REVISIÓN

BIOLOGY AND FISHERY OF THE ARGENTINE HAKE (*Merluccius hubbsi*)*

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SUMMARY. Argentine hake (*Merluccius hubbsi*) is a demersal, eurythermic and euryhaline species associated to subantarctic waters of the continental shelf and slope. The species, considered the main fishery resource of Argentina that in 2011 reached the maximum catch and export levels, distributes from Southern Brazil to 55° S in a 50-400 m depth range. The three stocks identified, located between 34° S-41° S, south of said latitude and in the San Matías Gulf, show differences as regards reproduction and nursery areas and time, meristic and morphometric characters, abundance level and growth parameters. At the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP) annual assessments of the exploitation status of the stocks north and south of 41° S are carried out and management recommendations made. In this chapter, the biology, fishery characteristics, population abundance and structure and management recommendations for the two main Argentine hake stocks are described.

Key words: Argentine hake, biology, fishery, assessment, management.

BIOLOGÍA Y PESQUERÍA DE LA MERLUZA (*Merluccius hubbsi*)

RESUMEN. La merluza (*Merluccius hubbsi*) es una especie demersal euritérmica y eurihalina asociada a aguas subantárticas de la plataforma y el talud continental. La especie, considerada el principal recurso pesquero de la Argentina que en 2011 alcanzó los máximos niveles de captura y exportación, se distribuye desde el sur de Brasil hasta los 55° S en un rango de profundidad de 50-400 m. Los tres *stocks* identificados, ubicados entre los 34° S-41° S, al sur de dicha latitud y en el Golfo San Matías, muestran diferencias en lo relativo a áreas y épocas de reproducción y cría, caracteres merísticos y morfométricos, niveles de abundancia y parámetros de crecimiento. En el Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP) se realizan evaluaciones anuales del estado de explotación de los *stocks* que se encuentran al norte y sur de los 41° S y se brindan recomendaciones a la administración pesquera. En el presente capítulo se describen la biología, características de la pesquería, abundancia y estructura poblacional y recomendaciones de manejo para los dos principales *stocks* de merluza.

Palabras clave: Merluza, biología, pesquería, evaluación, manejo.

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INTRODUCTION

Argentine hake (*Merluccius hubbsi*) annual extraction, that in 2011 reached 51% of total catches and the international commercial value attained, make of hake the main species in the ocean region off Argentina. The high abundance level and quality of meat fostered the development of the fishery.

Deepening of knowledge of different features related to its fishery biology allowed to improve estimates of the population status of the two main fishing stocks located north and south of 41° S. In the 80's evaluation was performed using holistic models of production surplus. In the 90's APV-ADAPT and XSA analytical age structured models and stock differentiated evaluations were implemented. In 1993, to assess biomass and the population structure, a series of research cruises were carried out. Swept area and hydroacoustic methods were used to evaluate juveniles and the stock reproductive specimens. The information gathered, the available fishing statistics and the Observers Onboard Program improved understanding of the stock status thus allowing for more accurate management recommendations.

In this chapter, the biological and fishery characteristics of Argentine hake main stocks north and south of 41° S, the population status and management recommendations are described.

Oceanographic characteristics and species distribution

Argentine hake distributes over one of the most extensive continental shelves between 34° S-55° S and 50-400 m depth (Otero *et al*., 1982; Bezzi and Dato, 1995) (Figure 1). Although with lower levels of abundance than those recorded between 35° S and 48° S, it also reaches the Brazilian shelf up to 23° S (Lorenzo and Vaz-Dos Santos, 2011). Such a wide distribution range is related to the physical features of the environment. It is a species characteristic of subantarctic waters limited by the Malvinas and Brazil currents and shelf waters. The species, considered to be eurythermic and euryhaline, makes vertical migrations passing through the thermocline above which temperature ranges 16-18 °C (Angelescu and Prenski, 1987).

The circulation of the Malvinas and Brazil currents along the isobaths generates a strong seasonal variability along the slope. The cold, subantarctic waters of the Malvinas Current of low salinity and rich in dissolved nutrients flow northwards and the subtropical, warm and brackish waters of the Brazil current do it southwards, over the eastern border of the shelf. The currents, that meet close to 38° S, generate a thermohaline frontal region known as the Brazil/Malvinas confluence. The subtropical and subantarctic waters, that coexist and mix in said zone, produce important physical-chemical gradients that favour the presence of a high concentration of nutrients which implies important biological consequences for the whole ecosystem (Piola *et al*., 2000). The intensity of the front, greater in Winter than in Summer, has a N-S above 53.5° S orientation (Saraceno *et al*., 2004). The fluctuations of the confluence zone that comprises hundreds of kilometers cause temperature anomalies. At an annual scale, variability shows a maximum latitudinal displacement northwards at the end of Winter and southwards in Summer.

The entrance of waters of low salinity and rich in nutrients from the Río de la Plata river, of a large impact on shelf waters, generates an intense salinity front on the surface that modifies the coastal circulation and the mixing conditions. The circulation of the Malvinas Current also generates a shelf break front with shelf waters in which relatively high concentrations of phytoplankton persist from Spring through Autumn (Guerrero and Piola, 1997). The region, of an important primary production, shows high values of chlorophyll *a* in Spring (Carreto *et al*., 2007). The larger food availability and species diversity of fronts are important for herbivore growth.

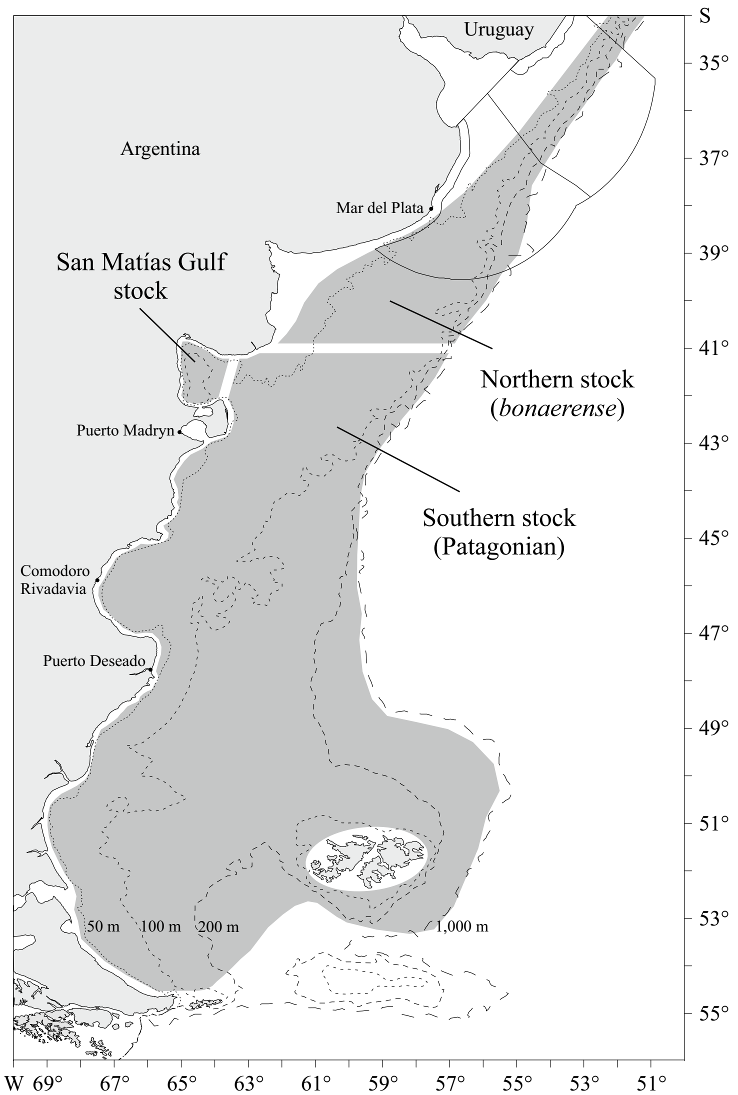

Figure 1. Argentine hake (*Merluccius hubbsi*) total distribution area, stocks and main ports.
Figura 1. Área total de distribución de merluza (Merluccius hubbsi), *stocks y principales puertos.*

Variations in oceanographic and topographic conditions produce changes in the species distribution (Figures 2 and 3). The largest aggregations of juveniles are found between 35° S and 37° S (Renzi *et al*., 2005), an area with a 6-13 °C temperature range, 33.5-34 salinity and greater thermohaline spatial variability of bottom waters (Louge *et al*., 2011 a). In December and April-May, north of 35° S juveniles are found in warmer waters around 15 °C and salinity above 34 which indicates the presence of subtropical waters (Louge *et al.*, 2011 a, b) not detected during Spring due to the displacement of the Malvinas/Brazil confluence. Temperature, between 6 and 11 °C, was lower than in Autumn. In both seasons adult individuals were found at greater density at 37° S-41° S and between 7-13 °C and 5-10 °C thermal range (Louge and Molinari, 2011).

In the coastal zones high tides generate the Valdés Peninsula front at approximately 42° 60' S (Guerrero and Piola, 1997) and the Patagonian current thermohaline front of cold, less salty waters that forms in the Strait of Magellan and moves north-northwest.

The studies performed during Summer in the breeding area of the San Jorge Gulf and adjacent waters (45° S-47° S) indicated the presence of the front, concentration of individuals mainly in zones of thermal and saline gradients (Louge *et al*., 2004, 2011 b) and the highest juvenile density in shallow waters with 8-10 °C temperature and 33.2-33.6 salinity; adults were detected in and around the area with 8-12 °C bottom temperature and 33.2-33.5 salinity.

In Winter, the largest aggregations of juveniles between 41° S-48° S were found in coastal areas inside and north of the San Jorge Gulf with 7-10 °C temperature and 33.3-33.8 salinity and those of adults in the center of the shelf at a slightly lower temperature (6-9 °C) and higher salinity (33.4-33.9). The distribution limit was the Malvinas Current (Louge *et al*., 2009).

Stock units

At present, the Northern (*bonaerense*) (34° S-41° S), the Southern (Patagonian) (41° S-55° S) and the San Matías Gulf (41° S and 42° S-63° W) hake stocks are recognized (Figure 1). Studies to differentiate stocks started in the 70's. Christiansen and Cousseau (1971) analyzed maturity stages and estimated indices that allowed to recognize two main spawning periods, one in Summer (October-March) in the north-patagonian area and the other in Winter (June-July) between 37° S and 38° S at depths below 180 m. In the eggs and larvae two-year study by Ciechomski and Weiss (1973) the distribution of eggs and larvae in different seasons between 31° S and 47° S was described. They indicated a Winter spawning area north of the Río de la Plata river up to 31° S and the presence of eggs in Summer in shelf waters between 39° S and 47°

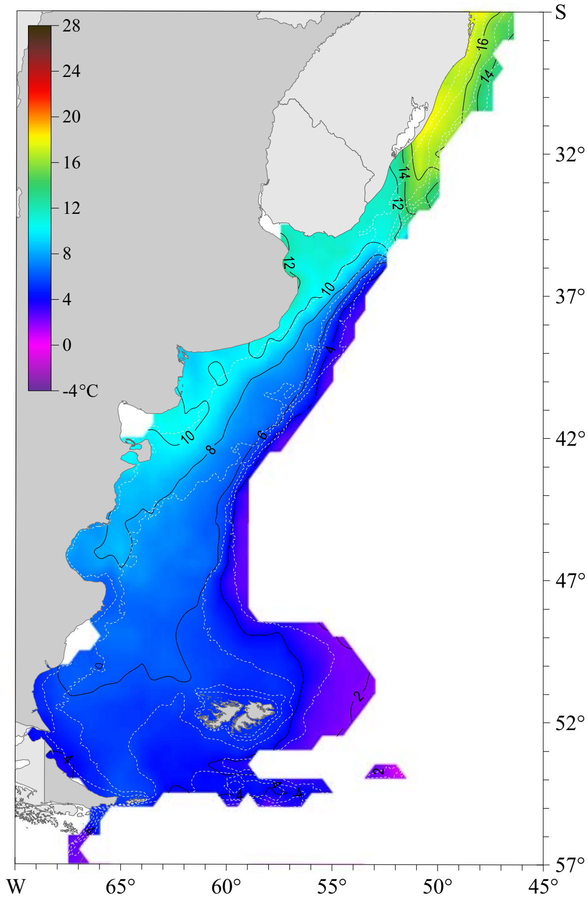

Figure 2. Distribution of bottom isotherms in Winter. Taken from Baldoni *et al*. (2015).

Figura 2. Distribución de las isotermas de fondo en invierno. Tomado de Baldoni et al. (2015).

S. Ciechomski *et al.* (1975) indicated a spawning area with high concentrations of eggs in the Escondida Island area (43° S-65° W).

Ehrlich and Ciechomski (1994) suggested that the location of spawning areas, eggs and larvae are indicators that allow to differentiate population units and mentioned that the highest concentrations of eggs were found in the north in Winter and in the south in Summer. They noted that egg density was high in Summer and intermediate in Autumn, with an increase of the reproductive activity in May and presence of eggs up to 35° S, mostly in the slope region.

