REVISIÓN

BIOLOGY AND FISHERY OF LONG TAIL HAKE (*Macruronus magellanicus*) IN THE SOUTHWEST ATLANTIC OCEAN*

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SUMMARY. Long tail hake is one of the most important finfish resources in the Southwest Atlantic Ocean (SAO). This demersal-pelagic fish is widely distributed from 35° S to 56° S between 50 and 800 m depth. In the Patagonian region the species is found on the shelf, associated with three different water masses: Coastal, Shelf and Malvinas Waters, while north of 45° S it is related to the shelf break, following the Malvinas waters. A separate small stock, evident because of its different growth patterns, occurs inside San Matías Gulf. There is no strong difference in growth patterns between sexes, however females are larger than males, principally after the first maturity that occurs at 3 years old. Maximum age observed was 16 years old, but fish older than 12 years are scarce in the population. The dietary composition changes during the life cycle, juveniles are mainly microphagous and adults incorporate larger preys of several invertebrates and vertebrates taxa. Principal food items are zooplankton species; the most abundant are hyperiid amphipods and euphausiids. Fish and cephalopods are secondary prey. Few fish species predate on long tail hake: Southern hake (*Merluccius australis*), spiny dogfish (*Squalus acanthias*), and Argentine hake (*M. hubbsi*). Cannibalism is not reported in long tail hake. Spawning areas have not been detected yet but some signals in somatic conditions allow inferring that this process may occur during spring. A systematic series of summer demersal standard swept area trawl surveys has been conducted since 1992 to assess the population, suggesting that maximum long tail hake biomass was more than 2 million tonnes in the mid 1990's. Those results were employed as an index of abundance in the annual stock assessment to establish the Total Allowable Catch, but neither environmental variables nor economic effects have been considered yet. Fishing activities began during the mid 1970's when yields were not significant, but beginning in the 1980's several fleets targeted long tail hake, increasing catches up to 168,000 t. Products are exported to Europe, Asia and South America.

Key words: Long tail hake, *Macruronus magellanicus*, SAO, biology, assessment, fishery.

BIOLOGÍA Y PESQUERÍA DE LA MERLUZA DE COLA (*Macruronus magellanicus*) EN EL OCÉANO ATLÁNTICO SUDOCCIDENTAL

RESUMEN. La merluza de cola es uno de los recursos pesqueros más importantes del Océano Atlántico Sudoccidental (OAS). Este pez demersal pelágico se encuentra ampliamente distribuido desde 35° S a 56° S entre 50 y 800 m de profundidad. En la región patagónica, la especie se encuentra en la plataforma continental, asociada a tres masas de agua diferentes: Aguas Costeras, de Plataforma y de Malvinas, mientras que al norte de 45° S se relaciona con esta última masa de agua y se halla restringida al borde del talud continental. Un efectivo pesquero independiente, evidente por su patrón de crecimiento diferencial, habita en el interior del Golfo San Matías. No existen diferencias en

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el crecimiento entre los sexos, sin embargo las hembras son más grandes que los machos, principalmente después de alcanzada la primera madurez que ocurre a los 3 años de edad. La edad máxima observada ha sido de 16 años, pero los peces mayores de 12 años son escasos en la población. La composición de la dieta cambia durante su ciclo de vida. Con dieta principalmente zooplanctófaga, los principales ítems alimento son los anfípodos hipéridos y los eufáusidos. Los peces y los cefalópodos se incorporan como presa secundaria. No se ha detectado canibalismo en la merluza de cola. Solo pocas especies de peces son sus predadoras: la merluza austral (*Merluccius australis*), el tiburón espinoso (*Squalus acanthias*) y la merluza (*M. hubbsi*). No se han detectado áreas de reproducción, pero algunos indicios en las condiciones somáticas permiten inferir que este proceso podría producirse durante la primavera. Desde 1992 se ha realizado una serie cruceros de investigación con el objetivo de estimar el tamaño poblacional durante el verano. Durante la década de los noventa, la biomasa de la merluza de cola superaba los 2 millones de toneladas, alcanzando actualmente la mitad. Tales estimaciones han sido empleadas como índices de ajuste en la evaluación de abundancia indirecta de la población para poder establecer la captura total permisible. Las variables ambientales y los efectos económicos no han sido considerados aún en el modelo de evaluación. Las actividades pesqueras comenzaron a mediados de la década de los setenta cuando los rendimientos no eran relevantes, pero a partir de los ochenta varias flotas dirigieron su esfuerzo a la merluza de cola, incrementando las capturas hasta las 168.000 t. El procesamiento de las capturas es realizado a bordo y los productos finales son directamente exportados a Europa, Asia y América del Sur.

Palabras clave: Merluza de cola, *Macruronus magellanicus*, OAS, biología, abundancia, pesquería.

INTRODUCTION

The long tail hake, *Macruronus magellanicus*, is one of the main species of fish which inhabit the Southwest Atlantic Ocean (SAO). Its significant presence south of 45° S, where it lives in cold temperate waters of the Malvinas Current, appears to be recent in geological terms. Consequently, the species is currently in expansion, so some aspects of its biological cycle are not completely understood. Several biological characteristics, mainly its adaptive and opportunistic capacity and the absence of competition, have allowed it to establish in ecological niches which have been liberated principally due to anthropogenic effects, resulting in its dominance in the Patagonian species assemblage.

It is one of the most important white flesh species, occupying second place in total annual landings after the Argentine hake (*Merluccius hubbsi*). The evolution of its fishing had several stages, in which a number of fleets have participated, and their objectives have depended on the demand of international markets. Precautionary management strategies have been established to create a certified fishery with an individual transferable quota system (ITQ).

TAXONOMY

M. magellanicus is accepted as a member of the Macruronidae Family (Günther, 1887; Angelescu and Gneri, 1960) which is distributed in the Southern Hemisphere. This family may be considered a primitive sister group to the Gadoidei and dissimilar to the Genus *Merluccius* (Nelson, 1994). Nevertheless, some morphological aspects identify *Macruronus* as a member of the Merlucciidae Family (Hart, 1946; Menni *et al*., 1984; Cohen *et al*., 1990; Cousseau, 1993). Recent analyses recognize that macruronids and merluccids seem to be a paraphyletic group (Endo, 2002).

GEOGRAPHICAL, BATHYMETRICAL AND SEASONAL DISTRIBUTION

Long tail hake is widely distributed around South America, both in the Southeastern Pacific and in the SAO (Figure 1). In the Atlantic it inhabits the Argentine shelf and slope, from 36° S to 56° S (Angelescu and Gneri, 1960), including San Matías Gulf (Roa *et al.,* 1976; Inada, 1983; González and Caille, 1995), San Jorge Gulf (Flowers and Roa, 1975; Giussi, 1996), the Strait of Magellan and the Fueguian Channels (Fenucci *et al.*, 1974; Lloris and Rucabado, 1991). Ranging from 20 to 600 m depth (Inada, 1983; Wöhler, 1987; Chesheva, 1995), the highest abundances occur between 50-200 m depth (Wöhler, 1987; Angelescu and Prenski, 1987). It is considered a demersal-pelagic species and with a preferred diet resulting in diurnal migrations.

Its distribution is closely related to the cold-temperate waters of the Malvinas Current (Angelescu and Gneri, 1960), which flows near the slope northwards and becomes deeper when it encounters the Brazilian Current near 40° S (Krepper and Rivas, 1979; Bianchi *et al.*, 1982). The species is also scarce but present on the Buenos Aires Province shelf as well as the slope where the Malvinas Current submerges (Bezzi, 1984; Giussi and Mari, 1999; Wöhler and Castañeda, 2000; García de la Rosa *et al.*, 2000).

South of 45° S the species is more abundant and some groups may be more concentrated in particular zones. During its life cycle, long tailed hake tolerates a relatively wide range of temperature (4-11 °C) and salinity (32.57-34.11). Age group schools move among different areas (Figure 2) probably following particular oceanographic conditions according to their needs and preferences, and also related to the three water masses present in the area (Giussi *et al.*, 1999 b, 2012 b). These water masses, named Coastal Waters, Shelf Waters, and the Malvinas Current, are characteri-

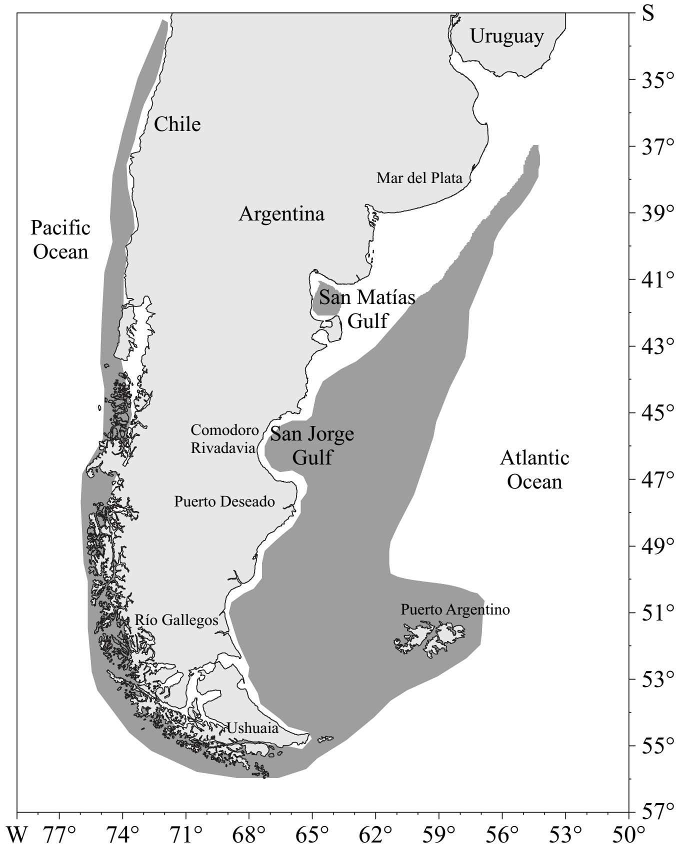

Figure 1. Geographical distribution of *Macruronus magellanicus* around South America.
Figura 1. Esquema de la distribución geográfica de Macruronus magellanicus *en América del Sur.*

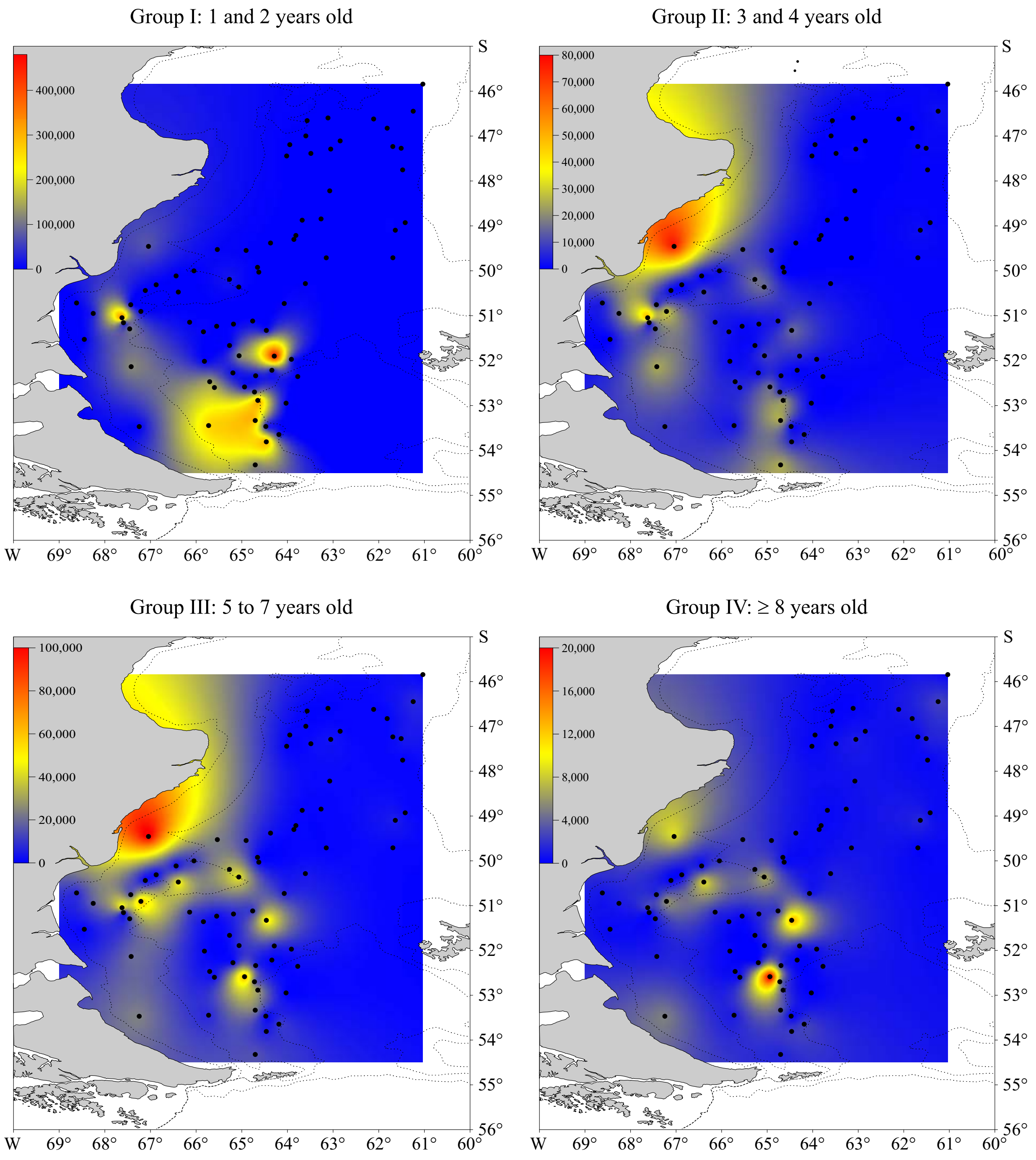

Figure 2. Presence of *Macruronus magellanicus* in different water masses during its life cycle. Redrawn from Giussi *et al.* (2012 b).

