CTMFM
Comisión Técnica Mixta del Frente Marítimo

Stripped weakfish

Marine Resource Fact Sheet

Biology and ecology

Fishery

Management

Trade

Resource identification [link 1]

Taxonomy
Class: Actinopterygii
Order: Perciformes
Family: Sciaenidae
Specie: *Cynoscion guatucupa* (Cuvier, 1830)

Nombres comunes
Argentine: pescadilla de red
Uruguay: pescadilla de calada
Brazil: maría mole, pescada olhuda
English name: *Stripped weakfish*
Other scientific names synonymous in use: *Cynoscion striatus*.
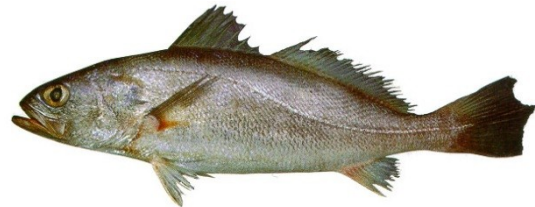
External distinguishing characteristics

Fusiform body, covered with regular to large scales, ctenoid. The lateral line runs parallel to the line of the back to the height of the middle of the second dorsal fin. Pointed snout. Narinas of regular size, very close to the eyes. Without barbel. Large eyes, contained 5-6 times in the length of the head. Dorsal fin in V, forming two contiguous crests, the first with spiny rays only, the second with a spiny radius and the other soft. Truncated flow. Anal cuts. The pectorals are inserted at the level of the posterior edge of the operculum. The ventral ones originate below the pectorals, end at the same level. Back of bluish grey body, clearing on the flanks, whitish abdominal area. Dorsal and dark grey caudal fin, pectoral, ventral and clearer anal.

Distinction of similar species in the area

It is distinguished from *Macrodon ancylodon*, king weakfish, mainly by the pattern of coloration and the shape of the caudal fin [link 2]. Recently, Pinter dos Santos-Ninim (2008) analyzed the morphometry in its phases of transformation of the family Scienidae in coastal waters of the southern and southeastern regions of Brazil distinguishing diagnostic characters for its identification. In the early stages of development (standard lengths between 11 and 87 mm) he determined that the morphometric characters, such as body height, head length, orbit diameter and upper jaw length, were less for *C. guatucupa* than *M. ancylodon* [link 3].

Geographical distribution

The striped weakfish (*Cynoscion guatucupa*) is a widespread pelagic-demersal fish predominantly found on the coast of South America, ranging from Rio de Janeiro, Brazil (22°S), to Chubut province, Argentina (43°S) (Cousseau and Perrotta, 2013). *C. guatucupa* belongs to a group of about 20 species corresponding to a multispecific demersal fishery (Carozza *et al*., 2001). Within this group, *C. guatucupa* is considered the second species in commercial importance after the whitemouth croaker (*Micropogonias furnieri*) (Ruarte and Aubone, 2004). The striped weakfish body size is close to 320 mm at maturity; its spawning period ranges from October to early April, with a main peak in October–November (Ruarte and Aubone 2004; Ruarte *et al*., 2004). It is a long-lived species (20-23 years). Argentine landings of striped weakfish come from catches from Samborombón Bay, part of the Zona Comun de Pesca (34°S to 39°S), and from El Rincon zone to the South of Buenos Aires province (39°S to 41°S)
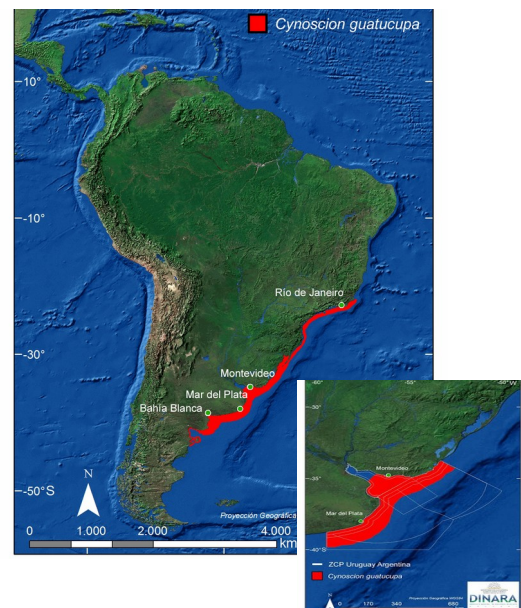
Figura 1. Distribution of striped weakfish (*Cynoscion guatucupa*) on the coast of South America and in the Zona Comun de Pesca (ZCP). Fuente: J. M. Caballero, Dirección Nacional de Recursos Acuáticos (DINARA) Proyecto FAO-DINARA UTF/URU/025/URU "Gestión de la Pesca en Uruguay".