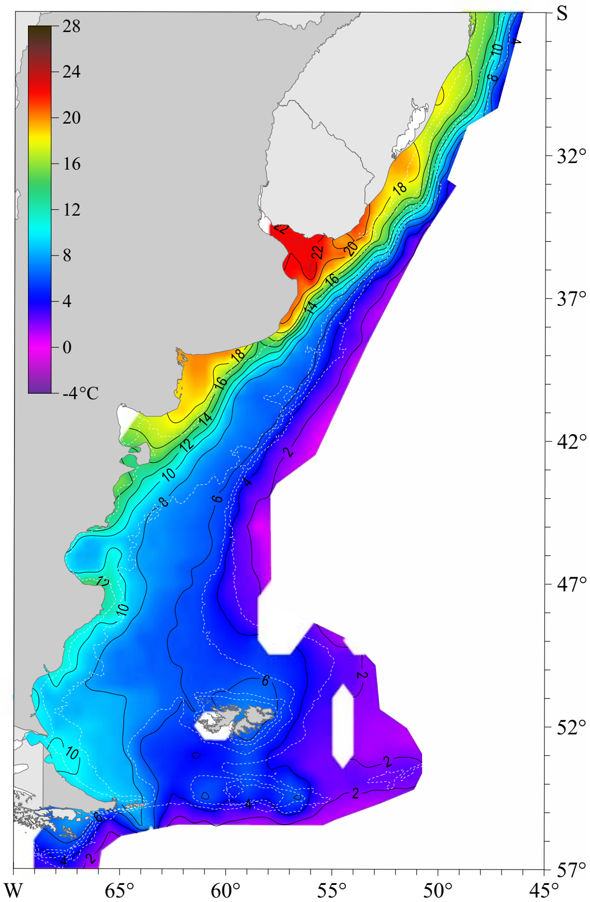

Figure 3. Distribution of bottom isotherms in Summer. Taken from Baldoni *et al*. (2015).
Figura 3. Distribución de las isotermas de fondo en verano. Tomado de Baldoni et al. (2015).

More recent studies corroborated that the Patagonian stock south of 41° S reproduces from November through April with the peak of activity between December and January (Macchi *et al*., 2004, 2007) and that spawning of the Northern stock occurs between 35° S and 37° S in May and June at 50-100 m depth (Rodrigues and Macchi, 2010).

Studies on parasitism such as those by Sardella (1984) and Sardella and Timi (2004) demonstrated a different degree of parasitic incidence between the two stocks, which is another indicator of separation. Otero *et al.* (1986) proved the existence of a permanent nursery zone north of 41° S different from the one between 43° S and 47° S in the San Jorge Gulf and adjacent waters. The meristic and morphometric characters used by Bezzi and Perrotta (1983) allowed to detect significant differences between the groups located north and south of 41° S.

Dato (1994) characterized hake distribution area using the species associations and their relation to environmental variables and concluded that there are differences in the composition of fish groups and oceanographic conditions. Ruarte (1997) analyzed the relation of otolith length and width with latitude based on three areas: the shelf north of 41° S, the shelf south of 41° S and the San Matías Gulf. He found significant differences in regression coefficients among the three areas.

Renzi *et al.* (1999), who used atomic absorption and spectrophotometric emissions to analyze the composition of 12 elements of *saggita* otolith, found significant differences in all of them between groups north and south of 41° S. Renzi *et al*. (2009 a) concluded that the higher growth rate found north of 41° S generates differences in the maximum size and that discrepancies are related to the uneven characteristics of the environment where Winter spawning occurs.

DESCRIPTION OF THE FISHERY

Offshore fishing in Argentina began in 1968 as a consequence of the reconversion of the coastal into an offshore fleet that had the sector off the Buenos Aires Province as the main operation area (Irusta *et al*., 2001).

The larger and more powerful ice-chilling vessels incorporated in 1973 allowed to reach the Patagonian stock fishing grounds in Summer, when massive spawning in the area around Escondida Island takes place. After 1975, due to the increase in the international demand for fish that brought about a raise in catches and higher market prices, an imported freezer fleet was incorporated (Figure 4). As a consequence of the decrease in the Northern stock abundance, at the beginning of 1985 the areas south of 41° S over the Patagonian shelf started to be exploited (Giangiobbe *et al.*, 1993). In the 90's, the expansion of the fishing activity in the southern sector translated into a sustained increase in landings from the Patagonian stock (Figure 5). The agreement signed by Argentina and the European Union in 1992 for the reconversion of the fleet resulted in the incorporation of a freezer fleet with a large fishing capacity that operated mainly south of 41° S. During the 1986-1996 period, total catches on the shelf between 41° S-48° S increased landings by 80% to reach 670,000 t (Figure 4) due to Argentine catches on the shelf between 41° S-48° S (Figure 5); those of the freezer fleet showed a maximum of approximately 304,000 t in 1997 (Figure 6). In 1999, the lower level of abundance detected produced displacement of the freezer fleet south of 48° S and the establishment of a permanent closed area to protect Patagonian stock juveniles. As a result, an important decline in argentine catches from 1999 through 2001 was observed (Figure 6). In 2010 the Individual Transferable Quotas (ITQ) system to regulate the fishery was implemented. At the same time, a year-round closed area to protect juveniles and a restricted fishing effort to protect spawners in the Escondida Island area were established.

Between 1987 and 2011, a decrease in the species abundance reduced catches of the stock north of 41° S by 57% (Figure 7). As a consequence, the offshore ice-chilling fleet moved operations southwards, between 39° S and 41° S where a high density of the Patagonian stock is found (Irusta *et al.*, 2009).

Type of fleet

The coastal, offshore and freezer fleets use bottom trawl nets to catch hake. The last two are the most important in terms of extraction levels that,

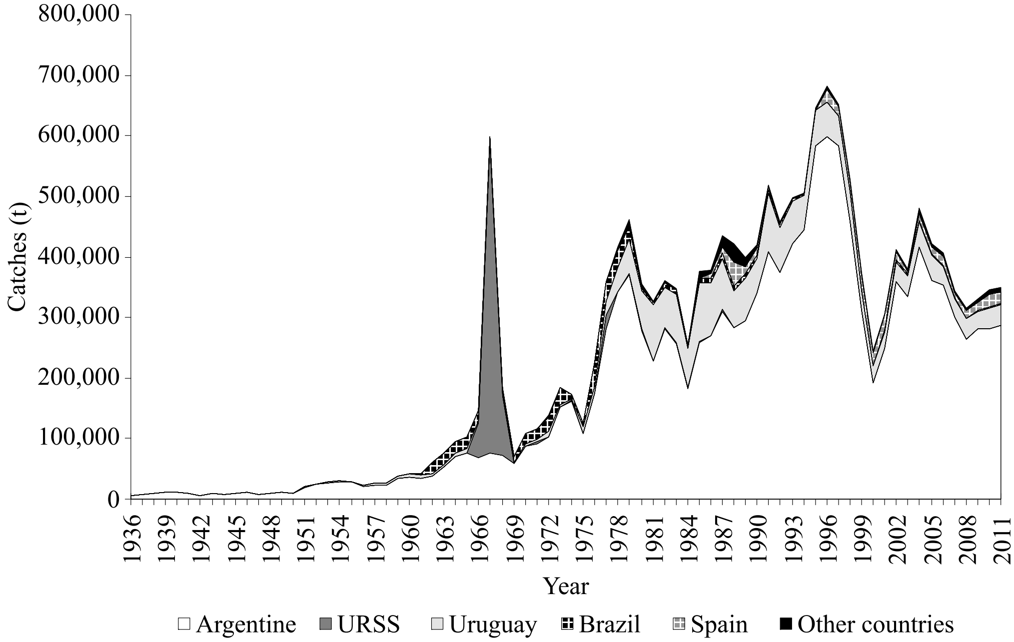

Figure 4. Argentine hake catches per country, 1936-2011 period.
Figura 4. Capturas de merluza por país, período 1936-2011.

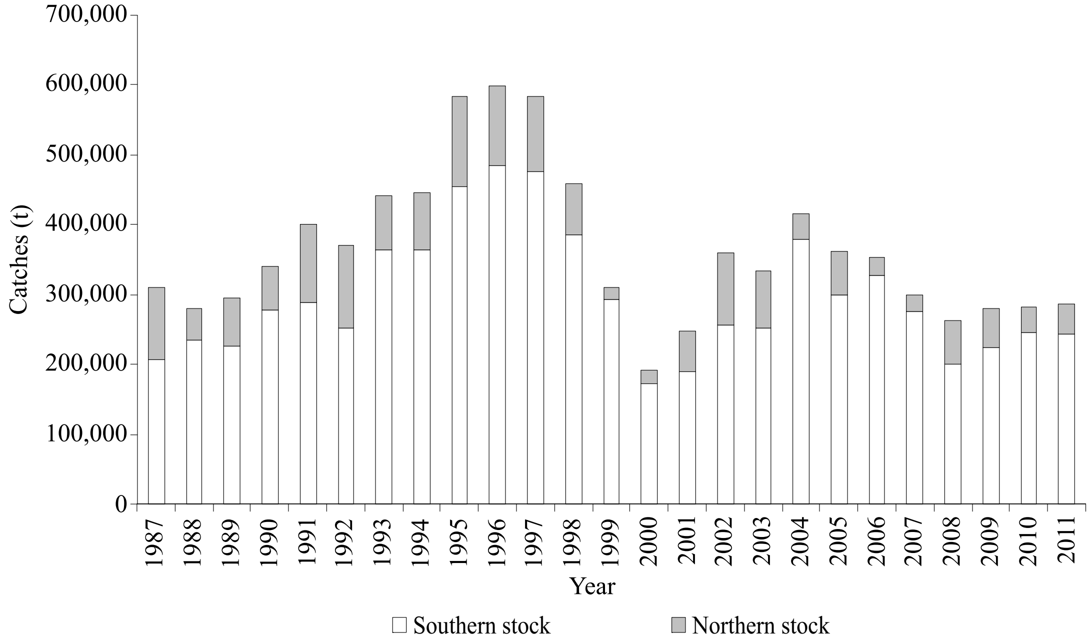

Figura 5. Argentine hake catches per stock, 1987-2011 period.
Figura 5. Capturas de merluza por stock, período 1987-2011.

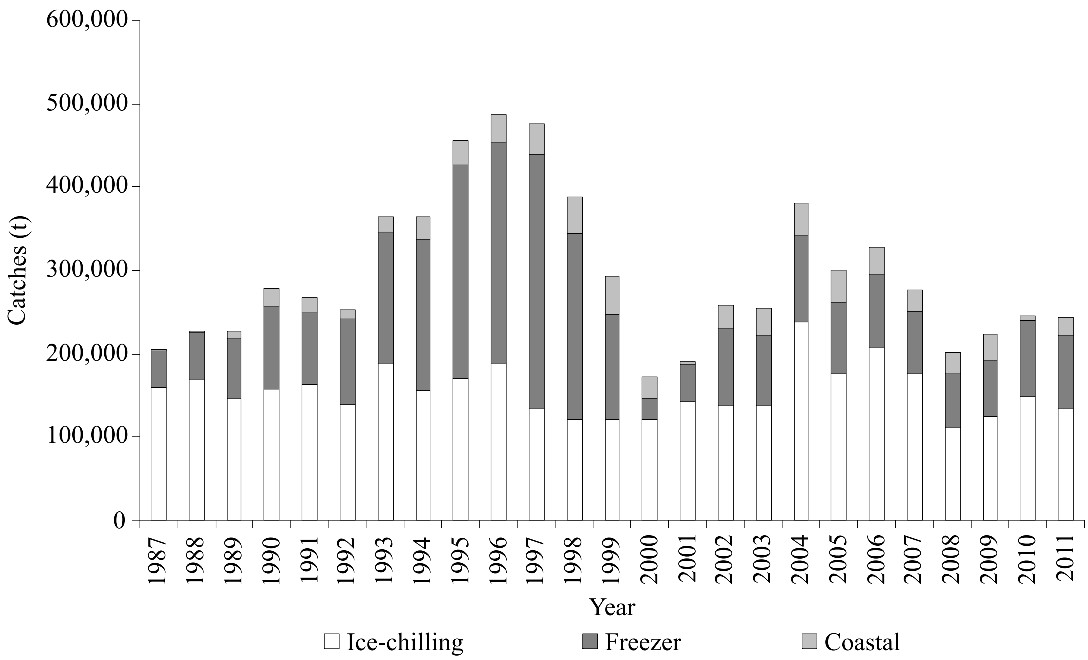

Figure 6. Argentine hake catches per type of fleet in the 1987-2011 period. Southern stock.
Figura 6. Capturas de merluza por tipo de flota en el período 1987-2011. Stock sur.