Figura 2. Presencia de Macruronus magellanicus *en cada masa de agua durante su ciclo de vida. Redibujado de Giussi et al. (2012 b).*

zed by different gradients of salinity and temperature (Fedulov *et al*., 1990). Juveniles prefer principally Shelf Waters, occurring mainly in the South near Tierra del Fuego and Isla de los Estados. Pre-adult and adult individuals showed a similar behaviour but also occur in Coastal Waters; the highest densities were located near the coast in the Northern area. Adults were present principally in Coastal and Shelf Waters but were also dispersed over the entire area.

The absence of geographic isolating barriers probably contributes to a panmictic population, except for the individuals in the San Matías Gulf. This is a semi-enclosed basin with restricted circulation that may interrupt the connection with groups from other areas. Notable differences in growth have been detected between them and the individuals which inhabit in the continental shelf (Giussi *et al*., 1999 a). Even though each age group prefers a particular water mass, its wide adaptability and presence in several areas, sometimes in densities, has provided some information to help understand its migration pattern. Some hypotheses about migratory routes have been formulated. Hart (1946) suggested that the species migrates to the south in spring and summer and to the north in winter. Inada (1983) indicated that the largest fishes move towards coastal waters to spawn during late winter. However, it appears that fish are concentrated in deeper waters during winter, moving to shallower waters in warmer seasons. North-south migration may be performed mainly by juveniles and younger adults, subsequently distributing over the entire area as they become adults (Giussi, 1996).

BIOLOGY AND LIFE HISTORY

Age and growth

Age determination of long tail hake is done by counting the growth rings present in *sagittae* otoliths (Figure 3). These are of elongated shape with a blunt anterior end and a sharpened and slightly lobulated posterior end. The dorsal edge is concave and the ventral edge is convex and

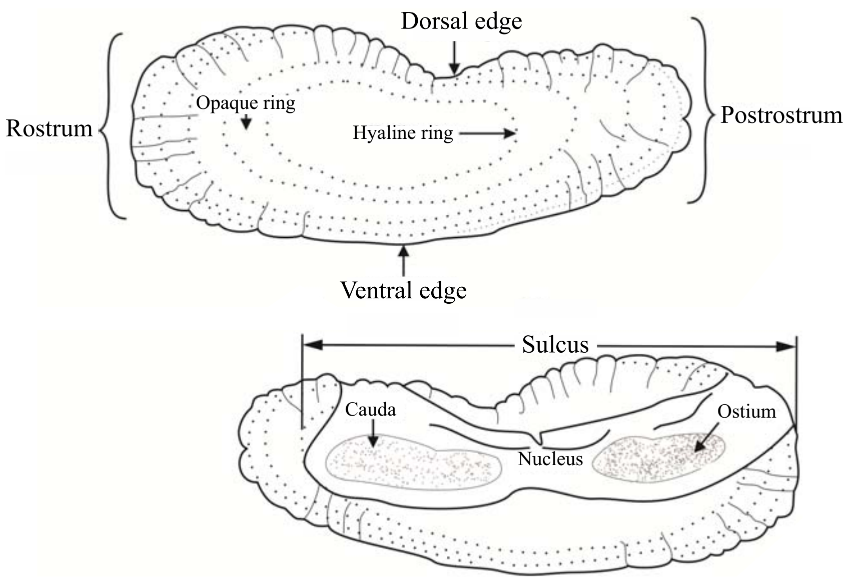

Figure 3. *Sagitta* otolith of *Macruronus magellanicus*. Redrawn from Giussi (1996).
Figura 3. Otolito sagitta de Macruronus magellanicus. *Redibujado de Giussi (1996).*

more crenulated, with crenulations being more pronounced in the otoliths of juveniles. The core or nucleus can easily be identified in the *sulcus* present on the proximal surface of the otolith. Growth rings are easily distinguishable on the otolith's distal surface after hydration. The opaque wide bands, reflecting rapid growth, would be formed during the summer months from December through March when food availability is high and therefore the growth of individuals increases. The translucent bands, narrow and crystalline, probably indicate a slower growth rate. One opaque and one translucent zone are formed annually enabling the determination of fish ages, which are assigned considering July 1 as the date of birth of the species (*i.e.*, the start of the spawning season), and it is also the time when the highest percentage of translucent edges is found (Giussi, 1996).

Growth in length (Table 1; Figure 4) as well as in weight (Table 2; Figure 5) have been very well explained by the von Bertalanffy (1938) model, where parameters were estimated by the maximum likelihood method (Aubone and Wöhler, 2000). This methodology allows a comparison of growth between sexes, and showed that the differences in this species are mainly related to the growth coefficient (K). Females have lower values, reaching their asymptotic length at a slower rate, growing faster than males up to 4 year old (Giussi, 2002; Giussi and Abachian, 2004, 2006; Abachian and Giussi, 2007, 2009; Abachian *et al.*, 2012; Zavatteri and Giussi, 2013; Zavatteri *et al.*, 2013). The values of the other parameters (L_∞ and t_0) are more influenced by the basic extreme data, that is, the maxima and minima.

The length-weight relationship is similar between sexes (Figure 6). However, females reach higher weight-at-age than males, exhibiting sexual dimorphic growth. There is a wide variability across years in both the maximum observed and the asymptotic weights (W_∞); these differences could be caused by the species adaptability to the changing ecosystem conditions more than to population changes (Zavatteri and Giussi, 2013).

Both mean length-at-age and mean weight-at-age show a similar growth pattern for males and females during the first three years. Differences become apparent after this age, when the proportion of mature individuals increases markedly. Growth in length is fast during the first two years; during this time the fish reaches more than half of its theoretical maximum length (Giussi, 1996). The largest size recorded in males is 100 cm total length (TL) and 3,570 g, while for females it is 110 cm TL and 4,400 g (Zavatteri and Giussi, 2013).

Frequently, the maximum ages in populations are 11 and 12 years in males and females, respectively (Zavatteri *et al.*, 2011; Abachian *et al.*, 2012), however 16 and 19 year old individuals were recorded sporadically (Giussi *et al.*, 2004).

Table 1. Growth parameters in length estimated by several authors.
Tabla 1. Parámetros de crecimiento en longitud estimados por varios autores.

	Giussi (1996)		Wöhler *et al.* (1999 b)		Zavatteri *et al.* (2013)		Zavatteri *et al.* (2016)	
Parameter	Males	Females	Males	Females	Males	Females	Males	Females
L_∞	82.34	93.17	88.147	100.92	85.98	93.12	88.94	104.01
K	0.299	0.216	0.245	0.190	0.249	0.209	0.223	0.151
t_0	-0.597	-1.222	-0.425	-0.610	-1.205	-1.414	-0.883	-1.621

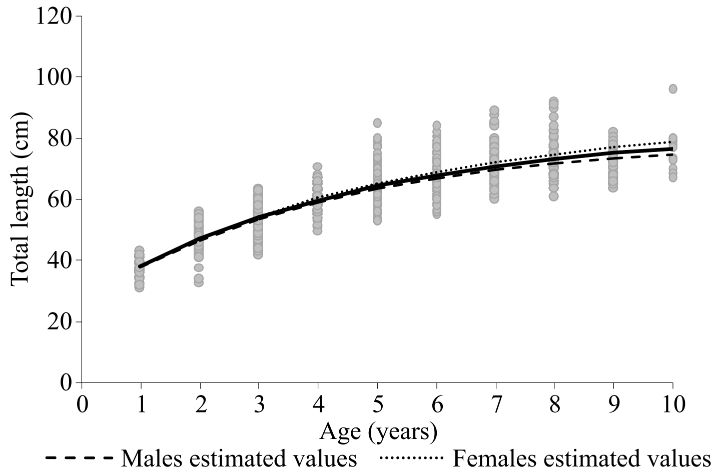

Figure 4. Growth in length of *Macruronus magellanicus*. Dots: observed data, line: theoretical curve.
Figura 4. Crecimiento en longitud de Macruronus magellanicus*. Puntos: datos observados, línea: curva teórica.*

Table 2. Growth parameters in weight (Zavatteri and Giussi, 2013).
Tabla 2. Parámetros de crecimiento en peso (Zavatteri y Giussi, 2013).

Parameter	2005	2006	2007
W_∞	1,517.1	1,679.4	1,866.8
K	0.243	0.237	0.235
t_0	-1.819	-1.689	-1.662

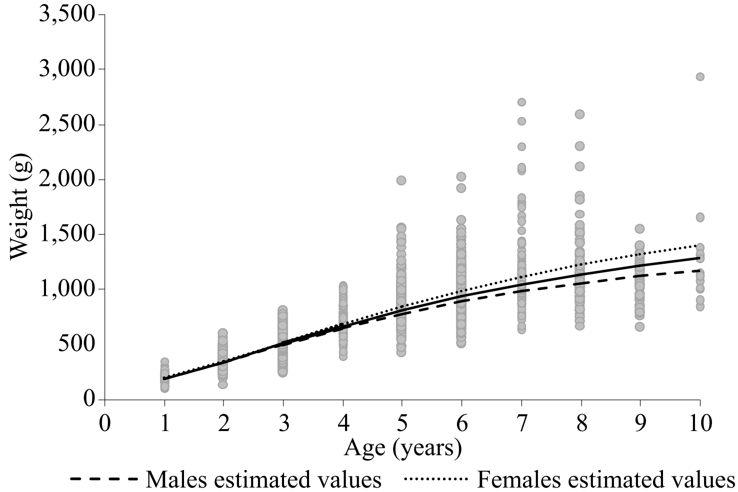

Figure 5. Growth in weight of *Macruronus magellanicus*. Dots: observed data, line: theoretical curve.
Figura 5. Crecimiento en peso de Macruronus magellanicus*. Puntos: datos observados, línea: curva teórica.*

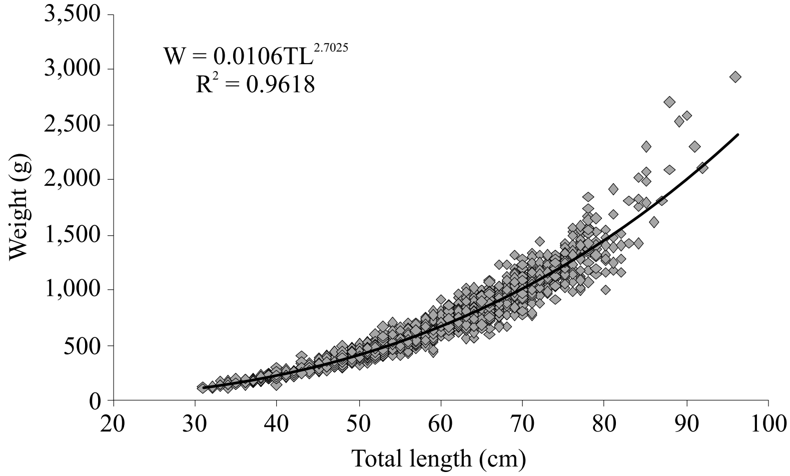

Figure 6. Length-weight relationship of *Macruronus magellanicus*. Diamond: observed data, line: theoretical curve.
Figura 6. Relación longitud versus peso de Macruronus magellanicus. *Rombos: datos observados, línea: curva teórica.*

Length frequency distribution

There is an interannual variability in length frequency distribution as a result of the strength of annual classes (Giussi *et al.*, 2002 b). Successful recruitments are frequently observed and the corresponding cohorts could be easily followed in consecutive years verifying their growth up to their extinction (Figure 7).

