent surveys support their view of a similar pattern for southern Patagonian shelf. As suggested earlier, at higher austral latitudes the secondary phytoplankton pulse, normally of lower magnitude, might not occur (likely due to light limitation) but a single longer phytoplankton maxima during late spring and summer would develop. Some differences in the production cycle depending on the latitude should be however expected, regarding mainly the delay period (the time it takes for effective grazing to develop from the start of algal production) which in turn will be related to temperature, bathymetric features and to the population dynamics of the species involved (Cushing, 1975; Kiørboe, 1993).

There is in contrast very little information about the outer Argentinian shelf off Malvinas and the adjacent southern deeper area. It appears to be a highly dynamic region showing a complex circulation pattern with the predominant influence of the Malvinas Current (Sánchez and Ciechomski, 1995 and references therein). High chlorophyll 'a' concentrations and phytoplankton growth have been reported throughout summer and autumn in the shelf-break (Carreto *et al.*, 1995) while maximum zooplankton biomasses have been found in winter and summer to the NE of the Malvinas Islands near the slope (Ciechomski and Sánchez, 1983). Values of Bongo net settled zooplankton volumes measured in spring (Rodhouse *et al.*, 1992) were roughly within the same range as we found in late winter. A distinctive zooplankton assemblage, mainly based on variations in abundance of predominantly neritic species typical of the southern zones was related to the water masses occurring over the same area at that time (Tarling *et al.*, 1995). The dominating

occurrence of euphausiids we found within the area may be related to the fact that they appear to be more buffered than copepods in responding to environmental fluctuations. Because of their relatively longer lifespan (~1 year versus ~1 month for copepods), they may be more capable of smoothing out some of the effects of seasonal variability (Pillar *et al.*, 1992). Besides, euphausiids are typically omnivorous, with a tendency towards either herbivorous or carnivorous behaviour, depending on the trophic conditions of their environment. Their occurrence is clearly reflected in the food of zooplanktivorous fish such as southern blue whiting, for which euphausiids prevail in the diet of juveniles and adults all year long while copepods and hyperiids amphipods appear to have rather a more seasonal importance (Otero, 1976,1977; Perrotta, 1982). Two very abundant euphausiid species occur around Malvinas: *Thysanoessa gregaria* and *Euphausia vallentini* (Ramírez, 1973). These species reach ovarian maturity by the end of the winter (Ramírez and Dato, 1983) and in spring larvae and adults peak noticeably within the southwestern area of the Malvinas Islands (Montú, 1977). A second fast-growing population of *T. gregaria* would develop in the same area during the summer (Ramírez and Dato, 1983). Hence, the feeding requirements of juvenile and adult blue whiting may be fully met in the area. On the other hand, the occurrence of large species of copepods such as *Calanus australis* and *C. propinquus* that apparently peak in September - December in the area along, with the small ones *Drepanopus forcipatus* and *Oithona helgolandica* occurring in high densities all year long (Ramírez, 1981), may provide good food conditions for the larvae and postlarvae. Eggs, nauplii and early copepodite stages of copepods are the most frequent organisms found in the guts of larvae of the northern blue whiting (Bainbridge and Cooper, 1973; Conway, 1980). At present we could not but speculate about the resulting production cycle in this area.

The recently gathered data of zooplankton biomass are within the range of former findings as it is

shown in Table 1. Differences in magnitude should be rather attributed to the different sampling methodologies applied throughout time, since major spatial and seasonal trends seem to keep the same. There is no evidence to suspect any dramatic change

in either group composition or abundance of zooplankton from the late 70's to nowadays.

Up to here we have reported on the synoptic distribution of zooplankton biomass at the time that massive spawning of southern blue whiting was

Table 1. Zooplankton biomass measured on the outer and mid continental shelf off Argentina to the south of 45° S. For comparison all the records were converted to wet weight by assuming $DW=0.17 WW$ (Båmstedt, 1986) and $WW(mg)=0.711 V (m^{-3})$ (Santos, 1994) where DW is dry weight, WW is wet weight and V is volume.

Tabla 1. Biomazas de zooplancton medidas en aguas de plataforma intermedia y externa al sur de los 45° S. A los efectos de la comparación todos los registros se expresaron en mg peso húmedo por metro cúbico. Cuando necesario se usaron las siguientes conversiones: $PS=0.17 PH$ (Båmstedt, 1986) and $PH (mg)=0.711 V (m^{-3})$ (Santos, 1994) donde PS es peso seco, PH es peso húmedo y V es volumen.

Season	Biomass mg WW m ⁻³	Sampler (mesh size, µm)	Original data measured as	Reference
Outer Shelf				
Winter	2 -70	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	7 - >700	Bongo net (505)	displacement volume	Ciechomski & Sánchez, 1983
	10 - 450	Nackthai (400)	wet weight	This study
Spring	10 -80	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	7 -700	Bongo net (505)	displacement volume	Ciechomski & Sánchez, 1983
	No data	Nackthai (400)	wet weight	This study
Summer	70 - 700	Bongo net (505)	displacement volume	Ciechomski & Sánchez, 1983
Autumn	2 -70	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	7 -70	Bongo net (505)	displacement volume	Ciechomski & Sánchez, 1983
	80 - 400	Nackthai (400)	wet weight	This study
Mid Shelf				
Winter	6 - 100	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	7 -70	Bongo net (505)	displacement volumen	Ciechomski & Sánchez, 1983
Spring	13 - 300	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	7 -700	Bongo net (505)	displacement volume	Ciechomski & Sánchez, 1983
	20 - 1500	Nackthai (400)	wet weight	This study
Summer	6 - 260	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	70 -700	Bongo net (505)	displacement volume	Ciechomshi & sánchez, 1983
Autumn	6 - 100	Conical net (300)	dry weight	Carreto <i>et al.</i> , 1981
	7 - 700	Bongo net (505)	displacement volumen	Ciechomski & Sánchez, 1983
	80 - 600	Nackthai (400)	wet weight	This study

expected to take place, along with the overall pattern occurring throughout the previous and following season in the Patagonian region. It quite clearly emerges that despite its economical importance, waters off Southern Patagonia as a whole, but primarily the area surrounding the Malvinas Islands, are still poorly known. Further exhaustive plankton research related to the physical environment needs to be carried out in order to characterize the production cycle and thus clearly establish the links between hydrography, plankton and the fish resources occurring in the region.

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