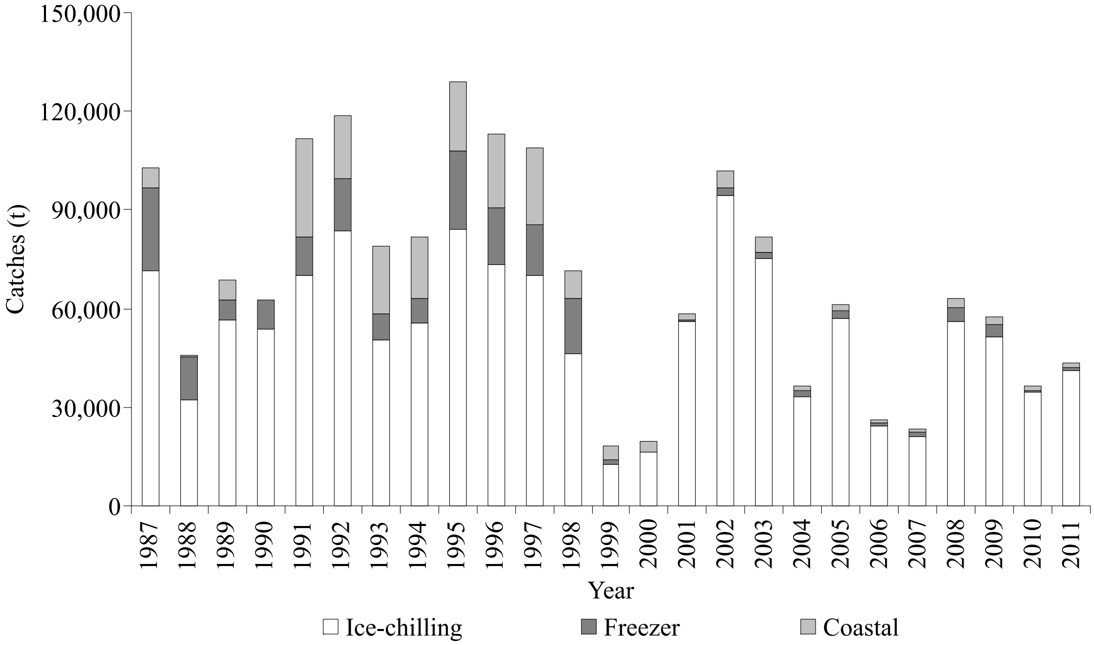

Figure 7. Argentine hake catches per type of fleet in the 1987-2011 period. Northern stock.
Figura 7. Capturas de merluza por tipo de flota en el período 1987-2011. Stock norte.

between 1987 and 2011, reached an average of 59-31% annual landings, respectively. The coastal and offshore fleets preserve fish in ice and unload it to manufacture products; the freezer fleet counts on the necessary machinery on board to produce skinless, boneless and gutted fillets. The autonomy of the coastal fleet is 1-3 days, that of the offshore fleet 10-15 days and in frezzers it reaches 30-60 days. Engine power in HP is 200-300, 300-2,700 and 1,000-3,000, respectively.

Fishing areas

The offshore fleet main fishing grounds are found north and east of the juvenile closed area (JCA) (Figure 8). Freezers register the largest catches south and southeast of the JCA (Figure 9). In Autumn freezers operate south of 48° S and the offshore fleet intensifies efforts on the northern stock (Irusta and Castrucci, 2012). In the area, another closed area to protect Patagonian spawners (SCA) was established.

Main landing ports

Mar del Plata is the main hake landing port supplied, mainly, by the offshore fleet. In the 1999-2011 period 150,000-200,000 t landings were recorded. The reduction observed in 1999 and 2000 was the result of the regulations implemented (Figure 10). From 1994 through 1998, years characterized by an intense exploitation of the Patagonian stock, the increase in the commercial activity developed in ports such as Puerto Madryn, Puerto Deseado and Comodoro Rivadavia brought about a reduction of operations in Mar del Plata.

Discard

The offshore fleet discards hake that does not reach the minimum size required for processing (Dato *et al*., 2001); in the frezzer fleet the fish caught is kept on board (Cañete *et al*., 1996). Direct discard estimates are performed annually

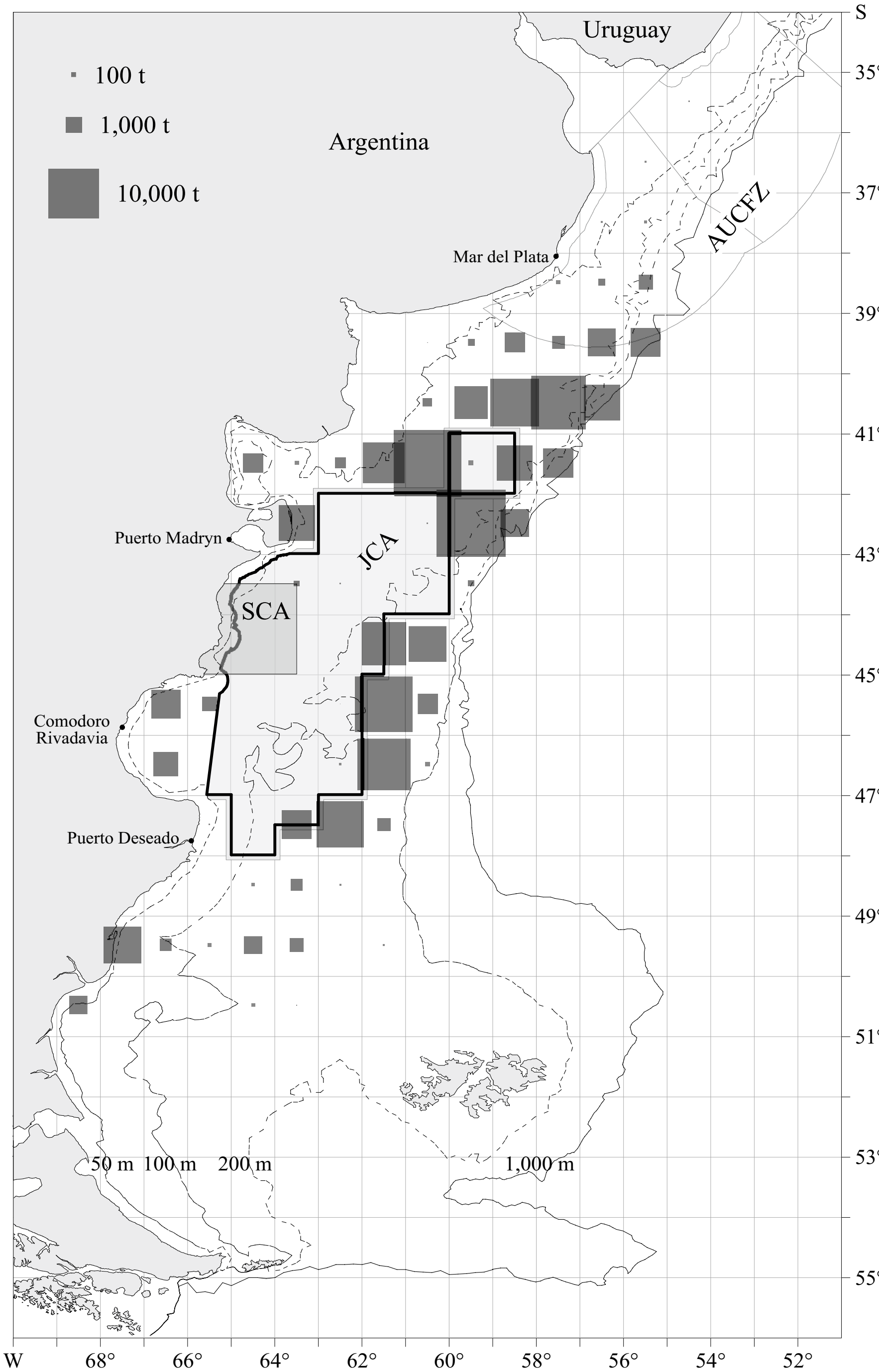

Figure 8. Annual distribution of the ice-chilling fleet catches per statistical rectangle. 2011. JCA: juvenile closed area, SCA: spawning closed area.

Figura 8. Distribución anual de las capturas de la flota fresquera por rectángulo estadístico. 2011. JCA: área de veda de juveniles, SCA: área de veda de desovantes.

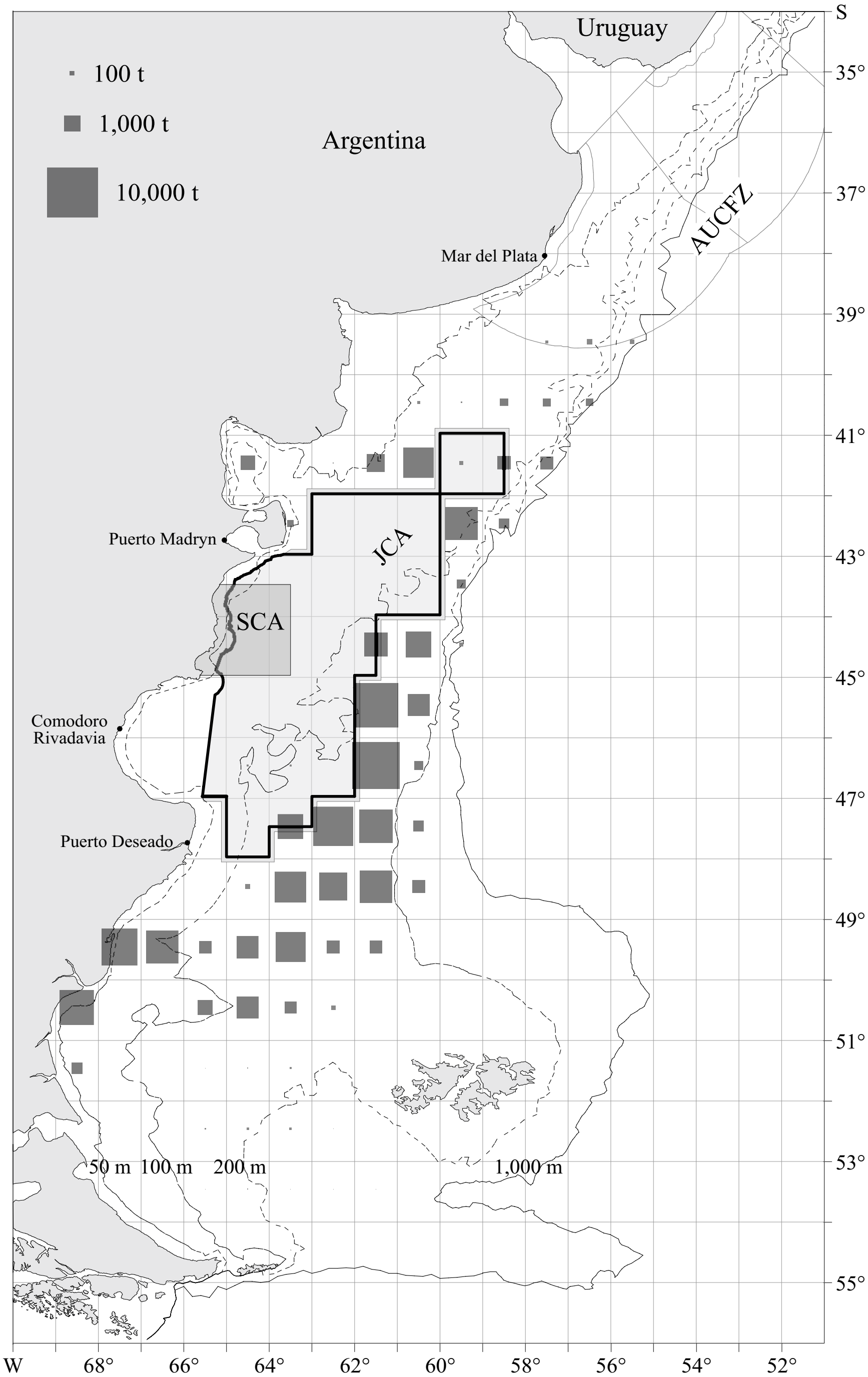

Figure 9. Annual distribution of the freezer fleet catches per statistical rectangle. 2011. JCA: juvenile closed area, SCA: spawning closed area.

Figura 9. Distribución anual de las capturas de la flota congeladora por rectángulo estadístico. 2011. JCA: área de veda de juveniles, SCA: área de veda de desovantes.