The absence of size segregation among individuals, with juveniles and adults occurring in the same areas, has made it difficult to understand migratory movements and to advise about specific fishery management.

Natural mortality

Estimations of natural mortality (M) using estimation methods which consider both growth parameters and environmental factors (Taylor, 1960; Rikhter and Efanov, 1976; Pauly, 1980; Jensen, 1996), have provided variable results related to the parameters used. The natural mortality rates range from 0.22 to 0.33 year^{-1}, with a mean value of 0.25 (Giussi, 2004; Giussi and Abachian, 2004, 2005, 2006; Abachian and Giussi, 2007, 2009; Abachian *et al.*, 2012; Zavatteri *et al.*, 2013). However, the value estimated from the stock assessment models were 0.36 or 0.42 year^{-1} depending on the index of abundance considered (Giussi and Zavatteri, 2015).

At the times when there was negligible fishing, the M values obtained were 0.329 and 0.354 year^{-1}, respectively (Giussi, 1996), using the method that considers the longevity of fish as the maximum age at which 99% of a cohort has died due to natural factors (Alagaraja, 1984).

Reproductive biology

Spawning time and location of the long tail hake spawning grounds are not yet clear, and there are different hypotheses on this subject. Locations of reported spawning grounds (Figure 8) are based either on macroscopic observations of gonads, using a maturity scale described for the Argentine hake (*M. hubbsi*), or by indirect assumptions related to concentration areas and feeding behaviour, as follows Janusz (1986) and Chesheva (1995). Inada (1983) and Bezzi (1984) postulated that spawning occurs during winter in midwater areas. Hart (1946) hypothesized that mature individuals might spawn during spring based on the finding that some fish usually feed

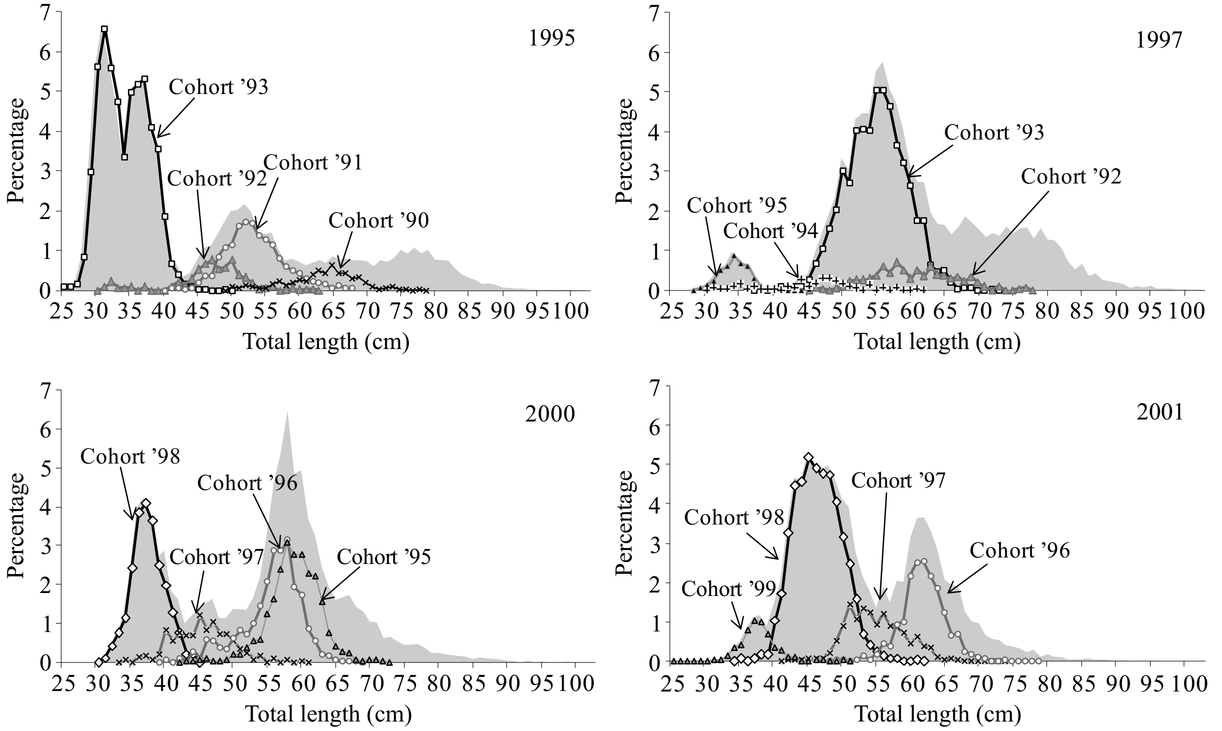

Figure 7. Length frequency distributions, in percentage, and cohorts included in them from research vessels. It is possible to follow some cohorts in different years.

Figura 7. Distribuciones de frecuencias de longitudes, en porcentaje, obtenidas en las cruceros de investigación, identificando las cohortes que las integran. Es posible seguirlas en años consecutivos.

heavily after spawning, and a great increase of food consumption by long tail hake, with a consequential increase of the total weight, was observed during summer.

Inada (1983) also postulated a reproductive movement from the continental slope to the coastal waters towards different spawning grounds, which could be located either in shallow waters south of 48° S or in San Matías Gulf. Inada’s hypothesis related to the latter spawning area was supported when Perrier and Di Giácomo (1999) detected a spawning group distributed over a large area inside San Matías Gulf during winter (August). Giussi (1993 a) also mentioned San Jorge Gulf as a spawning location, because males and females were recorded spawning there in spring (end of October), with a high predominance of males (3:1 sex ratio).

Gorini and Pájaro (2011) detected individuals in advanced maturity and spawning stage in areas located between 52° S and 55° S deeper than 200 m from June to October. This fact suggests the existence of small reproductive areas with appropriate characteristics for spawning and the retention of larvae and juveniles.

Machinandiarena and Ehrlich (1999) reported the presence of larvae (5.6-12.8 mm standard length (SL), Figure 9) south of Tierra del Fuego and Isla de los Estados at depths below 200 m, that could be consider as a nursery ground, where hatching occurs in late October or early November.

Length and age at 50% maturity were estimated with data obtained in summer surveys on the Patagonian shelf, outside the spawning season that probably occurs from July to November. These parameters, calculated for both sexes

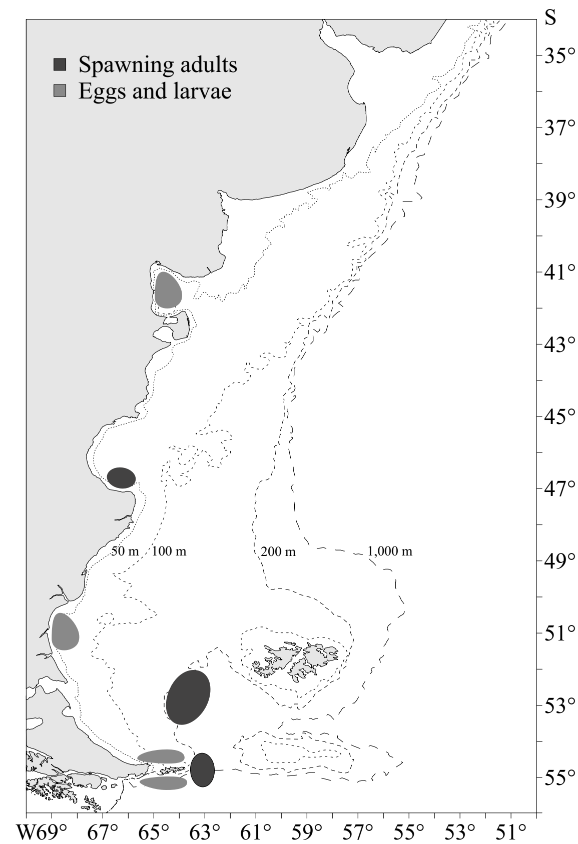

Figure 8. Location of mature individuals, eggs and larvae of *Macruronus magellanicus*.
Figura 8. Localización de los individuos maduros, huevos y larvas de Macruronus magellanicus.

together using data from 1995-2012, are 58.0 cm TL (Figure 10) and 3.6 years old (Figure 11). A comparison of these estimates with those obtained by several authors (Giussi and Wöhler, 2001; Giussi, 2002; Giussi and Abachian, 2004, 2006; Abachian and Giussi, 2007, 2009) showed a low variability in the values obtained; after age 5 (about 65 cm TL) most long tail hakes are mature.

Similar results were found in the San Matías Gulf where males and females first spawn at 45 and 54 cm TL, respectively (Perrier and Di Giácomo, 1999). Considering the differences in growth with other fishes that inhabit outside the mentioned gulf (Giussi *et al*., 1999 a), those lengths correspond to 4 year old specimens.

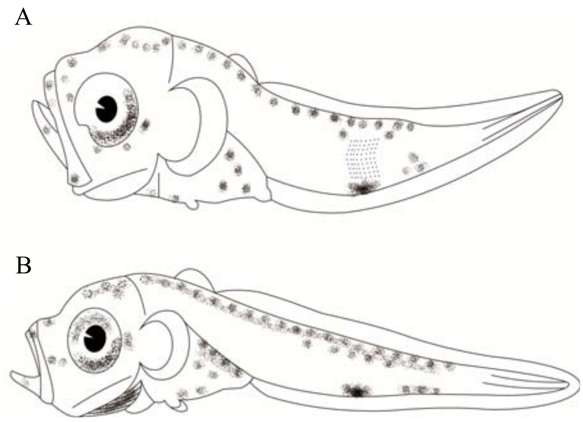

Figure 9. *Macruronus magellanicus* larvae: external morphology and pigmentation pattern. A) 8.24 mm standard length. B) 11.74 mm standard length. Redrawn from Machinandiarena and Ehrlich (1999).
Figura 9. Larvas de Macruronus magellanicus: *morfología externa y patrón de pigmentación. A) 8,24 mm de largo estándar. B) 11,74 mm de largo estándar. Redibujado a partir de Machinandiarena y Ehrlich (1999).*

Feeding ecology

The main prey species of long tail hake belong to the demersal and pelagic ecosystems, thus confirming that this species moves through different water layers during its daily migration (Angelescu and Prenski, 1987; Sánchez, 1999). Its main prey groups, in decreasing order of importance, are planktonic crustaceans, fishes and cephalopods (Bezzi, 1984; Prenski *et al*., 1997; Marí and Sánchez, 2002; Sánchez and Marí, 2005), with a trophic level of 3.08 that places it among tertiary predators (Figure 12). Seasonal and geographical variation in the diet composition and abundance of prey (Table 3) are observed during its life cycle (Angelescu and Gneri, 1960; Giussi *et al*., 2004), but this variability does not exist between sexes (Giussi *et al*., 2004).

Considering the percentage of prey occurrence in the stomach content (%F), zooplankton crustaceans are the principal diet item (50-97 %F); they include the amphipod *Themisto gaudichaudii* (40-75 %F) and euphausiids *Euphausia* sp. (20 %F).