Population and management units

Cynoscion guatucupa shows latitudinal differences in some population and biological parameters, such as growth, natural mortality, age / size of first maturity, fecundity as well as morphometric and meristic characters and its genetic structure. This has made it possible to postulate the existence of different population groups.

Based on meristic and morphometric comparisons, Díaz de Astarloa and Bolasina (1992) suggested that striped weakfish from southern Uruguay and northern Buenos Aires Province, Argentina could be a single stock, isolated from those striped weakfish from El Rincon, southern Buenos Aires Province, Argentina. Previous studies based on fecundity (Cassia, 1986), length-mass ratios and presence of both eggs and juveniles in both zones (Cordo, 1986), support this view.

Although it was not possible to determine significant differences between these two areas from the comparative study of the morphology and morphology of *C. guatucupa* otoliths (Volpedo, 2001), the analysis of the chemical composition of otoliths from these same locations showed significant differences in the Mg/Ca, Mn/Ca and Sr/Ca ratios. From these results it is postulated the existence of two populations, one in the north (Partido de la Costa and Mar del Plata) and another in the south of the province of Buenos Aires (El Rincón) (Volpedo and Fernández Cirelli, 2006).

Volpedo *et al*. (2007) postulate that the fish stocks of the striped weakfish on the South American coast would be at least three. The first located on the south coast of Brazil and Uruguay, the second in the northern area of the Buenos Aires coast (Bahia Samborombón and Partido de la Costa) and the third in the Buenos Aires south (El Rincón and Bahia San Blas) [link 4].

Timi *et al*., (2005) analyzed the parasites of *Cynoscion guatucupa* along South American Atlantic coasts. Two stocks of striped weakfish in the south-west Atlantic Ocean were identified using parasites as biological tags. Similarity within Argentinean and Uruguayan samples was similar to those between them, indicating the integrity of the southern stock. The low values of similarity between zones involving Brazilian striped weakfish support their separation as a different stock.

In contrast to these results, Haimovici (1997) and Vieira and Haimovici (1997) postulate that the population that inhabits the Treaty area could be part of the same population that extends to the Cape of Santa Marta (29° S). The authors base these conclusions on the reproductive dynamics of the species, the distribution of their breeding areas and seasonal migratory movements of the adults of southern Brazil accompanying the displacement of the cold water masses. Vieira Castelli (1990) analyzed the reproductive period of the striped weakfish landed in Rio Grande do Sul, did not identify important spawning areas in the area, concluding that the spawning of the species coincides with the movement of adults towards the coasts of Uruguay and Argentina during the spring.

Likewise, Haimovici (1997) and Vieira and Haimovici (1997) found similarity in the growth parameters, seasonality of reproduction and sizes and age at first maturity. Subsequently, Volpedo *et al*. (2009) analyze the chemical composition of the otoliths of this species by comparing samples from the ZCP and El Rincon. They determined in the ZCP a great variability in the concentration of seven chemical elements (Cr, Cu, Mg, Mn, Pb, Sr and Zn). In the El Rincon specimens, the variability in chemical composition is reduced, presenting values similar to those determined in the ZCP. The authors suggest from these results that there is connectivity between these two areas (ZCP and El Rincon) due to the displacements of the species, in the same way, could occur with specimens that would move between the coast of Brazil and the ZCP.