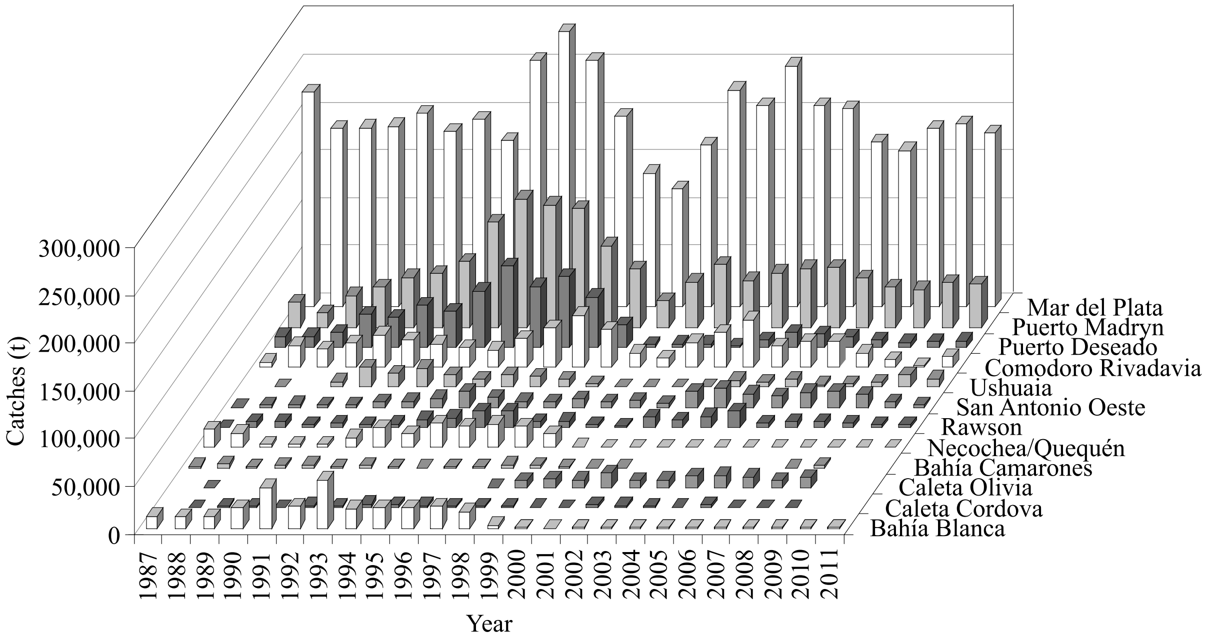

Figure 10. Argentine hake annual catches per landing port, 1987-2011 period.
Figura 10. Capturas anuales de merluza por puerto de desembarque, período 1987-2011.

using information derived from the INIDEP Observers Onboard Program (Irusta and D'Atri, 2010 a; D'Atri and Irusta, 2011).

Bycatch

In the shrimp (*Pleoticus muelleri*) fishery hake is caught as an incidental species, that is, as bycatch. Discard and bycatch occur due to the fact that fishing nets and fishing practices are not selective enough and that the habitat of the target species is shared by a large number of concurrent species.

The outrigger fleet operates in the San Jorge Gulf and surrounding waters south of 41° S (Fischbach *et al*., 2006) that coincides with the hake breeding area where future recruits concentrate. In Figure 11 outriggers global positioning system is shown.

Hake bycatch that includes individuals age 0-7 and over has the largest impact on the age 1 group (Villarino and Simonazzi, 2010). In order to improve results of the population status evaluation, bycatch and age structure were included in the Southern stock assessments (Villarino *et al*., 2012).

BIOLOGY AND LIFE CYCLE

Reproductive cycle and spawning areas

Argentine hake extensive reproductive period is proved by the presence of spawning individuals observed almost all year round in different sectors of the Argentine shelf. However, the peaks of reproductive activity occur during short periods in specific months that differ in the two main stocks. The Northern stock reproduces mainly in Autumn-Winter, mostly north of 38° 30' S in the Argentine-Uruguayan Common Fishing Zone (AUCFZ) (35° S-38° 30' S) with a spatial displacement in the spawning peak toward the northern area as the reproductive period advances

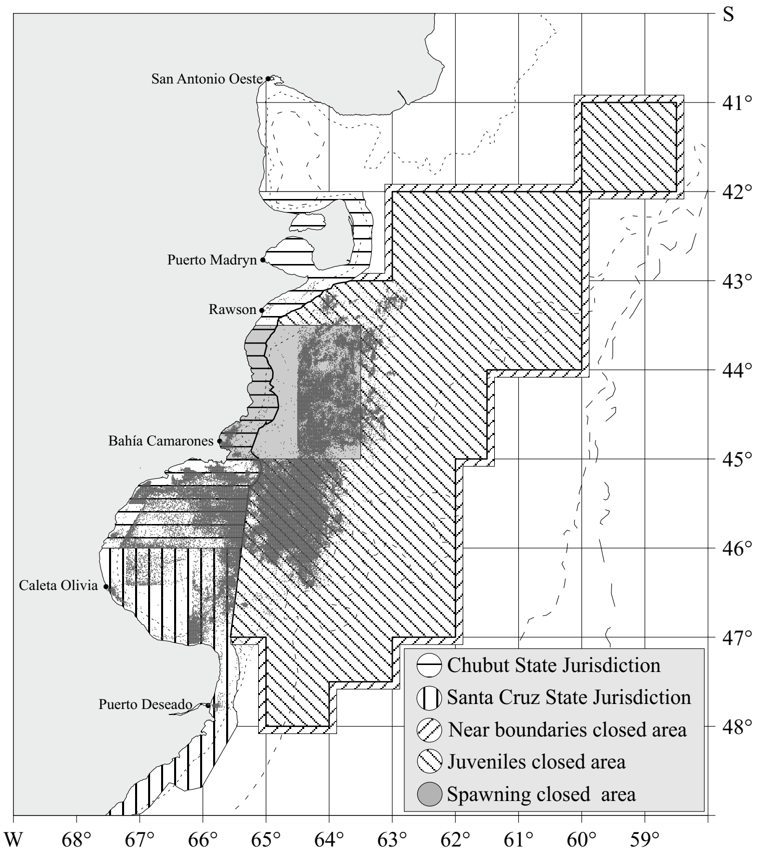

Figure 11. Satellite positions of shrimp fleet trawlings.
Figura 11. Posiciones satelitales de arrastre de pesca de la flota tangonera.

(Figure 12) (Macchi and Pájaro, 2003; Dato *et al*., 2009; Rodrigues and Macchi, 2010). In contrast, the Southern stock (*patagónico*) spawns mainly in Spring-Summer in the north Patagonian region (44° 30' S-45° S) with the peak of highest activity in December and January (Macchi *et al*., 2004). The analysis of the spatial distribution of hake aggregations in the area (Macchi *et al*., 2007) showed a movement of the species previous to the onset of spawning (October) from deeper waters (over 100 m depth) toward the coast (near the 50 m isobath) where reproduction takes place. Later on, in February, abundance of spawning individuals decreases since part of the population ceases its reproductive activity; then, post-spawning individuals move to deeper waters to feed (Macchi *et al*., 2007). Since young adult specimens (3-4 years) finish spawning earlier than large females (Macchi *et al*., 2004; Pájaro *et al*., 2005) the previous tend to abandon the spawning site. Another characteristic observed in the areas where the highest reproductive activity occurs is a sex ratio biased towards males (Pájaro *et al*., 2005; Macchi *et al*., 2010) which suggests the possibility of some courtship mechanism or competition between males before eggs are fertilized (Pájaro *et al*., 2005; Macchi *et al*., 2007; Ehrlich *et al*., 2013). The feeding activity during the spawning peak in January was higher in large females and young individuals, which indicates that old Argentine hake females may incorporate energy during the reproductive season (Macchi *et*

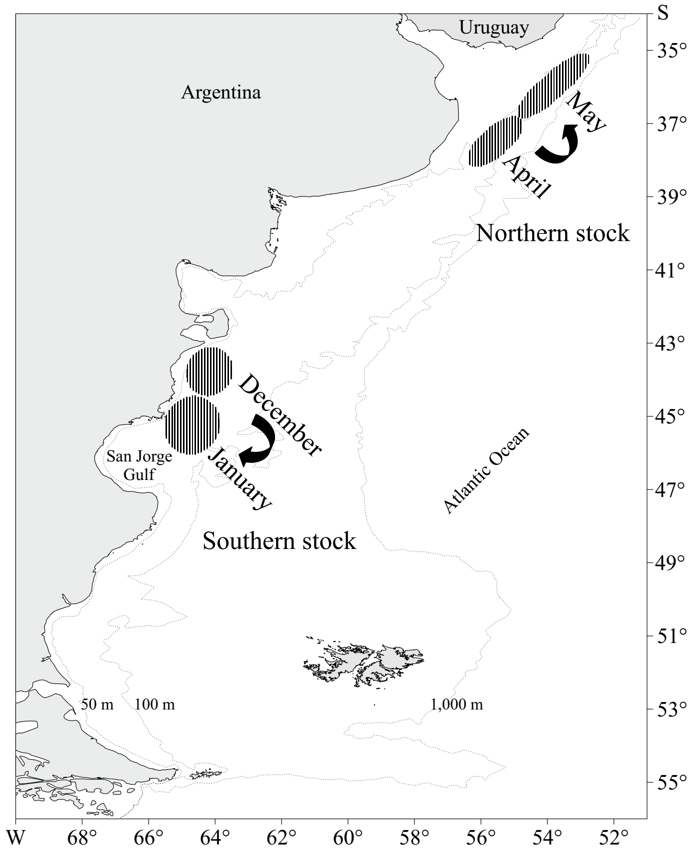

Figure 12. Main spawning areas of the Northern and Southern stocks.
Figura 12. Principales áreas de desove de los stocks norte y sur.

al., 2013). The energy allocation strategy is typical of an income breeder and similar to the one suggested for European hake (Dominguez-Petit and Saborido-Rey, 2010).

In spite of the temporal and spatial differences in the spawning activity of the two hake stocks, similar environmental characteristics in terms of temperature ranges (9-16 °C) were reported for the areas of spawning concentration. Spawning of both stocks appears to be associated to bottom thermal sources which would aid larval survival, considering that said hydrographic structures may act as zones of food concentration and as retention areas for the first life stages (Rodrigues and Macchi, 2010; Macchi *et al*., 2010). In fact, it was reported that the main spawning areas of both stocks are, in general, spatially coincident with the ones that show the largest concentration of larvae and postlarvae of the species (Rodrigues *et al*., 2015).

Reproductive potential

Argentine hake is a multiple spawner with an indeterminate annual fecundity (Hunter *et al*., 1992) which means that unyolked oocytes mature on a continuous basis and are spawned throughout the reproductive season (Macchi *et al*., 2004). Said characteristic suggests that, in order to estimate the total number of eggs produced during the spawning season, estimates of the number of oocytes spawned in one batch (batch fecundity) and the spawning frequency in the reproductive season are needed (Hunter and Goldberg, 1980). Only knowing those variables and the extension of the spawning season, an estimate of the reproductive potential of the species for the entire range of sizes and ages of spawning females may be obtained.

The mean values of batch and relative fecundity (number of eggs spawned in one batch and per gram of female) obtained with the gravimetric method (Macchi *et al*., 2004) for hake northern and southern stocks in different years are shown in Table 1. In general, batch fecundity in both stocks showed a positive relationship with most of the maternal characteristics of hake females such as total length, gutted weight or condition (Macchi *et al*., 2004; Rodrigues *et al*., 2015). The comparison of the fecundity values estimated during the main reproductive peak of both hake stocks did not show significant differences among years or populations of the same size range (Rodrigues *et al*., 2015). Nevertheless, a decrease in the batch and relative fecundity of the Patagonian stock as the reproductive period advanced related to an increase in the atresia processes was reported (Macchi *et al*., 2004). The spawning frequency (number of days between batch spawnings) obtained using the daily proportion of post-ovulatory follicles (Hunter and Goldberg, 1980) showed significant differences between both stocks (Table 1). The recovery time between oocyte batches in the Northern stock was almost twice (8-13 days) the time estimated for the southern stock (5-7 days) which suggests that, in the former, fewer batches during the reproductive season were produced (Rodrigues *et al*., 2015).

The analysis of egg quality based on the estimation oh the weight of hydrated oocytes showed, in general, higher mean values for the Northern stock (Table 1). On the other hand, the positive and significant relationship found between said variable and the size-age of spawners for both stocks suggests that large females produce a higher number and better quality of eggs in a reproductive period (Macchi *et al*., 2006; Rodrigues *et al*., 2015).

In summary, comparison of the reproductive potential estimated for both hake stocks showed

Table 1. Reproductive parameters mean values (batch fecundity, relative fecundity, dry weight of hydrated oocytes, spawning frequency) of Argentine hake females recorded during the reproductive peaks in the Northern and Southern stocks during the 2009-2011 period.

Tabla 1. Valores medios de los paramétros reproductivos (fecundidad parcial, fecundidad relativa, peso seco de oocitos hidratados, frecuencia de desove) de hembras de merluza registrados durante los picos reproductivos en los stocks norte y sur durante el período 2009-2011.

	Northern stock			Southern stock			
	2009	2011	2012	2009	2010	2011	2012
Batch fecundity (number of oocytes)*	767,369	599,633	497,646	750,089	655,912	694,440	690,420
Relative fecundity (number of oocytes g^{-1})*	556	551	497	535	520	538	528
Dry weight of 100 hydrated oocytes (mg)*	3.11	3.17	3.00	2.85	2.82	2.85	3.00
Spawning frequency (days)	13	8	10	5	6	7	7

*For females of 31-81 cm TL (Northern stock) and 29-90 cm TL (Southern stock).

great differences. The egg production considered for the Patagonian stock during the reproductive peak was, in average, between 1 and 2 magnitude order larger than the ones calculated for the northern group (Rodrigues *et al*., 2015). The difference is partly due to the large abundance of breeding specimens in the Patagonian region during the Summer spawning peak which indicates a concentration strategy that could be related to the existence of a frontal system in those waters (Macchi *et al*., 2010). Such a characteristic and the size structure dominated by large individuals would explain the higher spawning frequency and egg production observed in the Patagonian stock. The influence of maternal features on the quality of eggs suggests that large females may produce larger larvae with better chances of survival.