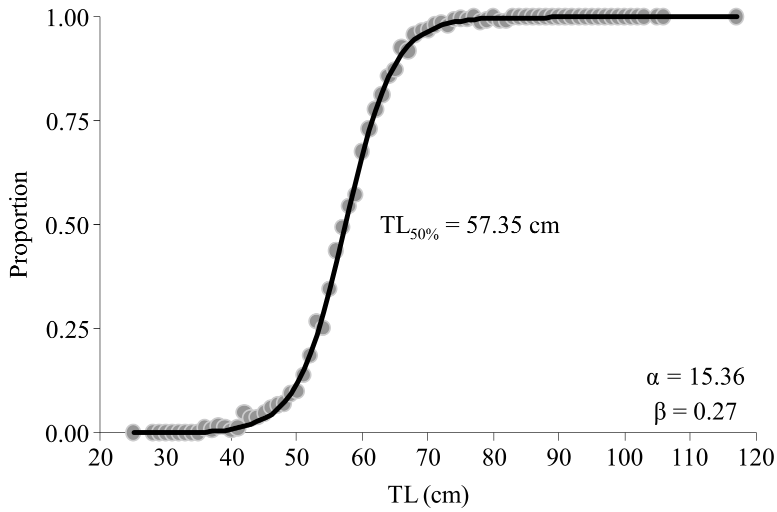

Figure 10. Maturity proportion of *Macruronus magellanicus* in length.
Figura 10. Proporción de individuos maduros de Macruronus magellanicus *en relación a la longitud.*

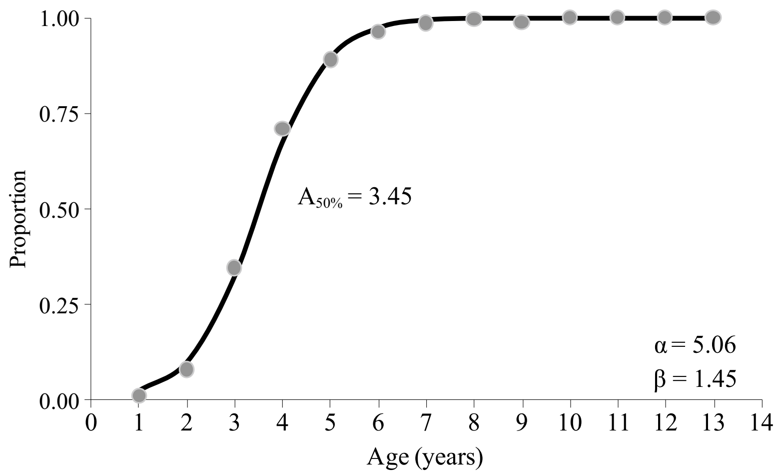

Figure 11. Maturity proportion per age for *Macruronus magellanicus*.
Figura 11. Proporción de individuos maduros de Macruronus magellanicus *por grupo de edad.*

Fish are the principal prey of larger adults (1-80 %F), generally juveniles and small species (Marí and Sánchez, 2002; Giussi *et al.*, 2004). *Patagonotothen* sp. (demersal benthonic species) and *Sprattus fuegensis* (pelagic) are the most frequent species in stomach contents, consumed mainly in shelf waters, while near the continental slope individuals of the Family Myctophidae acquire relevance. Diet also includes juveniles of *M. hubbsi* and individuals of age 0 of *M. magellanicus* (Giussi *et al.*, 2004) in lower frequencies. Within the cephalopods, the most common are the Patagonian squid (*Doryteuthis gahi* D'orbigny, 1835), the Argentine shortfin squid (*Illex argentinus* Castellanos, 1960), the lesser shining bobtail (*Semirossia tenera* Verril, 1880) and octopuses (*Octopus tehuelchus* D'orbigny, 1834 and *Eledone massyae* Voss, 1954), all of them considered

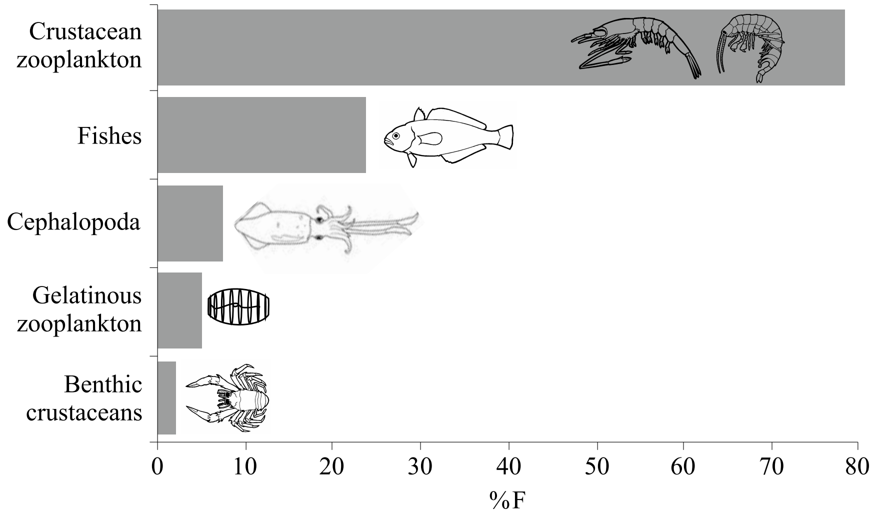

Figure 12. Main dietary component groups (%F) of *Macruronus magellanicus*.
Figura 12. Espectro trófico (%F) de Macruronus magellanicus.

as secondary food items. Benthic macrocrustaceans such as *Munida subrugosa* (2 %F), amphipods of the Family Gammaridae, isopods (< 0.5 %F), and pelagic organisms such as jelly fish (1-8 %F), *Sagitta* sp. (Chaetognatha), *Doliolum* sp. (Salpidae) and *Pleurobrachia* sp. (Ctenophora) were identified as occasional food items.

M. magellanicus feeds principally on zooplankton in the San Jorge and San Matías gulfs. In the former gulf, common hake juveniles, munids and shrimps are the secondary prey depending on the season (Sánchez and Prenski, 1996), while in San Matías Gulf, anchovies, penaeids and stomatopods are secondary prey (Perrier and Di Giácomo, 1999).

Predators

Long tail hake has many predators in the SAO. This species is a predominant prey item for Southern hake (*M. australis*, 38.2 %F) and toothfish (*Dissostichus eleginoides*, 22.2 %F) (Sánchez, 1999). Argentine hake (*M. hubbsi*), kingklip (*Genypterus blacodes*) and spiny dogfish (*Squalus acanthias*) are also important predators (Ehrhardt and Prenski, 1996; Wöhler *et al.*, 1999 b). Maximum predation occurs on the Patagonian shelf between 51° S-52° S and northern Isla de los Estados (55° S), affecting mainly long tail hakes between 0-3 years old (< 60 cm TL), where the highest abundances of southern hake are located (Sánchez, 1999). All the predator fish species are of large size (> 68 cm TL) and exert their principal predatory impact on those individuals of age 1 and 2 (Wöhler *et al.*, 1999 b). Annual predation removes 6% of long tail hake biomass (Wöhler *et al.*, 1999 b).

Parasites

Several taxonomic groups, like bacteria, fungi, myxosporidia and helminthes, parasitise different regions of the long tail hake body during the successive stages of its life cycle (Table 4).

Bacteria of the Genus *Photobacterium* sp. and *Vibrio*/*Beneckea* sp. have been identified in the intestine (Caría, 1981), and the parasitic fungus *Ichthyophonus hoferi* was found in the liver (Dumitrescu, 1979).

Dumitrescu (1979) observed *Kudoa* sp. in the musculature. Spores of *K. alliaria* (Schulman and Kovaljova, 1979) were found in parasitised zoo-

Table 3. Diet composition of *Macruronus magellanicus* in the Southwest Atlantic Ocean.
Tabla 3. Composición de la dieta de Macruronus magellanicus *en el Océano Atlántico Sudoccidental.*

Prey taxa	
Chaetognatha Sagittoidea	*Sagitta* sp.
Chordata Thaliacea	*Dolliolum* sp.
Ctenophora Tentaculata	*Pleurobrachia* sp.
Mollusca Cephalopoda	*Doryteuthis gahi*
	Illex argentinus
	Semirossia tenera
	Octopus tehuelchus
	Eledone massyae
Crustacea Malacostraca	*Themisto gaudichaudii*
	Euphausia spp.
	Gammaridae
	Isopoda
Crustacea Decapoda	*Munida subrugosa*
	Austropandalus grayi
	Peisos petrunkevitchii
	Pleoticus muelleri
Osteichthyes Gadiformes	*Macruronus magellanicus*
	Merluccius hubbsi
Osteichthyes Perciformes	*Patagonotohen* sp.
Osteichthyes Clupeiformes	*Sprattus fuegensis*
	Engraulis anchoita
Osteichthyes Myctophiformes	Myctophidae

planktonic invertebrates on which the long tail hake feeds (Incorvaia, 2004). During August and September the abundance of these parasites appears to increase as a result of the arrival of individuals from other areas with greater degrees of infection (Incorvaia and Hernández, 2009).

The helminthes classes Digenea, Nematoda and Cestoda, were found in different body parts. Suriano and Sutton (1981) determined that the long tail hake hosts a variety of species of Digenea, all of them located in the stomach: *Elytrophallus merlucii* (Szidat, 1954), *Derogenes varicus* (Müeller, 1784) and *Gonocerca phycidis* (Manter, 1925).

Dumitrescu (1979) found cestodes of the Genus *Botriocephalus* and *Heparoxylon trichiuri* in the gastrointestinal tract and the visceral peritoneum, respectively.

Two species of nematodes have been identified; *Hysterothylacium aduncum* is located in the intestine, while *Anisakis simplex* is found in several organs and muscle (Dumitrescu, 1979; Giussi, 1996). Infestation results from ingestion of fish and cephalopods during the adult stage beginning at 60 cm TL. Abundance and prevalence of these parasite species vary geographically and they may be considered as biological indicators of long tail hake fishing grounds (Incorvaia and Hernández, 2006).

Population Units

The large distribution area of long tail hake over the continental shelf and slope, and subtle differences the population structures (*i.e.*, age and growth, length composition) in separated areas, suggest the existence of more than one group. The degree of genetic polymorphism detected in this species is low compared to other marine fish. Historical demographic expansion could be associated with variations of the abundance. The haplotype diversity was not found in mutation-drift equilibrium among individuals from the continental shelf (D'Amato, 2006).

Several methodologies have been applied to corroborate the assumption mentioned above, without favorable results. The analysis of morphometric and meristic variables identified a subtle difference between sexes, mainly related to the thickness of the body as a result of the greater space that ovaries occupy in the abdominal cavity. The head size varied with latitude and, although the results are not yet conclusive, otolith dimensions could be an adequate tool to identify few differences among groups (Jerez *et al.*, 2013).

Table 4. Parasites located in different body regions of *Macruronus magellanicus* identified by several authors. From Giussi (1996).
Tabla 4. Parásitos localizados en diferentes regiones del cuerpo de Macruronus magellanicus *identificados por distintos autores. Tomado de Giussi (1996).*

Body region	Group	Species	Author
Digestive system	Bacteria	*Photobacterium* spp.	Caría (1981)
		Vibrio/Beneckea spp.	
	Fungi	*Ichthyophonus hoferi*	Dumitrescu (1979)
	Digenea	*Elytrophallus merlucii*	Suriano and Sutton (1981)
		Derogenes varicus	
		Gonocerca phycidis	
	Nematoda	*Anisakis* L3 Type 1	Incorvaia (pers. comm.)[1]
		Hysterothylacium aduncum	
	Cestoda	*Botriocephalus* sp.	Dumitrescu (1979)
		Heparowylon trichiuri	
Abdominal cavity	Nematoda	*Anisakis* sp.	Dumitrescu (1979)
Muscles	Nematoda	*Kudoa* sp.	Dumitrescu (1979)
	Nematoda	*Anisakis* sp.	Incorvaia and Carrizo (pers. comm.)[2]

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[2]Juan C. Carrizo, Programa "Desarrollo de Productos, Procesos y Transferencia de Tecnología" INIDEP, P. V. Ocampo N° 1, B7602HSA - Mar del Plata, Argentina.

The individuals present in the San Matías Gulf comprise a unique population unit geographically isolated from the Patagonian continental shelf. They exhibit distinct characteristics of growth, feeding and reproduction relative to the long tail hake from other areas (Perrier and Di Giácomo, 1999; Giussi *et al.*, 1999 a). Low genetic heterogeneity occurs in this area (D'Amato, 2006).

FISHERY

Abundance

Long tail hake biomass was initially estimated at the end of 1960's before there was fishing for this species (Bellisio and López, 1973; Otero *et al.*, 1981, 1982). Due to its importance in the ecosystem, a systematic series of research cruises carried out by the Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), began in 1992 to assess the biomass and population structure.

These cruises, using INIDEP's fishing research vessels "Capitán Oca Balda" and "Dr. Eduardo L. Holmberg", were conducted south of 45° S, from 50 to 400 m depths during summer (February-March) (Wöhler *et al.*, 1999 a), employing a stratified random sampling design (Cochran, 1977) and the swept area method (Alverson and Pereyra, 1969). The abundance of long tail hake was estimated to be more than one million tonnes, making it the most abundant finfish in the SAO, south 45° S (Giussi *et al.*, 2002 a). Between 1997 and 2005 the abundance was doubled as a result of strong recruitment of the species (Giussi *et al.*, 2004, 2011).