Sabadin *et al.*, (2010) analyzed the morphometric, microsatellite loci and mitochondrial control region variation of the striped weakfish from two feeding and spawning grounds in the coastal area of Buenos Aires province (Bahia San Borombon and El Rincon). The characterization of the body shape proved to be different between sites. Genetic structure analysis showed that the main source of genetic variation was within populations rather than among populations and low genetic differentiation was observed between sites. The striped weakfish inhabiting the coastal areas of Buenos Aires would exhibit two management units in agreement with other fishes studied in both areas.

The most recent information (Marques 2012) comes from the use of sequences from the mitochondrial control region to know the genetic structure of *Cynoscion guatucupa* throughout its range of distribution in the South West Atlantic. Although the author finds differences between Montevideo and La Paloma, Bahía Blanca and Torres, when analyzing the whole area he found a high variability within the populations, which is an indicator of the lack of genetic structuring. According to the author, this population homogeneity from the south of Brazil to Bahía Blanca would form a single management unit [link 5].

Figure 2. Population units of the *Cynoscion guatucupa* in the South-West Atlantic. Modified from Fernández Iriarte *et al* 2011.
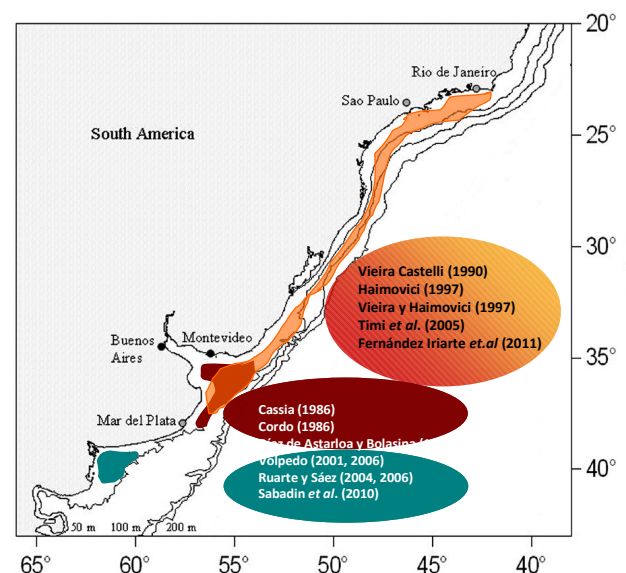
The results obtained from genetic analysis as with otoliths chemistry are not necessarily contradictory. In this sense, Thorrold *et al.* (2001) [link 6] referring to the fidelity of the natal homing in a metapopulation of a species of northwest Atlantic, *Cynoscion regalis*. The authors suggest that this finding may have direct implications in the management of this population or of this stock under the metapopulation concept.

Beyond these results and considerations, the management of *Cynoscion guatucupa* fisheries in the South West Atlantic is carried out from three management units: the first corresponds to the stock from Santa Catarina-Rio Grande do Sul (Ministerio da Agricultura, Pecuária e Abastecimento), the second corresponds to the area of the Treaty and is administered jointly by the CTMFM and CARP and the third, corresponding to El Rincon, is in charge of the Argentine Fishing Application Authority.

Biology and Ecology

Initial ontogenesis

Cynoscion guatucupa eggs are pelagic and spherical, 700 μ 840 μ in diameter and with single oil globule of 210 μ a 240 μ. The yolk is homogeneus and the corion has a smooth surface.

The embryonic and larval development of striped weakfish in the ZCP has been described by Ciechomski and Cassia (1982). The trend of development, from egg activation to larval hatching, was studied by artificial fertilization, using spawning adults and embryos under controlled experimental conditions. The embryonic and larval development of striped weakfish of the ZCP has been described in detail by Ciechomski and Cassia (1982) [link 7].