Distribution of eggs and larvae

The analysis of plankton samples collected in different regions of the ocean off the Argentine Sea showed that hake eggs have a wide spatial distribution which would explain why the largest abundance was observed in sectors and seasons in which the maximum concentrations of spawning females for both stocks were found (Ehrlich and Ciechomski, 1994). Similar results were obtained for hake larvae. Southern stock showed the highest density in the Escondida Island and Bahía Camarones while Northern stock presented the greatest abundance in the Buenos Aires region south of 35° S along the 50 m isobath during May and June.

The nursery area recorded for the Northern stock covers the 50 and 100 m isobaths south of 37° S and extends northwards to the 200 m isobath where the shelf narrows (Ehrlich, 2000; Ehrlich *et al*., 2013). It was reported that one of the retention mechanisms in the Northern stock breeding area could be the Ekman transport to the coast present throughout the year, specially during Winter when hake postlarvae and juveniles are found (Ehrlich, 2000).

In the Southern stock reproduction occurs near a frontal system produced by tide dynamics that results in a high biological productivity (Carreto *et al*., 1986; Viñas and Ramírez, 1996).

Recent studies performed in the north Patagonian region based on the analysis of samples collected in plankton nets and on acoustic records of fish larvae demonstrated that those of Argentine hake have a daily migratory behavior similar to that of adults that show daily vertical movements from near the bottom to the thermocline depth at night (Álvarez Colombo *et al*., 2011) which suggests that vertical migrations associated to the water circulation patterns characteristic of the region allow for retention of larvae during the peak of spawning in the zones of greatest productivity. Recent studies on food availability for larvae (Temperoni *et al*., 2014) and their nutritional condition (Díaz *et al*., 2012) confirm that the main retention zone is an optimum environment for feeding and growth of the first life stages. The study by Álvarez Colombo *et al*. (2011) showed that, as the reproductive period advances, size distribution of larvae and postlarvae moves southwards to the San Jorge Gulf, the main nursery area where age 0 recruitment takes place.

Length and age at first maturity

Estimates of length at first maturity per sex for each stock were based on the information gathered in hake research cruises carried out on board of RV "Dr. Eduardo L. Holmberg" in 1997 (Simonazzi, 2003). In both stocks females reached maturity at a larger length than males (Figure 13). Considering both stocks and sexes, the values for length at first maturity obtained, ranged 32-35 cm for 2.6-2.8 years old individuals.

Age and growth

The study on hake growth as a function of age was performed using the growth rings formed in

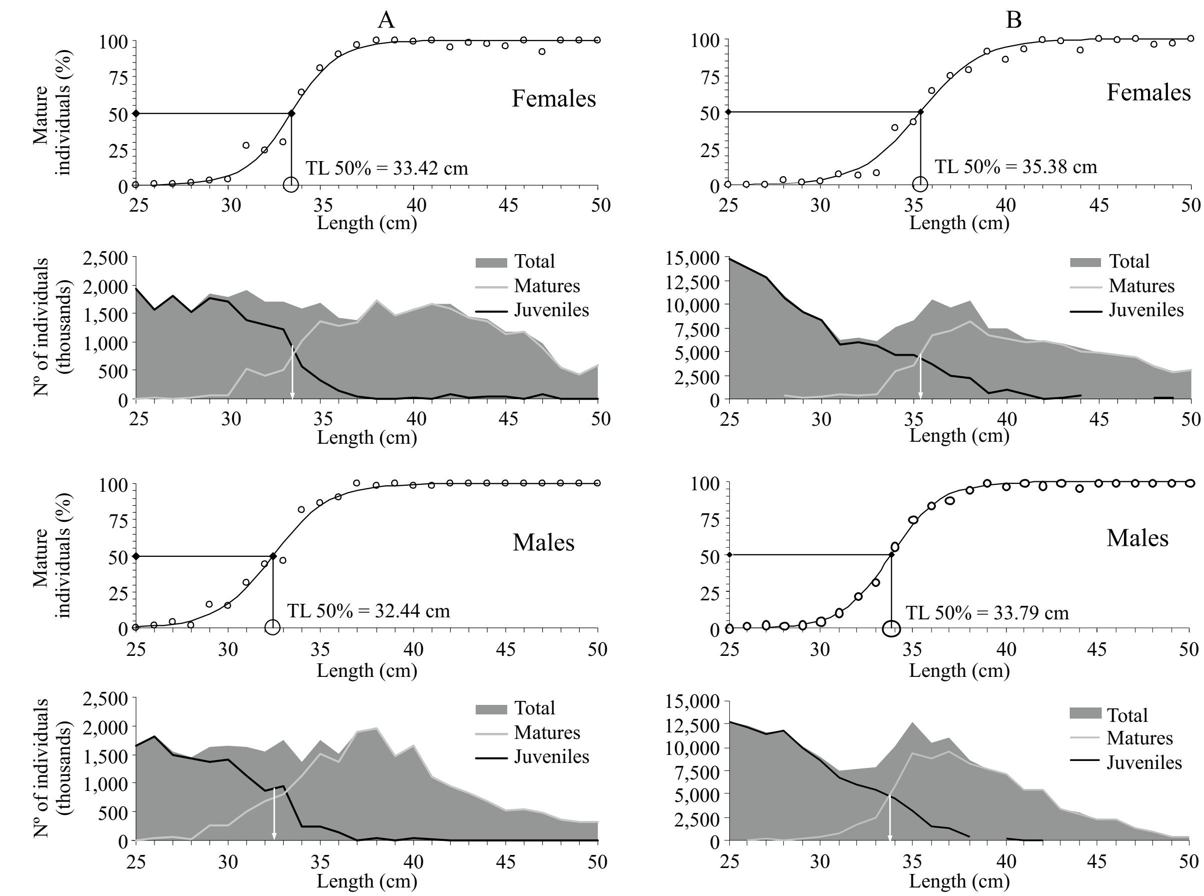

Figure 13. Length at first maturity, Northern stock (A) and Southern stock (B).
Figura 13. Longitud de primera madurez, stock norte (A) y stock sur (B).

saggitae otoliths, the most appropriate structure especially to assess old individuals (Otero, 1977). The age validation methods were based on the analysis of the border and marginal increase (Renzi and Pérez, 1992), length frequency distribution and dominant classes (Renzi *et al*., 2005). The hyaline ring is produced between March and October (mostly in Winter); the fastest growth occurs in Spring and Summer. At a given age, old individuals present a wide range of sizes.

Growth was estimated with data derived from research cruises using the von Bertalanffy model; to calculate parameters the maximum likelihood method was applied (Renzi *et al*., 2009 a) (Table 2). The mean sizes per age and sex were larger in the Northern stock. In the Merlucciidae Family, after the first maturity stage (2.6 years), females were notably larger than males of the same age (2.6 years) (Bezzi *et al*., 2004). The catabolic rate was higher in males; as a consequence, the maximum ages and sizes observed in males (13 years old and 64 cm total length) were lower than in females (15 years old and 92 cm total length).

As regards to growth weight, at age 3 males reached 50% and females 20% of the weight of a 10 years old individual. Beginning at age 3, growth rates diverge notoriously between sexes. While in males it increases up to age 3 then decline, in females the trend extended up to age 6 (Renzi *et al*., 2009 a).

Table 2. von Bertalanffy growth parameters model per stock.
Table 2. Parámetros de crecimiento del modelo de von Bertalanffy por stock.

	Northern stock		Southern stock	
Parameters	Males	Females	Males	Females
L_∞ (cm)	61.36	103.16	53.69	94.89
k	0.29	0.15	0.38	0.17
t_0	-0.16	-0.29	-0.10	-0.18

Growth of the age 0 group

Growth and spawning date of the age 0 group were estimated by counting the daily growth ring (Santos and Renzi, 1999). The data obtained was fitted to the Laird-Gompertz model. The analysis of otolith microstructure showed that the duration of the pelagic larval phase in both stocks was about two months. However, the significant differences found in the mean width of rings indicate disparities between stocks (Buratti and Santos, 2010). In the first year of life juveniles reached a maximum of 17-18 cm total length (Buratti, 2003).

Estimation of natural mortality

Prenski and Angelescu (1993) estimated annual natural mortality rates for the 1970-1987 period on the basis of predation. Rates varied from 0.18 to 0.47 with a 0.33 mean value. Pauly's (1980) formula used in subsequent studies considered growth parameters and a 5-10 °C thermal range that resulted in a 0.17-0.34 and 0.13-0.28 rate for males and females, respectively. More recently, the use of the Monte Carlo simulation of natural mortality in the Northern stock and other methods based on empirical relations, the life history theory and the maximum age as in Taylor (1960), Pauly (1980), Alagaraja (1984), Roff (1984), Djabali *et al*. (1994), Jensen (1996), Cubillos (2003), Zhang and Megrey (2006) allowed to conclude that mean value estimates were around 0.54 for males, 0.31 for females and 0.32 for both sexes combined (D'Atri, 2012) which explains why an M = 0.3 is employed during stock evaluation. At present, calculating M per age group is being considered. Previous estimates obtained with the Gislason *et al*. (2010) proposal indicated a decrease in rates from age 1 through 6 for both stocks.

AGE STRUCTURE OF STOCKS

Northern stock

The information derived from research cruises carried out to evaluate the northern stock during the 1996-2011 period showed that the differences found in distribution of age groups are related to latitude and depth. Juveniles (ages 0 and 1) concentrated mainly between 35° S-36° 30' S; the age 2 group, of a wider distribution, reached 39° S at less than 100 m depth. It was observed that the deeper the area the older the individual. In the slope zone only old females were found.

The diagnosis of the population status indicated a significant deterioration in adults and reproductive specimens (ages 3-7+) (Figure 14) which shows that abundance is highly dependent on recruitment (age 1; Irusta *et al*., 2010).

Southern stock

In the Southern stock age 0 and 1 groups were found between the coast and the 100 m isobath with concentrations at 43° 30' S-47° S and maximum yields within the San Jorge Gulf (Renzi *et al*., 2003). The distribution of the age 2 group was similar but extended up to 200 m. Individuals age 3 and over found from the shelf to the slope concentrated east of the mean shelf depth. During the reproductive period (October-April) adults shifted about in the area. Although distribution per age group was similar to that of the early 80's, a marked decrease in abundance of individuals above age 2 is observed at present. In 1997 below 6 years old specimens accounted for only a third of those estimated in 1982, and those above age 6 were occasionally found (Renzi *et al*., 2003). Annual variation in total biomass depends mainly on age 2 and 3 groups and, to a lesser extent, on those ages 1 and 4. Successful recruitments contribute to increase total abundance (Figure 15).

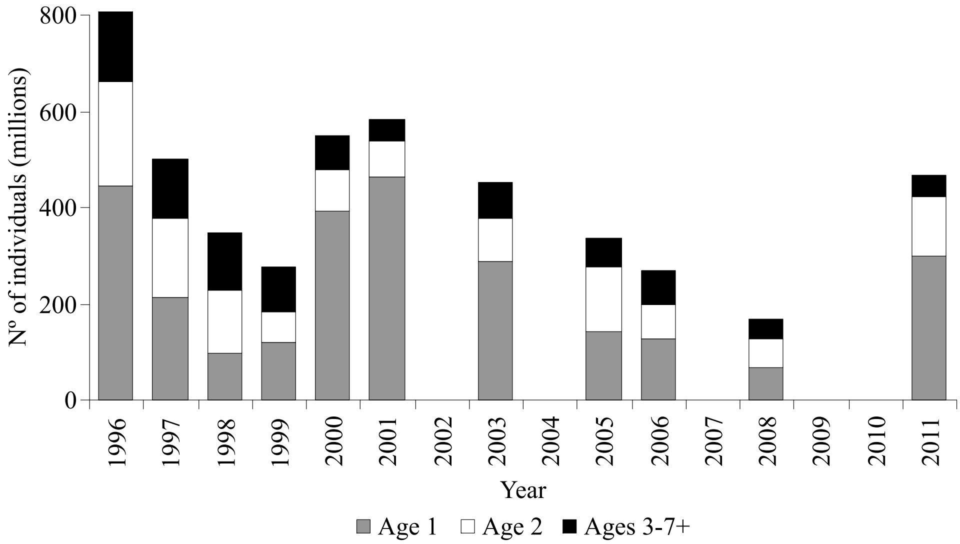

Figure 14. Age structure of the population in the 1996-2011 period. Northern stock.
Figura 14. Estructura de edades de la población en el período 1996-2011. Stock norte.