Stock assessment

The first stock assessment (Prenski *et al*., 1997; Wöhler *et al*., 1999 b) was performed using a Virtual Population Analysis (VPA) (Gulland, 1988), calibrated with indices from the commercial fishing fleet and research cruises. Later, the increase of knowledge about the stock structure enabled the use of Cohort Analysis (CA) (Pope, 1972), tuning it with indices obtained from research cruises (Wöhler *et al*., 1999 c, 2000, 2001, 2002; Wöhler and Hansen, 2003; Wöhler and Giussi, 2004; Giussi and Wöhler, 2005, 2006, 2007, 2009, 2010; Giussi *et al*., 2008).

In recent years, interruptions in the series of indices of abundance produced some instability in the model (CA) relative to earlier evaluations. Giussi *et al*. (2011) proposed a different model, Modified Cohort Analysis (MCA) (Hernández and Perrotta, 2008) which allows the natural mortality rate to vary with age, and estimates parameters using a Bayesian approach. Recently the long tail hake stock assessment (Giussi *et al*., 2012 a) was performed using a statistical catch-at-age model (SCAAM). It was implemented in a AD Model Builder platform (Fournier *et al*., 2012). This model was fitted to historical total annual catch data, catch-at-age compositions, and two indices of abundance obtained from research cruises. In order to validate the results obtained, and considering the uncertainty in natural mortality and in the estimation of initial biomass (B_0), three different models were proposed: a base model in which B_0 was estimated and M = 0.35 year^{-1}, and two alternative models both with B_0 = 1 million tonnes, Model 1 with M = 0.30 year^{-1} and Model 2 M = 0.35 year^{-1}.

This range of stock assessments all produced similar trends in population abundance (Figure 13), especially the runs for the periods 1985-2006, 1985-2007, 1985-2008 and 1985-2010, although there were differences in the estimates of absolute biomass (Giussi and Wöhler, 2007, 2009, 2010; Giussi *et al*., 2008). A trend of incre-

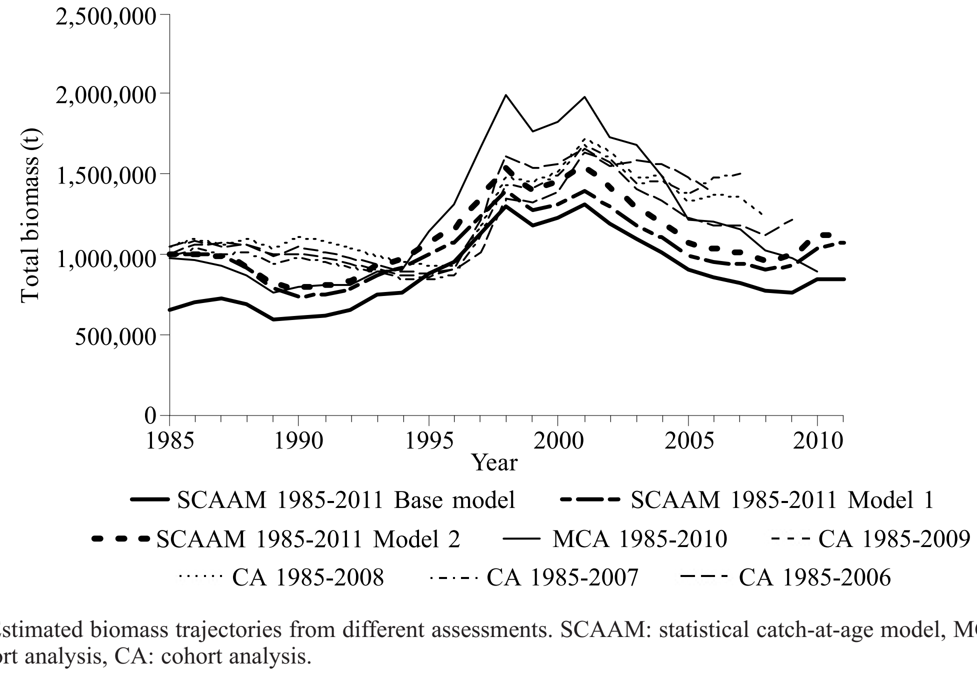

Figure 13. Estimated biomass trajectories from different assessments. SCAAM: statistical catch-at-age model, MCA: modified cohort analysis, CA: cohort analysis.

Figura 13. Evolución de la biomasa en diferentes períodos de evaluación. SCAAM: modelo estadístico de captura por edad, MCA: análisis de cohortes modificado, CA: análisis de cohortes.

ases in biomass began in 1995 associated with successful recruitments (Wöhler *et al*. 1999 b, c, 2000). The combination of the adaptive and opportunistic capacity of the species, the absence of competitors, and changes in the physical environment probably allowed this increase in population abundance (Giussi *et al*., 2004, 2012 a). After 2003 there was a decrease in the size of the population associated with weaker recruitments.

The medium and long term projections of future population state considered the uncertainty in the last estimation in the total biomass of the period analyzed, its standard error and confidence intervals, as well as two recruitment scenarios (Wöhler *et al*., 2001, 2002; Wöhler and Hansen, 2003; Wöhler and Giussi, 2004; Giussi and Wöhler, 2005, 2006, 2007, 2009, 2010; Giussi *et al*., 2008; 2012 a). These scenarios represent the strength of year class, one considering the overall period including the greatest variability and the lowest means, and the other in which the most successful recruitments were observed during the second half of the diagnosis, that results in a higher mean value (Figure 14).

The Total Allowable Catch (TAC) recommendations consider biological reference points and different harvest strategies. The values suggested are the result of applying a fishing mortality level (F_{safe}) that will produce a low (10%) probability of decreasing Spawning Stock Biomass (SSB) below a critical value in the following year (Francis, 1993; FAO, 1995). In the 2012 stock assessment, the SSB_{lim} value was 450 thousand tonnes and the SSB_{obj} was equivalent of the SSB_{2011} estimation, in accordance with the different models and scenarios considered (Giussi *et al*., 2013). Depending upon the chosen management objective the TAC for 2014 was estimated to be between 90 and 168 thousand tonnes. Stock assessments up to 2005 indicated that *M. magellanicus* was an underexploited stock (Wöhler *et al*., 2001, 2002; Wöhler and Hansen, 2003; Wöhler and Giussi, 2004; Giussi and Wöhler, 2005). Later evaluations indicated that the species was being exploited at a sustainable level (Giussi and Wöhler, 2006, 2007, 2009, 2010; Giussi *et al*., 2008, 2013).

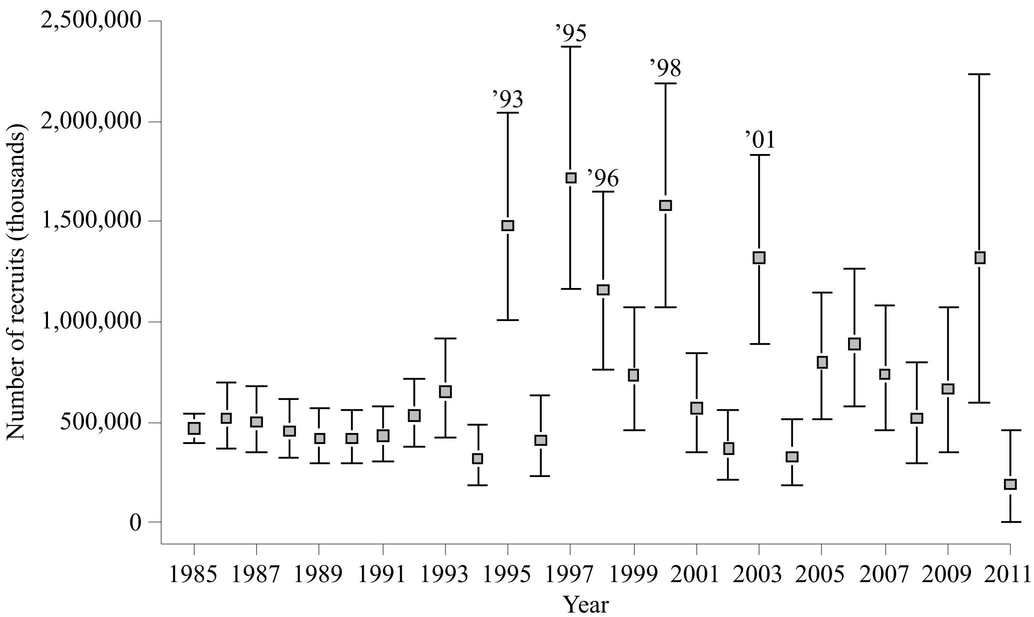

Figure 14. Estimated recruitment strengths from 1985 to 2011. From Giussi *et al*. (2012 a).
Figura 14. Evolución del reclutamiento estimado en el período de evaluación 1985-2011. Tomado de Giussi et al. (2012 a).

Fishery description

Prior to 2010, the long tail hake fishery management process established a maximum permissible catch available to the entire fleet (*i.e.*, a competitive TAC). Later, the Individual Quotas system was established, in which the government authority grants a percentage of the TAC to several fishing companies that have been operating historically in this fishery.

The commercial harvest of this species (Figure 15) began at the end of the 1970's, and remained low until the mid 1980's. There was an abrupt increase towards the end of that decade, when Russian and Bulgarian fleets operated under Argentinean agreements from 1986 to 1988. The first maximum historic capture occurred in 1988, when these fleets caught 80% of the total of 140 thousand tonnes recorded in the SAO (Giussi *et al*., 2013). Afterward several international political events which accelerated the dissolution of this agreement, a period of low captures, and a decline in the size of the fleet, occurred. Since the 1990's, Argentinean trawlers intensified their activity and caught more than 160 thousand tonnes. Currently, although landings are relatively high, a slight decrease in captures has been recorded.

There are no clear trends in the seasonal distribution of catches throughout the year (Figure 16), although the highest proportions of each annual catch are obtained during the second quarter according to Gorini *et al*. (2011).

Distribution of total length

Scientific observers are on board of a high percentage of commercial vessels which catch long tail hake in Argentina, so there is a great quantity of length-frequency information which is analyzed annually. Although the length structure of the catch is variable, the proportion of juveniles is usually greater than 50% of the catch. The mean length observed in the 2000-2011 period ranged from 52.8 to 59.1 cm TL, values close to the length at first maturity.

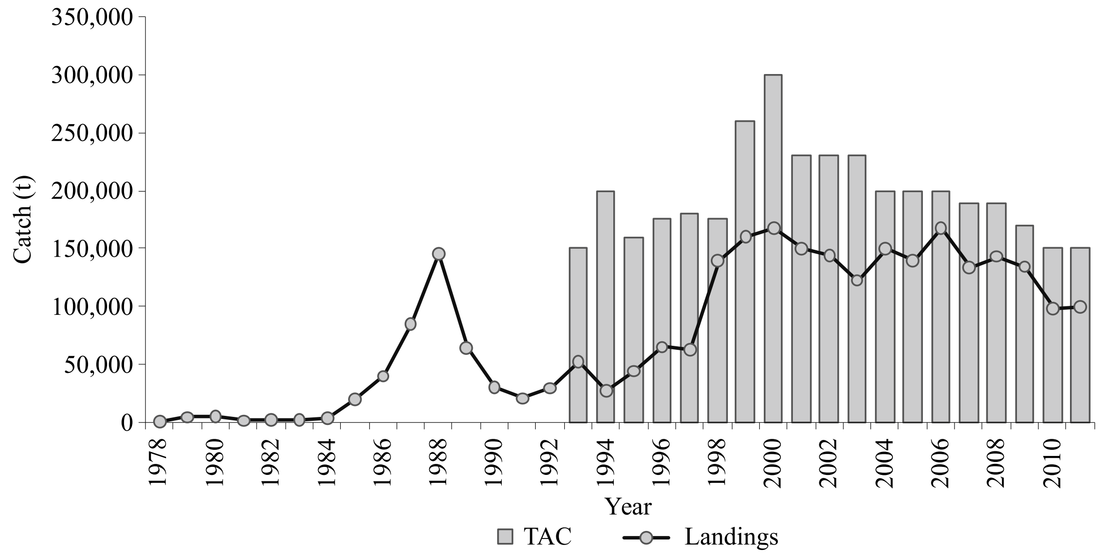

Figure 15. Annual catches from 1978 to 2011. The bars represent the Total Allowable Catch (TAC) established by the authority.

Figura 15. Capturas anuales desde 1978 a 2011. Las barras representan las capturas biológicamente aceptables (TAC) establecidas por la autoridad de aplicación.