From specimens fixed, the authors found that striped weakfish larvae at birth measure between 1.7mm and 1.9mm (TL) and are relatively undeveloped. The details of the evolution of the initial ontogeny are described in [link 8]. When reaching 17 cm (TL) the juveniles already present the meristic characters of the species. They describe the following characteristics of this stage: "*the height of the body at the level of the base of the pectoral fin represents 29% of the standard length, reducing this proportion in adults. At the level of the beginning of the anal fin, the height equals 18% and the peduncle caudal to 93% of standard length. The head is large occupying its length of 34% of the body. The preorbital distance and the diameter of the eye represent 15% and 28% of the length of the head respectively. The mouth is large and reaches to the middle of the eye. Premaxillary teeth are very pointed, arranged in two rows. On the front, there are two canines on each side*"

Growth
Larval, post-larval and metamorphosis phases

Ciechomski and Cassia (1978) [link 9], studied the growth of striped weakfish juvenile between 20 - 140 mm TL, based on data of the species in its natural habitat and under experimental conditions. The monthly growth of juveniles at sea was determined through the analysis of distribution of size frequencies of 5,000 individuals collected in a year. The fish in the aquarium were measured and weighed every two weeks. On the analysis of size frequency distribution and retro- calculation, it was concluded that the formation of the first annual ring in juveniles of this species occurs in specimens between 45 - 100 mm TL and 1.16 - 10.0 g weight. The average size of the marking of the first annual ring occurs between 70 - 80 mm. In juveniles between 79-102 mm at a temperature of 15 to 22 ° C the increase in length and weight was 2.01 mm and 0.896 g per week respectively.

Pereira (1986, cited in Viera and Haimovici 1993) identified striped weakfish juvenile from 30 to 40 mm TL in the Laguna de los Patos estuary only in December, April, May and June. He did not observe juveniles so small with a translucent mark, which was attributed to the fact that probably those born in summer form this complete mark only from the second winter and would be larger than the specimens of the same age class from Mar del Plata.

Juvenile and adult stage

The striped weakfish is a long-lived and slow-growing fish. Based on otoliths analysis, Ruarte and Sáez (2006) and Lorenzo (2009) determined the age and growth of specimens catches in research cruises carried out during the years 1998 - 1999 and 2007 respectively in the Treaty area. In both cases, the maximum age observed was 14 years. The estimated growth parameters according to the von Bertalanffy equation are presented in Table 1. Ruarte and Sáez (2006) found differences in the age and growth between ZCP and El Rincon, confirming those found when comparing the respective size-weight relationships (Cordo, 1986). The maximum ages observed in El Rincon were 21 and 23 years, in specimens up to 53 cm (Ruarte *et al*., 2000). The striped weakfish in the El Rincon area has a faster growth than in the ZCP since it reaches 80% of the L_∞ during the first 4 years of life. These differences in growth parameters and maximum ages can be related to the amplitude of environmental conditions in which the species inhabits, which tolerates temperatures between 13.1° C and 20.8° C and typical marine salinities (33-34 ups) (Ruarte *et al*., 2004). The average density of the population of the El Rincon area is three times lower than in the Uruguayan-Buenos Aires region.

Likewise, López Cazorla (2000) studied the age of striped weakfish in the Bahia Blanca estuary (39° S) with samples collected between April 1991 and May 1993. She concluded that the formation of the annual ring would occur between June and August. Age 0 was assigned to individuals between 5 and 15 cm LT. Adult females from 5 to 23 years were distributed in sizes between 40 and 52 cm TL while males from 7 to 22 years old between 50 and 51 cm TL.

Castelli-Viera and Haimovici (1993) proposed the existence of a latitudinal gradient in the north-south direction both in growth and observed maximum ages. The authors observed that the specimens between Cabo Frio and Torres would mark 8 years at 32 cm while those from Rio Grande do Sul, at 44 cm. Likewise, the maximum ages observed were 9 and 15 years respectively. Ruarte and Sáez (2003) verified the mentioned hypothesis of the latitudinal gradient with data from El Rincon. Later, Ruarte and Sáez, (2006) estimated maximum age and K minor values, suggesting that this decrease may be due to the increase in fishing in recent years.

A periodicity was observed in the formation of the growth zones, verifying that the translucent zones are formed in the winter months coinciding with the low temperatures and the gonadal maturation.

Table 1. von Bertalanffy parameters for females, males and pooled sexes of striped weakfish collected in the ZCP and El Rincon and Rio Grande do Sul.