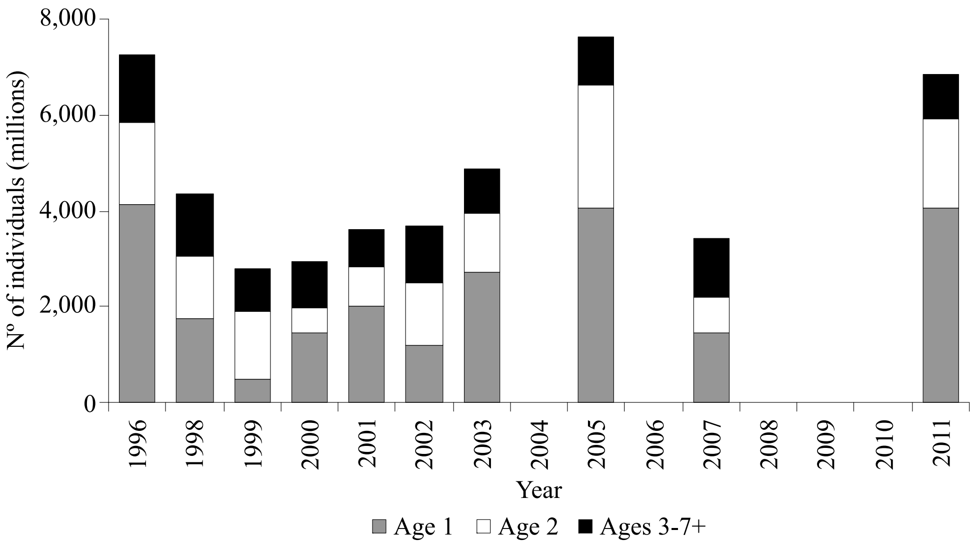

Figura 15. Age structure of the population in the 1996-2011 period. Southern stock.
Figura 15. Estructura de edades de la población en el período 1996-2011. Stock sur.

Feeding and trophic level

Variations in hake wide trophic spectrum and carnivorous habits are strongly related to size and availability of preys. The diet is composed of species of the meso and macrozooplankton (*Euphausia lucens* and *Themisto gaudichaudii*), fish (*M. hubbsi*, *Engraulis anchoita*, Myctophidae, *Patagonotothen ramsayi*, etc.) and cephalopods (*Illex argentinus* and *Doryteuthis* spp.) (Angelescu and Prenski, 1987). During larval stages, hake prey mainly on calanoid copepodites < 2 mm, among other more available items, deploying a specialist strategy (Temperoni and Viñas, 2013). In the pelagic feeding pattern observed in Summer in juveniles age 0 in the San Jorge Gulf hyperiid amphipod *T. gaudichaudii* and euphausiid *E. lucens* prevailed (Temperoni *et al.*, 2013). Other studies showed that, during Winter, in the region and adjacent waters individuals consumed zooplanktonic crustaceans thus enhancing cannibalism and that, in Summer, abundance of anchovy (*E. anchoita*) and Argentine shortfin squid (*I. argentinus*) in the area explained the preference showed for said species (Belleggia, 2012).

40-100% of the stomach content of juveniles consisted of hyperid amphipods and euphausiids; in adults they were recorded as secondary items (< 1%) consumed with larger preys. Cannibalism, observed throughout hake distribution area (Angelescu and Prenski, 1987) is an intra-specific relation that, with regional variations in intensity, occurs among groups of different sizes. 0-2 years old hake accounted for 96% cannibalism. The most important *M. hubbsi* predators were elasmobranches, namely *Dipturus chilensis*, *Squatina argentina*, *Squalus acanthias* and *S. mitsukurii* (Angelescu and Penski, 1987).

Co-occurring species

Renzi and Castrucci (1998) recorded 67 co-occurring species and estimated the percentages based on the yield (kg h^{-1}) obtained during the Northern stock evaluation. The most important were conger eel (*Bassanago albescens*), long tail hake (*Macruronus magellanicus*), blackbelly rosefish (*Helicolenus dactylopterus lahillei*), hawkfish (*Cheilodactylus bergi*), pink cuskeel (*Genypterus blacodes*), notothenids (*Notothenia* sp.), Argentine shortfin squid (*I. argentinus*), rays (*Raja* spp.) and spiny shark (*S. acanthias*). In research cruises carried out in Spring 2001 the same relative percentages were registered (Figure 16). Argentine hake, with only 11% of total catches, was placed fifth.

On the contrary, south of 41° S where Brazilian sandperch (*Notothenia* sp.), pink cuskeel (*G. blacodes*), spiny shark (*S. acanthias*), rays (*Raja* spp.), Argentine shortfin squid (*I. argentinus*), Patagonian squid (*D. gahi*), long tail hake (*M. magellanicus*) and elephant fish (*Callorhynchus callorhynchus*) associated species were found, hake represented 81% of the total (Figure 17).

Evaluation and management recommendations

Northern stock

The annual evaluation of the exploitation status of both hake stocks is done through the analysis of total biomass (TB) and reproductive biomass (SSB) trends, recruitment and juvenile and adult fishing mortality rates using the XSA (Extended Survivor Analysis). A decline in the population size found in previous assessments north of 41° S was observed (Irusta and D'Atri, 2009, 2010 b, 2011). As a result of high fishing mortality rates and poor recruitment levels that went down below the historical mean, in the 1986-2011 period total and reproductive biomass (ages 3-7+) decreased by 77 and 87%, respectively (Figure 18). The reproductive biomass that in 1999 fell below 100,000 t remained lower than the Biological Reference Points of 150,000-230,000 t estimated with the Ricker stock-recruitment relation.

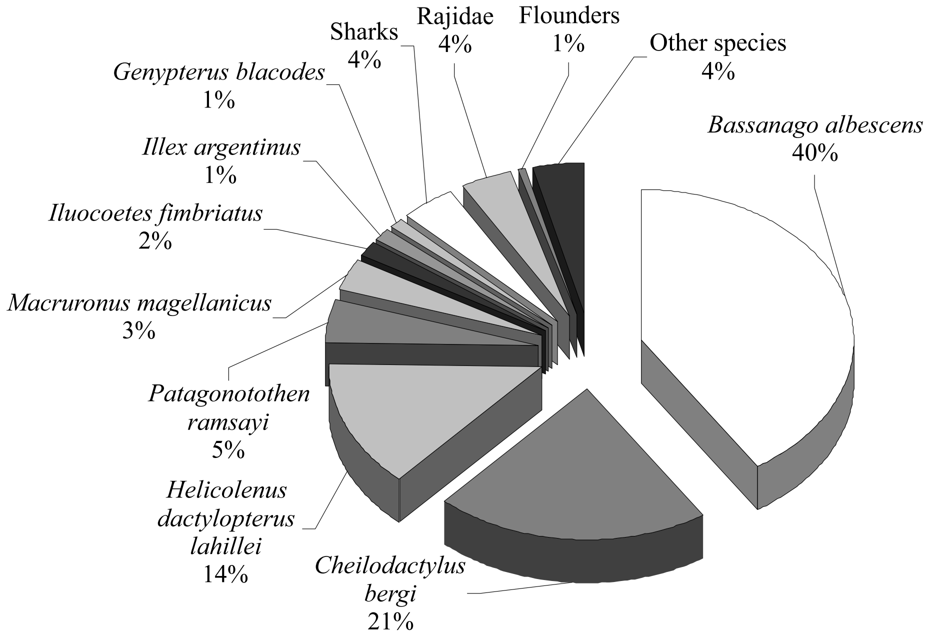

Figure 16. Percentage distribution of the co-occurring species of the Northern stock. Spring 2011.
Figura 16. Distribución porcentual de la fauna acompañante de merluza del stock norte. Primavera 2011.

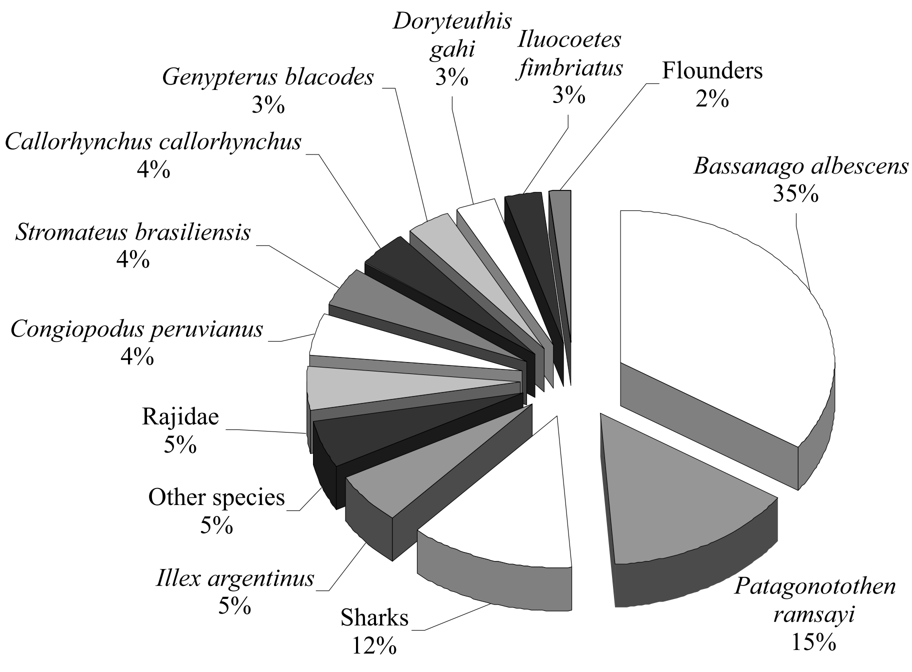

Figure 17. Percentage distribution of the co-occurring species in the Southern stock. Winter 2011.
Figura 17. Distribución porcentual de la fauna acompañante de merluza del stock sur. Invierno 2011.

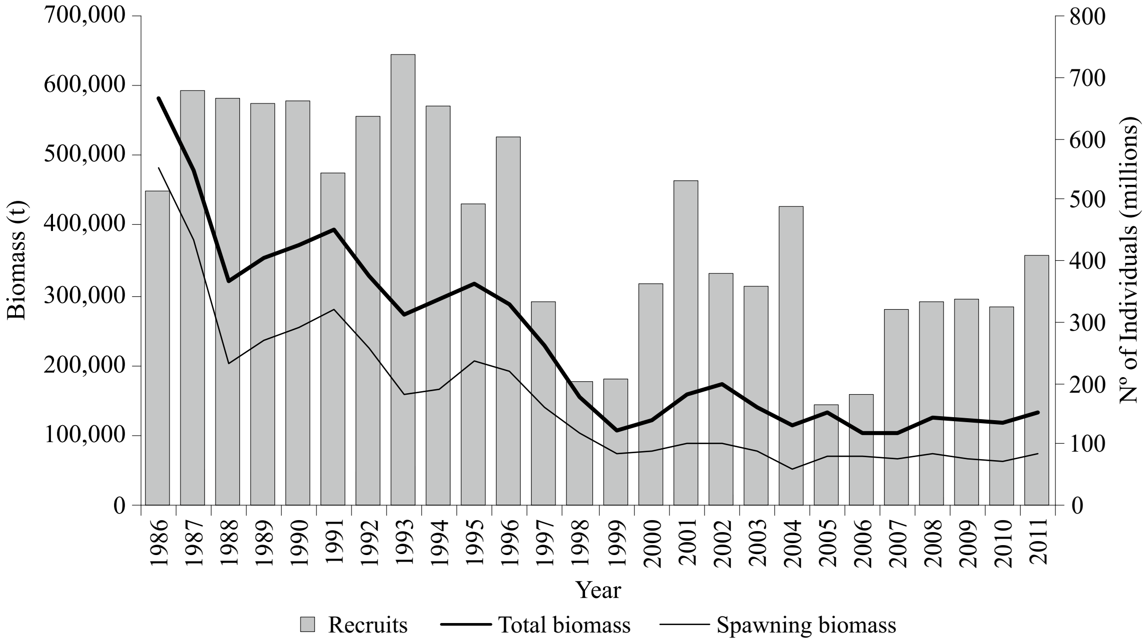

Figure 18. Total and reproductive biomass and number of recruits (age 1) estimated with the XSA. Northern stock.
Figura 18. Biomasa total y reproductiva y número de reclutas (edad 1) estimados con el XSA. Stock norte.

The low level of reproductive biomass estimated in 2011 generated uncertainty as regards success of future recruitments since the population appeared to be in a state of overfishing; thus, management recommendations aimed at recovering the SSB to 150,000 t in the short term (three years) and/or mid term (seven years). Other management alternatives comprised protection of the main reproductive area in Autumn and Winter, maintenance of closed areas all year round to protect juvenile concentrations and the use of selective nets to allow for the escape of juveniles. It must be mentioned that the stock is managed by the Comisión Técnica Mixta del Frente Marítimo (CTMFM) in the AUCFZ. In 2011 the Commission established the reduction of the Total Allowable Catch from 90,000 to 50,000 t to reduce fishing pressure on the stock. Also, with the objective of recovering the abundance and population structure of the stock north of 41° S, a Management Plan within the framework of the CTMFM was implemented.

Southern stock

In order to accurately evaluate the Southern stock population status, as from 2009 discards by the hake fleet and bycatch by the shrimp (*P. muelleri*) fleet are included in the estimates (Renzi *et al.*, 2009 b). The difference between the catches declared and the ones actually made is also considered. It must be noted that the evaluation period was shorter than for the Northern stock (Villarino *et al.*, 2012).