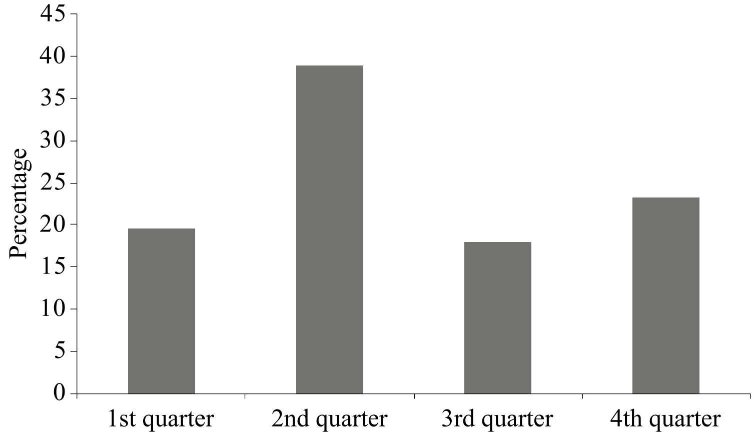

Figure 16. Percentage of annual catches obtained per quarter.
Figura 16. Porcentaje de capturas anuales obtenidas por trimestre.

Catch at age

Commercial catches comprise mainly 2-8 years old individuals depending on the year (Figure 17). There has been a change in the age composition of the landings since the beginning of the fishery. From 1985 to 1991, ages from 4-8 were predominant; from 1993 to 2011, the most abundant ages were 2-4 years. In some years, recruitment success affected the age composition; if the abundance of 1 year-old individuals is high, that cohort may appear strongly in consecutive years (Wöhler *et al*., 1999 a; Giussi *et al*., 2002 a).

Fleet and fishing areas

Although it is possible to catch long tail hake in several areas and in varying quantities on the continental shelf, the main fishing grounds are located south of 52° S deeper than 200 m (Figure 18).

Despite the variability in total catches observed since the beginning of the fishery (Figure 15), the proportion obtained from several fishing grounds in the last ten years has been comparable (Table 5). Those located in the extremes of the distribution were steady and represented less than 20% of the total, but the amount in the remaining were variable depending on the years considered. The intermediate ones were more relevant up to 2007, but later the tendency has been different (Gorini *et al*., 2007, 2012). While catches north of 52° S have decreased markedly, southern fishing ground catches have gradually increased, reaching more than 50% of the annual landings (Figure 19).

Because of the characteristic species distribution, no moratoria or restricted areas have been established, thus access for fishing boats is unrestricted except for the *surimi* fleet, which under current regulations may not operate north of 49° S (Resolution SAGPyA Nº 26/2009).

The main landing ports are Ushuaia, Puerto Madryn and Mar del Plata; the first two are located in Patagonia (Gorini *et al.*, 2012).

Products and markets

The fleet targeting long tail hake is composed entirely of trawlers, mainly large vessels that, depending both on their characteristics and on the depth of the schools, can use bottom or mid-water trawls. Freezer and factory vessels produce headed and gutted (H&G) fish and two types of fillets: skinned with bone in, and skinless and boneless. *Surimi* vessels obtain three different

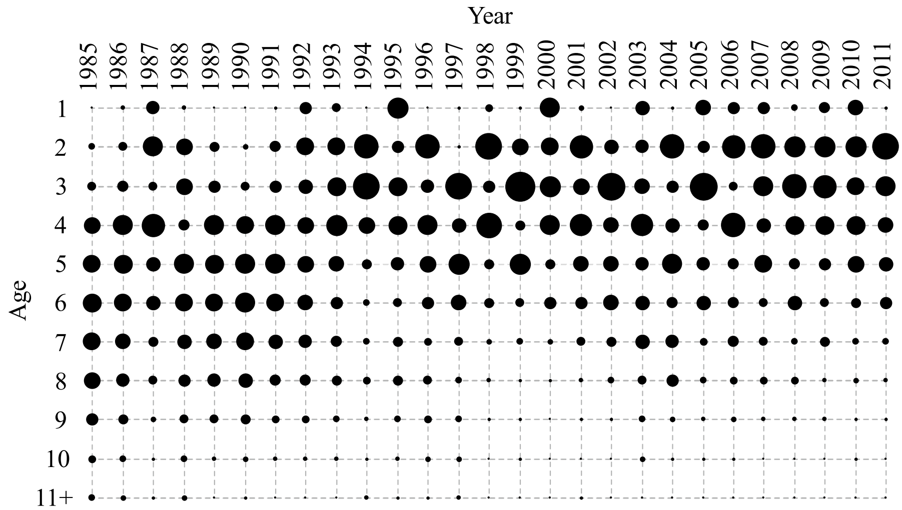

Figure 17. Catch-at-age proportions estimated, per year, for *Macruronus magellanicus* fishery.
Figura 17. Proporción de las capturas por edad observadas en la pesquería de Macruronus magellanicus*.*

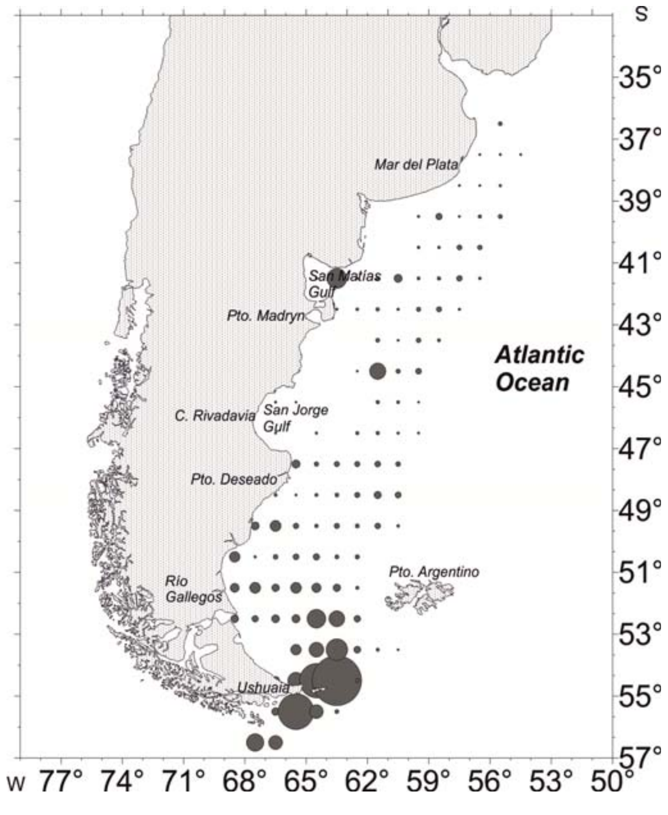

Figure 18. Location of catches declared in the fishery. Dots represent the average of catches obtained from 2000 to 2011.
Figura 18. Localización de las capturas declaradas en la pesquería. El tamaño de los puntos representa el promedio de las capturas obtenidas entre 2000 y 2011.

Table 5. Annual catches (t) declared by the commercial fleet, per fishing ground: north of 46° S; 47° S-51° S; 52° S-54° S; south of 55° S.
Tabla 5. Capturas anuales (t) declaradas por la flota comercial por área de pesca: norte de 46°S; 47° S-51° S; 52° S-54° S; sur de 55° S.

Year	North of 46° S	47° S-51° S	52° S-54° S	South of 55° S
2001	23,719	40,667	31,211	8,102
2002	17,443	30,865	36,030	14,234
2003	17,791	37,742	30,342	11,797
2004	16,912	30,443	54,526	15,027
2005	22,191	50,680	35,952	6,241
2006	15,728	43,603	49,209	12,511
2007	6,105	43,868	40,128	8,540
2008	19,015	15,201	61,830	14,201
2009	16,989	28,566	55,342	9,651
2010	12,589	12,428	42,579	13,489
2011	12,268	13,556	37,332	7,724

qualities of *surimi* depending on the proportion of long tail hake flesh in the mixture respect to other species, for example Southern blue whiting (*Micromesistius australis*).

The yield obtained depends upon the product, the body shape, and the technology employed. Time before commencement of processing is also important, because fish *rigor mortis* begins 10 h after capture, when the muscle viscosity increases (Trucco *et al.*, 1981). For this reason, to maintain more stable organoleptic properties, Manca and Trinchero (MS, in Giussi, 1996) recommended that processing had to be done on board soon after capture. Fillet yield, in weight, has been estimated between 36 and 49.7% of whole fish weight, depending on the total length of the individuals (Calabrese and Ibañez, 1980; Davidovich and Soule, 1981). For H&G product, yield increases to 68.3% (Calabrese and Ibañez, 1980).

Products obtained from long tail hake are of relatively high quality among finfishes of its type. All products are exported, since there is no internal demand in Argentina for this species. The amount of frozen fillets sold to other countries has been increasing in recent years, reaching 75% of Argentine fish exports. With respect to non-fillet frozen flesh, 94% corresponds to *surimi*, while the remaining 6% is sold as minced meat (SAGPyA, 2013 a).

Mean prices of exported products have increased gradually in recent years, except during the international economic crisis in 2009 which resulted in reduced demand for these products (SAGPyA, 2013 b, c).

During 2012, Japan and France were the two principal markets for long tail hake, together accounting for 36% of total sales. Brazil was third most important, while Spain has lost importance compared to Poland, Russia and the Ukraine (SAGPyA, 2013 c).

There has been a tendency for exports to derive from a smaller number of companies since 2008. In 2011 the number of companies exporting this species was 27, down from 30 in 2009 and 2010. The difference is stronger when compared to 2008; the number of companies has fallen 40% since that year (SAGPyA, 2013 a, c).

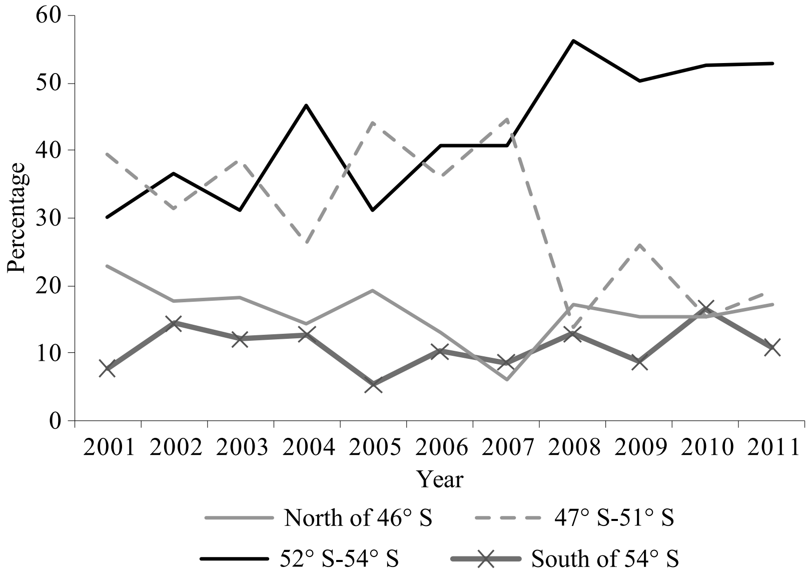

Figure 19. Trend of percentage of annual catches declared by the commercial fleet, per fishing ground.
Figura 19. Tendencia de los porcentajes de las capturas anuales declaradas por la flota comercial por área de pesca.

REFERENCES

ABACHIAN, V.E. & GIUSSI, A.R. 2007. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2007. Inf. Téc. INIDEP Nº 66/2007, 9 pp.

ABACHIAN, V.E. & GIUSSI, A.R. 2009. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2009. Inf. Invest. INIDEP Nº 88/2009, 8 pp.

ABACHIAN, V.E., ZAVATTERI, A., GIUSSI, A.R. & DI LEVA, I. 2012. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2011. Inf. Invest. INIDEP N° 42/2012, 10 pp

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

ALVERSON, D.L. & PEREYRA, W.T. 1969. Demersal fish explorations in the Northeastern Pacific Ocean. An evaluation of exploratory fishing methods and analytical approaches to stock and yield forecast. J. Fish. Res. Board Can., 26 (8): 1985-2001.

ANGELESCU, V. & GNERI, F. 1960. Contribución al conocimiento bioecólogico de la merluza de cola (*Macruronus magellanicus*, Lönnberg). Actas y trabajos del Primer Congreso Sudamericano de Zoología (La Plata) 12-24/10/59. CIC. CNICT. Ecología, 3-18.

ANGELESCU, V. & PRENSKI, L.B. 1987. Ecología trófica de la merluza común del Mar Argentino (Merlucciidae, *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 561, 205 pp.

AUBONE, A. & WÖHLER, O.C. 2000. Aplicación del método de máxima verosimilitud a la estimación de parámetros y comparación de curvas de crecimiento de von Bertalanffy. INIDEP Inf. Téc., 37, 21 pp.