Results showed that survival of successful cohorts led to reach the adult stage thus producing an increase of the reproductive biomass in 2006, 2007, 2010 and 2011 to values close to the Biological Reference Points of 550,000 and 450,000 t (Figure 19). To improve the balance between the proportion of juveniles and reproductive individuals adequate measures should be implemented. To protect the stock, the establishment of closed areas for spawners in Summer, for juveniles all year round and the use of selective nets to allow for the escape of juveniles are to be considered.

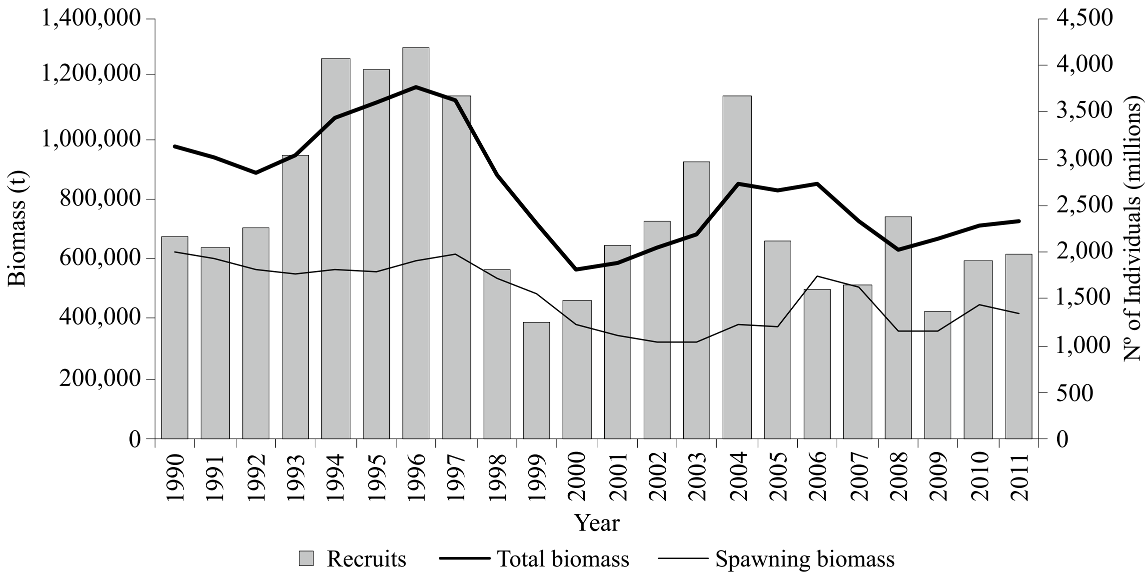

Figure 19. Total and reproductive biomass and number of recruits (age 1) estimated with the XSA. Southern stock.
Figura 19. Biomasa total y reproductiva y número de reclutas (edad 1) estimados con el XSA. Stock sur.

Markets and products

Hake is commercialized as a whole, fresh, refrigerated and frozen product with low value added. Skinless, boneless and gutted fillets, that account for almost 70% of sales, are priced 81% over the rest and have a lower level of commercialization. The ports of Mar del Plata and Puerto Madryn concentrate 54% of exports. Fresh and refrigerated products account for 80% of the total. Skinless, boneless and gutted fillets continue heading current exports at prices that, in recent years, went from 1,467 to 1,588 U$S per tonne. Over 50% of frozen goods are exported to Spain and Italy followed by France, Greece, Italy, New Zealand, Belgium, Brazil, Chile, Poland, Portugal and Ukraine. Fresh products go to Cameroon, China, Spain, USA, Italy and Brazil.

The decline in international consumption was especially reflected in higher-priced products in countries such as Italy, Germany and France. Brazil continues to be the most important market for Argentina hake exports, showing a price increase of 12% in 2012.

REFERENCES

ALAGARAJA, K. 1984. Simple methods for estimation of parameters for assessing exploited fish stocks. Indian J. Fish., 31: 177-208.

ÁLVAREZ COLOMBO, G., DATO, C., MACCHI, G., PALMA, E., MACHINANDIARENA, L., CHRISTIANSEN, H.E., BETTI, P., MARTOS, P., CASTRO-MACHADO, F., BROWN, D., EHRLICH, M., MIANZAN, H. & ACHA, E.M. 2011. Distribution and behavior of Argentine hake larvae: Evidences of a biophysical mechanism for self-recruitment at the North Patagonian shelf Waters. Cienc. Mar., 37 (4 B): 633-657.

ANGELESCU, V. & PRENSKI, L. 1987. Ecología trófica de la merluza común del Mar Argentino (Merluccidae, *Merluccius hubbsi*). Parte 2. Dinámica de la alimentación, analizada sobre la base de las condiciones ambientales, la estructura y las evaluaciones de los efectivos en su área de distribución. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), Nº 423, 248 pp.

BALDONI, A., MOLINARI, G.N., RETA, R. & GUERRERO, R.A. 2015. Atlas de temperatura y salinidad de la plataforma continental del Atlántico Sudoccidental: períodos cálido y frío. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata, 85 pp.

BELLEGGIA, M. 2012. Composición de la dieta de la merluza (*Merluccius hubbsi*) correspondiente al efectivo sur en invierno de 2011 y verano 2012 en el sector de la plataforma entre 41°-48° S. Inf. Invest. INIDEP Nº 47/2012, 13 pp.

BEZZI, S. & DATO, C. 1995. Conocimiento biológico pesquero del recurso merluza (*Merluccius hubbsi*) y su pesquería en la República Argentina. INIDEP Doc. Cient., 4: 3-52.

BEZZI, S. & PERROTTA, R. 1983. Determinación de la unidad de stock de la merluza *Merluccius hubbsi* del Mar Argentino a través del análisis de los caracteres merísticos y morfométricos. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), Nº 429, 30 pp.

BEZZI, S.I., RENZI, M., IRUSTA, C.G., SANTOS, B., TRINGALI, L.S., EHRLICH, M.D., SÁNCHEZ, F., GARCÍA DE LA ROSA, S.B., SIMONAZZI, M. & CASTRUCCI, R. 2004. Caracterización biológica y pesquera de la merluza (*Merluccius hubbsi*). In: SÁNCHEZ, R.P. & BEZZI, S.I. (Eds.). El Mar Argentino y sus recursos pesqueros. Tomo 4. Los peces marinos de interés pesquero. Caracterización biológica y evaluación del estado de explotación. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 157-205.

BURATTI, C. 2003. Microestructura de los otolitos *sagittae* de larvas y juveniles de *Merluccius hubbsi* (Marini, 1933): Análisis comparativo entre sus áreas de distribución bonaerense y norpatagónica. Seminario de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, 55 pp.

BURATTI, C.C. & SANTOS, B.A. 2010. Otolith microstructure and pelagic larval duration in two stocks of the Argentine hake, *Merluccius hubbsi*. Fish. Res., 106 (1): 2-7.

CAÑETE, G., DATO, C. & VILLARINO, M.F. 1996. Caracterización del proceso de descarte de merluza (*Merluccius hubbsi*) en la flota de buques congeladores y factorías. Inf. Téc. Int. DNI-INIDEP N° 111/1996, 19 pp.

CARRETO, J.I., NEGRI, R.M. & BENAVIDES, H.R. 1986. Algunas características del florecimiento del fitoplancton en el frente del Río de la Plata. I. Los sistemas nutritivos. Rev. Invest. Desarr. Pesq., 5: 7-29.

CARRETO, J., CARIGNAN, M., MONTOYA, N. & CUCCHI COLLEONI, A. 2007. Ecología del fitoplancton en los sistemas frontales del Mar Argentino In: CARRETO, J.I. & BREMEC, C. (Eds.). El Mar Argentino y sus recursos pesqueros. Tomo 5. El ecosistema marino. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 157-205.

CHRISTIANSEN, H.E. & COUSSEAU, M.B. 1971. La reproducción de la merluza y su relación con otros aspectos biológicos de la especie. Boletín Instituto Biología Marina (Mar del Plata), Nº 20: 43-73.

CIECHOMSKI, J.D. & WEISS, G. 1973. Nota sobre la presencia de huevos y larvas de merluza, (*Merluccius merluccius hubbsi*), en el Mar Argentino. Physis A, 32 (84): 155-160.

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

CUBILLOS, L.A. 2003. An approach to estimate the natural mortality rate in fish stocks. Naga, 26 (1): 17-19.

DATO, C. 1994. Caracterización del área de distribución de merluza (*Merluccius hubbsi*) a través de las asociaciones de especies con su fauna acompañante. In: XI Simposio Científico Tecnológico, Comisión Técnica Mixta del

Frente Marítimo, Mar del Plata, Argentina, Resúmenes: 4.

DATO, C.V., MACCHI, G.J. & RODRIGUES, K.A. 2009. Abundancia, estructura de tallas y área de reproducción de la merluza (*Merluccius hubbsi*) entre 35° S y 41° S durante mayo de 2009. Inf. Téc. Of. INIDEP Nº 32/2009, 13 pp.

DATO, C., VILLARINO, M.F. & CAÑETE, G. 2001. Estimación indirecta del descarte de merluza para el efectivo al sur de 41° S a partir del año 1998 y consideraciones sobre la evolución de este proceso en los últimos años. Inf. Téc. Int. DNI-INIDEP Nº 10/2001, 9 pp.

D'ATRI, L.L. 2012. Estimación de la mortalidad natural en el efectivo norte de merluza (*Merluccius hubbsi*) aplicando Simulación de Montecarlo. Inf. Invest. INIDEP Nº 92/2012, 25 pp.

D'ATRI, L.L. & IRUSTA, C.G. 2011. Comparación entre la captura declarada de merluza (*Merluccius hubbsi*) en los partes de pesca comercial y la estimada por los observadores a bordo de la flota fresquera arrastrera de altura al sur del paralelo 41° S durante el año 2010. Inf. Invest. INIDEP Nº 29/2011, 14 pp.

DÍAZ, M.V., MACCHI, G.J. & OLIVAR, M.P. 2012. Condición nutricional de las larvas de merluza *Merluccius hubbsi* en la zona de cría norpatagónica durante enero-febrero de 2011. Inf. Invest. INIDEP Nº 45/2012, 20 pp.

DJABALI, F., MEHAILIA, A., KOUDIL, M. & BRAHMI, B. 1994. Assessment of equations for predicting of natural mortality in Mediterranean teleosts. Naga, 17: 33-34.

DOMÍNGUEZ-PETIT, R. & SABORIDO-REY, F. 2010. New bioenergetic perspective of European hake (*Merluccius merluccius* L.) reproductive ecology. Fish. Res., 104: 83-88.

EHRLICH, M.D. 2000. Distribución y abundancia de huevos, larvas y juveniles de merluza (*Merluccius hubbsi*) en la Zona Común de Pesca Argentino-Uruguaya. 1996-1998. Frente Marit., 18 (A): 31-44.

EHRLICH, M.D. & CIECHOMSKI, J.D. 1994. Reseña sobre la distribución de larvas de merluza (*Merluccius hubbsi*) basada en veinte años de investigaciones. Frente Marit., 15 (A): 37-50.

EHRLICH, M., MACCHI, G.J., MADIROLAS, A. & MACHINANDIARENA, L. 2013. Vertical distribution of hake *Merluccius hubbsi* in spawning aggregations in north Patagonian waters of the Southwest Atlantic. Fish. Res., 138: 89-98.

FISCHBACH, C., DE LA GARZA, J. & BERTUCHE, D. 2006. La pesquería del langostino patagónico en el período 1991-2005. Inf. Téc. Int. DNI-INIDEP N° 03/2006, 21 pp.

GIANGIOBBE, S., VERAZAY, G. & IBAÑEZ, P. 1993. Análisis del comportamiento de la flota pesquera argentina sobre el recurso merluza durante el período 1985-1988. Frente Marit., 14 (A): 23-32.

GISLASON, H., DAAN, N., RICES, J.C. & POPE, J. 2010. Size, growth, temperature and natural mortality of marine fish. Fish Fish., 11: 149-158.

GUERRERO, R. & PIOLA, A. 1997. Masas de agua en la plataforma continental. In: BOSCHI, E.E. (Ed.). El Mar Argentino y sus recursos pesqueros. Tomo 1. Antecedentes históricos de las exploraciones en el mar y las características ambientales. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 107-118.

HUNTER, J.R. & GOLDBERG, S.R. 1980. Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax*. Fish. Bull., 77 (3): 641-652.

HUNTER, J.R., MACEWICZ, B.J., LO, N.C.H. & KIMBRELL, C.A. 1992. Fecundity, spawning, and maturity of female Dover sole *Microstomus pacificus*, with an evaluation of assumptions and precision. Fish. Bull., 90: 101-128.

IRUSTA, C.G. & CASTRUCCI, R. 2012. Análisis de la flota comercial de altura argentina que operó sobre la merluza (*Merluccius hubbsi*) en 2012 y 2011. Inf. Invest. INIDEP Nº 1/2012, 29 pp.

IRUSTA, C.G. & D'ATRI, L.L. 2009. Evaluación del estado del efectivo norte de 41° S de la merluza (*Merluccius hubbsi*) y estimación de la captura biológicamente aceptable para el año 2010. Inf. Téc. Of. INIDEP N° 45/2009, 39 pp.