BELLISIO, N. & LÓPEZ, R. 1973. Prospección pesquera del Mar Argentino. I. Merluza de cola, *Macruronus magellanicus* Lönnberg. Monografías Recursos Pesqueros, Buenos Aires, Serv. Nac. Pesca, Minist. Agric. Ganad., 1, 48 pp.

BEZZI, S.I. 1984. Aspectos biológico pesqueros de la merluza de cola del Atlántico Sudoccidental. Rev. Invest. Desarr. Pesq., 4: 63-80.

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

CALABRESE, R. & IBAÑEZ, P. 1980. Rendimientos en troncos y en filets con y sin piel de pescados patagónicos. In: ANGELESCU, V. (Ed.). Campañas de investigación pesquera realizadas en el Mar Argentino por los B/I "Shinkai Maru" y "Walther Herwig" y por el B/P "Marburg", años 1978 y 1979. Resultados de la parte prgentina. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), 383: 172-174.

CARÍA, M.A. 1981. Investigación de la flora bacteriana de peces marinos y la correlación con su ambiente. Incidencia de *Vibrio*/*Beneckea* spp en flora bacteriana intestinal. Campañas IX y XII del B/I "Shinkai Maru". In: ANGELESCU, V. (Ed.). Campañas de investigación pesquera realizadas en el Mar Argentino por el B/I "Shinkai Maru" y "Walther Herwig" y por el B/P "Marburg", años 1978 y 1979. Resultados de la parte argentina. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), 383: 313-317.

CHESHEVA, Z.A. 1995. The biology of Magellan hake (*Macruronus magellanicus*) from the Southwest Atlantic. J. Ichthyol., 35 (3): 29-39.

COCHRAN, W.G. 1977. Sampling technics. John Wiley and Sons, New York, 330 pp.

COHEN, D.M., INADA, T., IWAMOTO, T. & SCIALABA, N. 1990. FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop., 125 (10), 442 pp.

COUSSEAU, M.B. 1993. Las especies del orden gadiformes del Atlántico sudamericano comprendido entre 34° y 55° S y su relación con las de otras áreas. Frente Marit., 13 (A): 7-108.

D'AMATO, M.E. 2006. Demographic Expansion and Subtle Differentiation in the Long-Tailed Hake *Macruronus magellanicus*: Evidence from Microsatellite Data. Mar. Biotechnol., 8: 189-201.

DAVIDOVICH, L.A. & SOULÉ, C.L. 1981. Rendimiento en peso por fileteado manual. Estudio con diferentes especies de peces del Mar Argentino. Campaña VI del B/I "Walther Herwig". In: ANGELESCU, V. (Ed.). Campañas de Investigación Pesquera realizadas en el Mar Argentino por el B/I "Shinkai Maru" y "Walther Herwig" y por el B/P "Marburg", años 1978 y 1979. Resultados de la Parte Argentina. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata) 383: 175-177.

DUMITRESCU, E. 1979. La parasitation des éspèces *Macruronus magellanicus* et *Merluccius spp.* de la zone del îles Falkland. Cercet. Mar./Rech. Mar., 12: 233-238.

EHRHARDT, N.M. & PRENSKI, L.B. 1996. Estimación preliminar de la mortalidad natural de la merluza de cola (*Macruronus magellanicus*) en la plataforma sur-patagónica (Argentina). Rev. Invest. Desarr. Pesq., 10: 23-29.

ENDO, H. 2002. Phylogeny of the order Gadiformes (Teleostei, Paracanthopterygii). Mem. Grad. Sch. Fish. Sci. Hokkaido Univ., 49 (2): 75-149.

FAO. 1995. Precautionary approach to fisheries. Part 1: guidelines on the precautionary approach to capture fisheries and species introductions. FAO Fish. Tech. Pap., 350 (1), 52 pp.

FEDULOV, P.P., REMESLO, A.V., BURYKIN, S.N. & POLISHCHUK, J.A. 1990. Variabilidad de la Corriente de Malvinas. Frente Marit., 6 (A):

121-127.

FENUCCI, J.L., VIRASORO, C., COUSSEAU, M.B. & BOSCHI, E.E. 1974. Campaña Tierra del Fuego 74. Informe preliminar. Contrib. Inst. Biol. Mar. (Mar del Plata), Nº 261, 37 pp.

FLOWERS, J. & ROA, B. 1975. Report on the investigation in the Gulf of San Matías and the Gulf of San Jorge. FAO FI: DP/Arg. 65/510/3, 64 pp.

FOURNIER, D.A., SKAUG, H.J., ANCHETA, J., IANELLI, J., MAGNUSSON, A., MAUNDER, M.N., NIELSEN, A. & SIBERT, J. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw., 27: 233-249.

FRANCIS, R.I.C.C. 1993. Monte Carlo evaluation of risks for biological reference points used in New Zealand fishery assessments. In: SMITH, S.J., HUNT, J.J. & RIVARD, D. (Eds.). Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci., 120: 221-230.

GARCÍA DE LA ROSA, S.B., MARÍ, N.R. & SÁNCHEZ, F. 2000. Distribución espacial de la merluza de cola (*Macruronus magellanicus*) y de la merluza común (*Merluccius hubbsi)* entre 34° y 48°S, y su relación porcentual por cuadrícula de pesca, para los años 1998 y 1999. Inf. Téc. Int. DNI-INIDEP Nº15/2000, 27 pp.

GIUSSI, A.R. 1993. Análisis de la composición por clases de longitud y edad de la merluza de cola en el Golfo San Jorge (años 1989-1991). Informe Final Beca de Iniciación CONICET, 4 pp.

GIUSSI, A.R. 1996. Estudio de algunos aspectos del ciclo vital de la merluza de cola *Macruronus magellanicus*, Lönnberg, 1907. Tesis de Doctorado*,* Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, 151 pp.

GIUSSI, A.R. 2002. Parámetros poblacionales de la merluza de cola del Atlántico Sudoccidental. Año 2001. Inf. Téc. Int. DNI-INIDEP N° 01/2002, 7 pp.

GIUSSI, A.R. 2004. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2003. Inf. Téc. Int. DNI-INIDEP N° 38/2004, 8 pp.

GIUSSI, A.R. & ABACHIÁN, V.E. 2004. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2004. Inf. Téc. Int. DNI-INIDEP N° 111/2004, 8 pp.

GIUSSI, A.R. & ABACHIAN, V.E. 2005. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2005. Inf. Téc. Int. DNI-INIDEP N° 78/2005, 9 pp.

GIUSSI, A.R. & ABACHIÁN, V.E. 2006. Parámetros poblacionales de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Año 2006. Inf. Téc. INIDEP N° 46/2006, 9 pp.

GIUSSI, A.R. & MARÍ, N.R. 1999. Distribución y abundancia de la merluza de cola, *Macruronus magellanicus*, al norte de los 45°S. Inf. Téc. Int. DNI-INIDEP N° 102/1999, 5 pp.

GIUSSI, A.R. & WÖHLER, O.C. 2001. Estimación de la edad y la longitud de primera madurez de la merluza de cola (*Macruronus magellanicus*). Período 1995-2001. Subcom. Científ. Comis. Pesq. Atlant. Sur., 6 pp.

GIUSSI, A.R. & WÖHLER, O.C. 2005. Evaluación de la abundancia de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Período 1985-2004. Inf. Téc. Int. DNI-INIDEP N° 29/2005, 25 pp.

GIUSSI, A.R. & WÖHLER, O.C. 2006. Evaluación de la abundancia de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Período 1985-2005. Inf. Téc. INIDEP N° 23/2006, 22 pp.

GIUSSI, A.R. & WÖHLER, O.C. 2007. Evaluación de la abundancia de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Período 1985-2006. Inf. Téc. INIDEP N° 28/2007, 23 pp.

Giussi, A.R. & Wöhler, O.C. 2009. Evaluación de la abundancia de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Período 1985-2008. Inf. Téc. Of. INIDEP N° 37/2009, 24 pp.

Giussi, A.R. & Wöhler, O.C. 2010. Evaluación de la abundancia de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Período 1985 y 2009. Inf. Téc. Of. INIDEP Nº 25/2010, 26 pp.

Giussi, A.R. & Zavatteri, A. 2015. Incidencia de la mortalidad natural en la estimación de la abundancia de la merluza de cola. Inf. Invest. INIDEP Nº 54/2015, 9 pp.

Giussi, A.R., Hansen, J.E. & Wöhler, O.C. 2002 a. Estimated total abundance and numbers-at-age of longtail hake (*Macruronus magellanicus*) in the Southwest Atlantic during the years 1987-2000. Sci. Mar., 66 (3): 283-291.

Giussi, A.R., Hansen, J.E. & Wöhler, O.C. 2004. Biología y pesquería de la merluza de cola (Pisces: Macruronidae, *Macruronus magellanicus*). 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: 321-346.

Giussi, A., Hernández, D. & Abachián, V.E. 1999 a. Differences in growth of long tail hake (*Macruronus magellanicus*) from two areas of south-western Atlantic Ocean. 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: 131-134.

Giussi, A.R., Mari, N.R. & Sánchez, F. 2002 b. Estimación de la biomasa y composición por longitudes de la merluza de cola a partir de campañas estivales. Período 1992 a 2002. Inf. Téc. Int. DNI-INIDEP N° 18/2002, 12 pp.

Giussi, A.R., Wöhler, O.C. & Abachian, V.E. 2008. Evaluación de la abundancia de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Período 1985 - 2007. Inf. Téc. Of. INIDEP N° 58/2008, 23 pp.

Giussi, A.R., Di Marco, J.E., Zavatteri, A. & Wöhler, O.C. 2012 a. Evaluación de la abundancia de la población de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental entre los años 1985 y 2011. Inf. Téc. Of. INIDEP N° 40/2012, 21 pp.

Giussi, A.R., Aubone, A., Rodríguez, J.S., Di Marco, J.E. & Zavatteri, A. 2011. Evaluación de la abundancia de la población de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental entre los años 1985 y 2010. Inf. Téc. Of. INIDEP N° 37/2011, 22 pp.

Giussi, A.R., Di Marco, J.E., Zavatteri, A., Cueto, S.J. & Wöhler, O.C. 2013. Evaluación de la abundancia de la población de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Período 1985 - 2012. Inf. Téc. Of. INIDEP N° 30/2013, 24 pp.

Giussi, A.R., Reta, R., Abachian, V., Álvarez Colombo, G. & Sabatini, M. 1999 b. Environmental preferences of long tail hake, *Macruronus magellanicus*, during its life cycle in the southern Patagonian area (45°-55°S). Proc. 4th Open Science Meeting LOICZ, Regimes of Coastal Change. Bahía Blanca, Argentina, p. 105.

Giussi, A.R., Reta, R., Zavatteri, A., Di Marco, J.E. & Hernández, D. 2012 b. Environmental preferences of long tailed hake during its life cycle in the Southwest Atlantic. Proc. 6th World Fisheries Congress "Sustainable Fisheries in a Changing World", Edimburgo, PSA1.34.

González, R. & Caille, G. 1995. Composición por especies y estimaciones del descarte en la pesquería demersal del Golfo San Matías. In: COLACMAR 6º, Congreso Latinoamericano de Ciencias del Mar (COLACMAR), Mar del

Plata, Argentina, Resúmenes: 99.

GORINI, F.L. & PÁJARO, M. 2011. Características reproductivas y longitud de primera madurez de la merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Período 2003-2010. Inf. Invest. INIDEP N°104/2011, 16 pp.

GORINI, F.L., DI MARCO, E.J. & WÖHLER, O.C. 2007. Estadística pesquera de peces demersales australes en el Atlántico Sudoccidental (Período 1980-2002). INIDEP Inf. Téc., 67, 90 pp.

GORINI, F.L., GIUSSI, A.R. & WÖHLER, O.C. 2011. Actualización de la estadística pesquera de peces demersales australes en el Atlántico Sudoccidental (Período 1998-2010). Inf. Téc. Of. N° 38/2011, 74 pp.

GORINI, F.L., GIUSSI, A.R. & WÖHLER, O.C. 2012. Estadística pesquera de peces demersales australes en el Atlántico Sudoccidental (Período 1999-2011). Inf. Téc. Of. INIDEP N° 19/2012, 75 pp.

GULLAND, J.A. 1988. Fish population dynamics: the implications for management. John Wiley and Sons, Chichester, 422 pp.

GÜNTHER, A. 1887. Report on the deep-sea fishes collected by H. M. S. "Challenger" during the years 1873-6. Rep. Sci. Res. Challenger. Zool., 22, 335 pp.

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

HERNÁNDEZ, D.R. & PERROTA, R.G. 2008. Modificación del análisis de cohortes de Pope para extender su aplicación a un rango más amplio de valores de mortalidad natural y mortalidad por pesca. Rev. Invest. Desarr. Pesq., 19: 23-36.

INADA, T. 1983. A review of the species composition, distribution and migration of the bottom fishes in the waters off Argentina. In: Informe del grupo Ad hoc de trabajo sobre los recursos pesqueros de la plataforma continental patagónica, Roma, 7-11 febrero 1983. FAO Inf. Pesq. 297, 83 pp.

INCORVAIA, I.S. 2004. Identificación y cuantificación de mixosporideos parásitos de la merluza de cola. Inf. Téc. Int. DNI-INIDEP N° 89/2004, 9 pp.

INCORVAIA, I.S & HERNÁNDEZ, D.R. 2006. Nematodes parásitos como indicadores biológicos de *Macruronus magellanicus*. INIDEP Inf. Téc., 61, 17 pp.

INCORVAIA, I.S & HERNÁNDEZ, D.R. 2009. Variaciones estacionales e interanuales en la presencia de quistes de *Kudoa alliaria* en *filets* de la merluza de cola. Inf. Invest. INIDEP Nº 7/2009, 7 pp.

JANUSZ, J. 1986. Occurrence and biology of Patagonian whiphake *Macruronus magellanicus* in the Falkland Islands areas. Bull. Sea Fish. Inst. Gdynia, 17: 14-19.

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.

JEREZ, B., HERNÁNDEZ, D.R., GIUSSI, A.R., & MALASPINA, A. 2013. Análisis de la unidad poblacional de la merluza de cola (*Macruronus magellanicus*). Estudio de las variaciones morfológicas somáticas y de los otolitos en relación con su distribución geográfica. Rev. Invest. Desarr. Pesq., 22: 79-94.

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

LLORIS, D. & RUCABADO, J. 1991. Ictiofauna del Canal de Beagle (Tierra del Fuego), aspectos ecológicos y análisis biogeográfico. Publ. Espec. Inst. Esp. Oceanogr., 8, 182 pp.

MACHINANDIARENA, L. & EHRLICH, M. 1999. Detección de un área de cría de la merluza de cola (*Macruronus magellanicus*) en el Mar Argentino. Rev. Invest. Desarr. Pesq., 12: 45-50.

MARÍ, N.R. & SÁNCHEZ, F. 2002. Espectros tróﬁcos específicos de varias especies de peces demersales de la región austral y sus variaciones anuales entre 1994 y 2000. Inf. Téc. Int. DNI-INIDEP N°88/2002, 9 pp.

MENNI, R., RINGUELET, R. & ARÁMBURU, R. 1984. Peces Marinos de la Argentina y Uruguay. Hemisferio Sur, Buenos Aires, 359 pp.

NELSON, J. 1994. Fishes of the world. John Wiley & Sons, New York, 600 pp.

OTERO, H.O., BEZZI, S.I., RENZI, M.A. & VERAZAY, G.A. 1982. Atlas de los recursos pesqueros demersales del Mar Argentino. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), Nº 423, 248 pp.

OTERO, H.O., BEZZI, S.I., PERROTTA, R.G., PÉREZ COMAS, J.A., SIMONAZZI, M.A. & RENZI, M.A. 1981. Los recursos pesqueros demersales del Mar Argentino. Parte III: Distribución, estructura de la población, biomasa y rendimiento potencial de la polaca, el bacalao austral, la merluza de cola y del calamar. In: ANGELESCU, V. (Ed.). Campañas de investigación pesquera realizadas en el Mar Argentino por los B/I "Shinkai Maru" y "Walther Herwig" y el B/P "Marburg". Años 1978 y 1979. Resultados de la parte argentina. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), Nº 383: 28-41.

PAULY, D. 1980. On the interrelationship between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. int. Explor. Mer, 39 (2): 175-192.

PERRIER, M.R. & DI GIÁCOMO, E.E. 1999. La merluza de cola en la pesquería del Golfo San Matías: un recurso. In: Avances en métodos y tecnología aplicados a la investigación pesquera. Seminario final de Proyecto INIDEP-JICA sobre Evaluación y monitoreo de recursos pesqueros 1994-1999. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 209-211.

POPE, J.G. 1972. An investigation of the accuracy of Virtual Population Analysis using Cohort Analysis. Res. Bull. Int. Comm. NW Atlantic Fish, 9: 65-74.

PRENSKI, L.B., EHRHARDT, N.M. & LEGAULT, C. 1997. Evaluación del estado de explotación de la merluza de cola (*Macruronus magellanicus*) en la plataforma sudpatagónica Argentina. Rev. Invest. Desarr. Pesq., 11: 5-17.

RESTREPO, V.R. 1997. An implementation of the age-structured production model with application to West Atlantic bluefin tuna fisheries. Int. Comm. Cons. Atl. Tunas, Coll. Vol. Sci. Pap., 46 (2): 348-353.

RIKHTER, V.A. & EFANOV, V.N. 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc., 76/VI/8, 12 pp.

ROA, B., VIRASORO, C. & BEZZI, S. 1976. Los recursos demersales del Golfo San Matías (Pcias. de Río Negro y Chubut). Estudio sobre la biología pesquera de la merluza de cola, *Macruronus magellanicus* Lönnberg. Informe Mimeografiado. Instituto Biología Marina y Pesquera y Universidad Nacional Comahue, Argentina, 26 pp.

SAGPYA. 2013 a. [Web en línea]. Exportaciones Pesqueras 2009: comportamiento de los principales mercados. Dirección de Economía Pesquera.<http://www.minagri.gob.ar/site/pesca/pesca_maritima/04=informes/05-economia_pesquera/_informes/800000_Exportaciones%20e%20importaciones%20pesqueras%20%20Informes%20Anuales/500000_2009/090103_Exportaciones%20Pesqueras%202009%20%20Comportamiento%20de%20los%20principales%20mercados.pdf>. [Consulta: 7 January 2013].

SAGPYA. 2013 b. [Web en línea]. Exportaciones e Importaciones Pesqueras 2001-2006 <http://www.minagri.gob.ar/site/pesca/pesca_maritima/04=informes/05-economia_pesquera/_informes/800000_Exportaciones%20e%20importaciones%20pesqueras%20-%20Informes%20Anuales/800000_2001%20-%202006/080101_Exportaciones%20e%20Importaciones%20pesqueras%202001-

2006.pdf>. [Consulta: 7 January 2013].

SAGPyA. 2013 c. [Web en línea]. Exportaciones Pesqueras: comportamiento de los principales mercados 2012. Dirección de Economía Pesquera. <http://www.minagri.gob.ar/site/pesca/pesca_maritima/04=informes/05-economia_pesquera/_informes/800000_Exportaciones%20e%20importaciones%20pesqueras%20%20Informes%20Anuales/200000_2012/120703_Exportaciones%20Pesqueras%20201%20%20Comportamiento%20de%20los%20principales%20mercados.pdf>. [Consulta: 7 January 2013].

Sánchez, F. 1999. Ecología trófica de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. In: Avances en métodos y tecnología aplicados a la investigación pesquera. Seminario final de Proyecto INIDEP-JICA sobre Evaluación y monitoreo de recursos pesqueros 1994-1999. Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Mar del Plata: 135-138.

Sánchez, F. & Marí, N.R. 2005. Interacciones tróficas entre especies de peces demersales en la región austral entre 45° S y 54° S. Inf. Téc. Int. DNI-INIDEP N° 91/2005, 9 pp.

Sánchez, F. & Prenski, L.B. 1996. Ecología trófica de peces demersales en el Golfo San Jorge. Rev. Invest. Desarr. Pesq., 10: 57-71.

Suriano, D. & Sutton, C. 1981. Contribución al conocimiento de la fauna parasitológica argentina VII. Digeneos en peces de la plataforma del Mar Argentino. Rev. Mus. La Plata (Nueva Ser.) Secc. Zool., 12: 261-271.

Taylor, C.C. 1960. Temperature, growth and mortality of the Pacific cockle. J. Cons. int. Explor. Mer, 26 (1): 117-124.

Trucco, R.E., Lupín, H.M., Giannini, D.H., Crupkin, M., Boeri, R.L. & Barassi, C.A. 1981. Características del "*rigor mortis*" de algunas especies de peces de la plataforma patagónica (Campañas N° IV y N° V del B/I "Walther Herwig"). In: Angeluscu, V. (Ed.). Campañas de Investigación Pesquera realizadas en el Mar Argentino por los B/I "Shinkai Maru" y "Walther Herwig" y por el B/P "Marburg", años 1978 y 1979. Resultados de la Parte Argentina. Contrib. Inst. Nac. Invest. Desarr. Pesq. (Mar del Plata), Nº 383: 151-154.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Hum. Biol., 10: 181-213.

Wöhler, O.C. 1987. Contribución al estudio de la distribución batimétrica de algunas especies de peces demersales y calamares en el Mar Argentino. Seminario de Licenciatura, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, 78 pp.

Wöhler, O.C. & Castañeda, F. 2000. La pesca de la merluza de cola al norte de los 48°S. Observaciones preliminares acerca de la potencialidad de desarrollo de la pesquería en el área y su relación con la captura incidental de otras especies. Inf. Téc. Int. DNI-INIDEP Nº 5/2000, 9 pp.

Wöhler, O.C. & Giussi, A.R. 2004. Evaluación de la abundancia de la merluza de cola (*Macruronus magellanicus*) del Atlántico Sudoccidental. Período 1985-2003. Inf. Téc. Int. DNI-INIDEP Nº 36/2004, 38 pp.

Wöhler, O.C. & Hansen, J.E. 2003. Evaluación de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Período 1985-2002. Inf. Téc. Int. DNI-INIDEP Nº 34/2003, 23 pp.

Wöhler, O.C., Giussi, A.R. & Hansen, J.E. 1999 a. Análisis secuencial de la población de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Período 1985 - 1996. Rev. Invest. Desarr. Pesq., 12: 27-43.

Wöhler, O.C., Cordo, H.D., Giussi, A.R. & Hansen, J.E. 2000. Evaluación de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Período 1985-1998. Inf. Téc. Int. DNI-INIDEP Nº 08/2000, 27 pp.

Wöhler, O.C., Hansen, J.E., Cordo, H.D. & Giussi, A.R. 1999 c. Evaluación del estado de explotación y recomendaciones de manejo de la merluza de cola (*Macruronus magellani-*

cus) del Atlántico Sudoccidental. Período 1985-1997. Inf. Téc. Int. DNI-INIDEP Nº 6/1999, 16 pp.

WÖHLER, O.C., HANSEN, J.E., GIUSSI, A.R. & CORDO, H.D. 2001. Tendencia de la abundancia de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental durante el período 1985-2000 y recomendaciones de la captura biológicamente aceptable correspondiente al año 2001. Inf. Téc. Int. DNI-INIDEP Nº 15/2001, 11 pp.

WÖHLER, O.C., HANSEN, J.E., GIUSSI, A.R. & CORDO, H.D. 2002. Evaluación de merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Periodo 1985-2001. Inf. Téc. Int. DNI-INIDEP Nº 27/2002, 23 pp.

WÖHLER, O.C., GIUSSI, A.R., GARCÍA DE LA ROSA, S.B., SÁNCHEZ, F., HANSEN, J.E., CORDO, H.D., ÁLVAREZ COLOMBO, G.L., INCORVAIA, S., RETA, R. & ABACHIAN, V.E. 1999 b. Resultados de la campaña de evaluación de peces demersales australes efectuada en el verano de 1997. INIDEP Inf. Téc., 24, 70 pp.

ZAVATTERI, A. & GIUSSI, A.R. 2013. Estimación y análisis comparativo de los parámetros de crecimiento en peso de la merluza de cola (*Macruronus magellanicus*) en el Atlántico Sudoccidental. Inf. Invest. INIDEP Nº 81/2013, 19 pp.

ZAVATTERI, A., ABACHIAN, V.E., GIUSSI, A.R. & DI LEVA, I. 2013. Estimación de la edad, el crecimiento y la mortalidad natural de la merluza de cola (*Macruronus magellanicus*) en el Océano Atlántico Sudoccidental durante el verano de 2010. INIDEP Inf. Téc., 85, 16 pp.

ZAVATTERI, A., GIUSSI, A.R., BARRUTIA, A.M. & ABACHIAN, V.E. 2016. Estimación del crecimiento, longitud y edad de primera madurez y mortalidad natural de la merluza de cola (*Macruronus magellanicus*) capturada por la flota en el Océano Atlántico Sudoccidental. Año 2012. INIDEP Inf. Téc., 16, 22 pp.

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