IRUSTA, G. & D'ATRI, L. 2010 a. Comparación entre la captura declarada de merluza (*Merluccius hubbsi*) en los partes de pesca comerciales y la estimada por los observadores a bordo de la flota fresquera arrastrera de altura que operó al sur del paralelo 41°S durante el año 2009. Inf. Invest. INIDEP Nº 26/2010, 14 pp.

IRUSTA, C.G. & D'ATRI, L.L. 2010 b. Evaluación del estado del efectivo norte de 41° S de la merluza (*Merluccius hubbsi*) y estimación de la captura biológicamente aceptable para el año 2011. Inf. Téc. Of. INIDEP Nº 42/2010, 28 pp.

IRUSTA, C.G. & D'ATRI, L.L. 2011. Evaluación del estado del efectivo norte de 41° S de la merluza (*Merluccius hubbsi*) y estimación de la captura biológicamente aceptable para el año 2012. Inf. Téc. Of. INIDEP Nº 43/2011, 31 pp.

IRUSTA, C.G., CASTRUCCI, R. & SIMONAZZI, M. 2009. Pesca comercial y captura por unidad de esfuerzo de la merluza (*Merluccius hubbsi*) entre 34° y 41° S durante el período 1986-2005 y evidencias sobre cambios en la distribución y composición por tallas del recurso. INIDEP Inf. Téc., 74, 37 pp.

IRUSTA, C.G., D'ATRI, L.L. & LORENZO, M.I. 2010. Diagnóstico del estado del recurso merluza (*Merluccius hubbsi*) realizado en el ámbito de la Comisión Técnica Mixta del Frente Marítimo. Frente Marit., 22: 193-206.

IRUSTA, G., BEZZI, S., SIMONAZZI, M. & CASTRUCCI, R. 2001. Los desembarques argentinos de merluza entre 1987 y 1997. INIDEP Inf. Téc., 42, 24 pp.

JENSEN, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci., 53: 820-822.

LORENZO, M.I. & VAZ-DOS SANTOS, A.M. 2011. Growth pattern of the young of the year Argentine hake *Merluccius hubbsi* Marini, 1933 (Gadiformes Merluccidae) along the Brazilian and Uruguayan coast. Environ. Biol. Fish, 91: 155-164.

LOUGE, E. & MOLINARI, G. 2011. Distribución de la merluza (*Merluccius hubbsi*) del efectivo norte con relación a la temperatura y la salinidad. Otoño-primavera 1998-2010. Inf. Invest. INIDEP Nº 98/2011, 13 pp.

LOUGE, E., MOLINARI, G. & CASTRUCCI, R. 2011 a. Distribución de la merluza (*Merluccius hubbsi*) en la Zona Común de Pesca Argentino-Uruguaya en relación con parámetros oceanográficos. Diciembre 1995-2000. Frente Marít., 22, 177-190.

LOUGE, E.B., RETA, R., SANTOS, B.A. & HERNÁNDEZ, D.R. 2004. Variaciones interanuales (1995-2000) de la temperatura y la salinidad registradas en los meses de enero en el Golfo San Jorge y aguas adyacentes (43° S-47° S). Rev. Invest. Desarr. Pesq., 16: 27-42.

LOUGE, E., RETA, R., SANTOS, B. & HERNÁNDEZ, D. 2009. Distribución de merluza (*Merluccius hubbsi* Marini, 1933) en el Mar Argentino (41°-48°S) en relación con parámetros oceanográficos durante el invierno (1996-2003). Rev. Biol. Mar. Oceanogr., 44 (2): 497-510.

LOUGE, E., RETA, R., SANTOS, B. & HERNÁNDEZ, D. 2011 b. Distribución estival del stock sureño de la merluza argentina (*Merluccius hubbsi* Marini, 1933) en el área de cría (44°-47°S) en relación con parámetros oceanográficos (1996-2001). Lat. Am. J. Aquat. Res., 39 (1): 82-92.

MACCHI, G.J. & PÁJARO, M. 2003. Fecundidad, producción potencial de huevos y talla de primera maduración de la merluza (*Merluccius hubbsi*) en el área de reproducción otoñal (35°-39°30'S). Inf. Téc. Int. DNI-INIDEP Nº 86/2003, 13 pp.

MACCHI, G.J., MARTOS, P. & RETA, R. 2010. Offshore spawning of the Argentine hake (*Merluc-*

cius hubbsi) Patagonian stock. Pan. Am. J. Aquat. Sci., 5 (1): 22-35.

Macchi, G.J., Pájaro, M. & Dato, C. 2007. Spatial variations of the Argentine hake (*Merluccius hubbsi*) spawning shoals in the Patagonian area during a reproductive season. Rev. Biol. Mar. Oceanogr., 42 (3): 345-356.

Macchi, G.J., Pájaro, M. & Ehrlich, M. 2004. Seasonal egg production pattern of the Patagonian stock of Argentine hake (*Merluccius hubbsi*). Fish. Res., 67: 25-38.

Macchi, G.J., Leonarduzzi, E., Diaz, M.V., Renzi, M. & Rodrigues, K.A. 2013. Maternal effects on fecundity and egg quality of the Patagonian stock of Argentine Hake (*Merluccius hubbsi*). Fish. Bull., 111 (4): 325-336.

Macchi, G.J., Pájaro, M., Militelli, M.I., Radovani, N. & Rivas, L. 2006. Influence of size, age and maternal condition on the oocyte dry weight of Argentine hake (*Merluccius hubbsi*). Fish. Res., 80 (2-3): 345-349.

Otero, H.O. 1977. Edad y crecimiento de la merluza (*Merluccius merluccius hubbsi*). Physis (A), 36 (92): 41-58.

Otero, H., Giangiobbe, S. & Renzi, M. 1986. Aspectos de la estructura de población de la merluza común (*Merluccius hubbsi*). II. Distribución de tallas y edades. Estadios sexuales. Variaciones estacionales. Publ. Com. Téc. Mix. Fr. Mar., 1 (1): 147-179.

Otero, H., Bezzi, S., Renzi, M. & Verazay, G. 1982. Atlas de los recursos pesqueros demersales del Mar Argentino. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), Nº 423, 248 pp.

Pájaro, M., Macchi, G.J. & Martos, P. 2005. Reproductive pattern of the Patagonian stock of Argentine hake (*Merluccius hubbsi*). Fish. Res., 72: 97-108.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 stocks. J. Cons. int. Explor. Mer., 39: 175-192.

Piola, A.R., Campos, E.J.D., Moller, O.O., Charo, M. & Martinez, C. 2000. Subtropical shelf front off eastern South America. J. Geophys. Res., 105 (C3), 6566-6578.

Prenski, B. & Angelescu, V. 1993. Ecología trófica de la merluza común (*Merluccius hubbsi*) del Mar Argentino. Parte 3. Consumo anual de alimento a nivel poblacional y su relación con la explotación de las pesquerías multiespecíficas. INIDEP Doc. Cient., 1, 119 pp.

Renzi, M. & Castrucci, R. 1998. Análisis cualicuantitativo de la fauna acompañante en la pesquería de merluza (*Merluccius hubbsi*) al norte de 41° S. Inf. Téc. Int. DNI-INIDEP N° 24/1998, 20 pp.

Renzi, M. & Pérez, M. 1992. Un criterio para la determinación de la edad en juveniles de merluza (*Merluccius hubbsi*) mediante la lectura de otolitos. Frente Marit., 11 (A): 15-31.

Renzi, M.A., Santos, B.A. & Abachian, V. 2009 a. Crecimiento de la merluza (*Merluccius hubbsi*) del Atlántico Sudoccidental entre 1993-2003 al norte y sur de 41° S. INIDEP Inf. Téc., 76, 33 pp.

Renzi, M., Santos, B. & Simonazzi, M. 1999. Edad, crecimiento y estructura poblacional de merluza. In: Avances en métodos y tecnología aplicados a la investigación pesquera. Seminario final del Proyecto INIDEP-JICA sobre Evaluación y monitoreo de recursos pesqueros 1994-1999. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 107-110.

Renzi, M., Santos, B. & Simonazzi, M. 2003. Estructura por edad y sexo de la población de merluza. In: Aportes para la evaluación del recurso merluza (*Merluccius hubbsi*) al sur de los 41º S. Año 1999. INIDEP Inf. Téc., 51: 57-76.

Renzi, M., Santos, B. & Simonazzi, M. 2005. Estructura por edad y sexo de la población de merluza (*Merluccius hubbsi*) en el área norte de 41° S. Período 1993-1999. Frente Marit., 20 (A): 37-45.

Renzi, M., Villarino, M.F. & Santos, B. 2009

b. Evaluación del estado del efectivo sur de 41° S de la merluza (*Merluccius hubbsi*) y estimación de las capturas biológicamente aceptables correspondientes al año 2009 y 2010. Inf. Téc. INIDEP 46/2009, 37 pp.

RODRIGUES, K.A. & MACCHI, G.J. 2010. Spawning and reproductive potencial of the Northern stock of Argentine hake (*Merluccius hubbsi*). Fish. Res., 106: 560-566.

RODRIGUES, K., MACCHI, G.J. & MILITELLI, M.I. 2015. Comparative study of spawning pattern and reproductive potential of the Northern and Southern stocks of Argentine hake (*Merluccius hubbsi*). J. Sea Res., 102: 22-32.

ROFF, D.A. 1984. The evolution of life history parameters in teleosts. Can. J. Fish. Aquat. Sci., 41: 989-1000.

RUARTE, C.O. 1997. Relaciones del tamaño y peso del otolito con la longitud y edad del pez en la merluza (*Merluccius hubbsi*) para tres zonas del Mar Argentino. Seminario de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, 38 pp.

SANTOS, B.A. & RENZI, M.A. 1999. Estudios de edad en el grupo 0 de merluza (*Merluccius hubbsi*). In: Avances en métodos y tecnología aplicados a la investigación pesquera. Seminario final del Proyecto INIDEP-JICA sobre Evaluación y monitoreo de recursos pesqueros 1994-1999. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 111-113.

SARACENO, M., PROVOST, C., PIOLA, A.R., BAVA, J. & GAGLIARDINI, A. 2004. Brazil Malvinas Frontal System as seen from 9 years of advanced very high resolution radiometer data. J. Geophys. Res., 109. C05027. doi:10.1029/2003JC002127

SARDELLA, N.H. 1984. Mixosporidios parásitos musculares de peces del Mar Argentino. (Incidencia, reacciones de respuesta ante la agresión parasitaria, consideraciones zoogeográficas y aspectos tecnológicos). Tesis de Doctorado, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, 66 pp.

SARDELLA, N. & TIMI, J. 2004. Parasites of Argentine hake in the Argentine Sea: population and infracommunity structure as evidence for host stock discrimination. J. Fish Biol., 65: 1472-1488.

SIMONAZZI, M.A. 2003. Relación longitud-peso y longitud-edad de primera madurez sexual de la merluza. In: TRINGALI, L.S. & BEZZI, S.I. (Eds.). Aportes para la evaluación del recurso merluza (*Merluccius hubbsi*) al sur de los 41° S. Año 1999. INIDEP Inf. Téc., 51: 11-26.

TAYLOR, C.C. 1960. Temperature, growth and mortality, of the Pacific cockle. ICES J. Mar. Sci., 26: 117-124.

TEMPERONI, B. & VIÑAS, M.D. 2013. Food and feeding of Argentine hake (*Merluccius hubbsi*) larvae in the Patagonian nursery ground. Fish. Res., 148: 47-55.

TEMPERONI, B., VIÑAS, M.D. & BURATTI, C. 2013. Feeding strategy of juveniles (age-0+ year) Argentine hake *Merluccius hubbsi* in the Patagonian nursery ground. J. Fish Biol., 83: 1354-1370.

TEMPERONI, B., VIÑAS, M.D., MARTOS, P. & MARRARI, M. 2014. Spatial patterns of copedod diversity in relation to a tidal front system in the main spawning and nursery area of the Argentine hake *Merluccius hubbsi*. J. Mar. Syst., 139: 433-445.

VILLARINO, M.F. & SIMONAZZI, M.A. 2010. Evolución del *by-catch* de merluza (*Merluccius hubbsi*) en la pesquería del langostino patagónico (*Pleoticus muelleri*) en el período 2000-2003. Inf. Téc. Int. INIDEP N° 15/2010, 30 pp.

VILLARINO, M.F., SANTOS, B.A. & RENZI, M. 2012. Evaluación del estado de explotación del efectivo sur de 41° S de la merluza (*Merluccius hubbsi*) y estimación de las capturas biológicamente aceptables correspondiente al año 2013. Inf. Téc. Of. INIDEP N° 38/2012, 27 pp.

VIÑAS, M.D. & RAMÍREZ, F.C. 1996. Gut analysis of first-feeding anchovy larvae from the Patagonian spawning areas in relation to food availability. Arch. Fish. Mar. Res., 43 (3): 231-256.

ZHANG, C.I. & MEGREY, B.A. 2006. A revised Alverson and Carney model for estimating the instantaneous rate of natural mortality. Trans. Amer. Fish. Soc., 135: 620-633.

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