		Machos	Hembras	Sexos agrupados
ZCP	1997 - 1998	$Lt = 59,33 [1-e^{-0,15(t-(-1,77))}]$	$Lt = 55,52 [1-e^{-0,19(t-(-1,44))}]$	$Lt = 57,02 [1-e^{-0,19(t-(-1,53))}]$
	2007	$Lt = 55,60 [1-e^{-0,21(t-(-1,11))}]$	$Lt = 54,13 [1-e^{-0,21(t-(-1,40))}]$	$Lt = 54,18 [1-e^{-0,22(t-(-1,21))}]$
El Rincón	1997 - 1998	$Lt = 46,64 [1-e^{-0,42(t-(-0,15))}]$	$Lt = 48,48 [1-e^{-0,39(t-(-0,05))}]$	$Lt = 47,75 [1-e^{-0,39(t-(-0,17))}]$
Río Grande do Sul	**1977 - 1981**	$Lt = 48,04 [1-e^{-0,28(t-(-0,214))}]$	$Lt = 51,69 [1-e^{-0,23(t-(-0,34))}]$	$Lt = 50,12 [1-e^{-0,26(t-(-0,19))}]$

The annual parameters of the height/weight relationship showed significant differences between sexes. The values corresponding to the curve adjusted to measurements come from the sampling of two research cruises conducted by the B/I "Dr. E.L. Holmberg" in the ZCP in December 1998 and November 1999 [link 10] are the following:

Males $P = -0,0198*Lt^{2,78}$ N = 530
Females $P = -0,0189*Lt^{2,80}$ N = 582

In the Southeast region of Brazil, the size/weight ratio was estimated from 6,598 specimens between the 58 and 575 mm obtained from commercial fishing samplings carried out in Rio Grande do Sul, with the following parameters: $a = 1.94 \times 10^{-5}$, $b = 2.87$ (Haimovici and Velasco, 2000).

Reproduction

The striped weakfish is a multiple spawner with indeterminate annual fecundity. The reproductive activity in the coastal waters of Buenos Aires province ranges from October to March whit a main peak in November. The same pattern was found in samples from the landing in Rio Grande do Sul by Vieira and Haimovici (1997). Macchi (1998) finds spawning females in the El Rincon area during November, while most of the individuals were in maturation for the ZCP. Eggs and larvae of the species have been found in two zones, one corresponding to El Rincon and another that extends from Mar del Plata to 36° 30'S with the 50 m isobath as the external limit (Cassia and Booman, 1986). Juveniles of less than 10 cm are abundant in very coastal areas, detecting the highest concentrations near of Cabo San Antonio (Lasta and Acha, 1993).

The reproductive biology of the striped weakfish, inhabiting the estuarine waters of the Rio de la Plata and adjacent marine zone, was studied using macroscopic and histological analysis of the gonads by Milliteli (2007). Highly significant differences between males and females (28.4 cm TL and 31.3 cm TL, respectively) were obtained. The estimated length at first sexual maturity for both sexes was 29.8 cm LT. Also from a macroscopic analysis, Lorenzo (2009) estimated the age of first maturity for females in 3.1 years, (L_{50} females = 32 cm) and for males in 2.5 years (L_{50} males = 29.4 cm). For pooled sexes (L_{50} = 30.7 cm), was 3 years. The ratio L_{50}/t_{50} indicated that males showed a higher growth rate than females (11, 9 and 10.7 cm / year respectively).

The distribution of the maturity stage of this specie in the ZPP and El Rincon during the spawning season (November) was analyzed by Macchi and Acha (1998). The authors showed a predominance of mature individuals, with the exception of the Montevideo coastal where a high proportion of juveniles was identified. In El Rincon, the composition of stages showed a predominance of spawning females. In the trawl group closest to the coast, made between Bahía Blanca and Claromecó, a high proportion of juveniles and the absence of spawning females were observed [link 11]. Subsequently, Militelli (2004) [link 12], with the same aim, showed a predominance of juvenile specimens (stage 1), with the exception of zone 2, where a greater number of maturing and spawning females was observed, although in a very low proportion (stage 2 and 3 respectively). The proportions of sexes in the different zones, (ZCP and El Rincon), showed no relationship with the percentage of spawning individuals (Fig. 3).
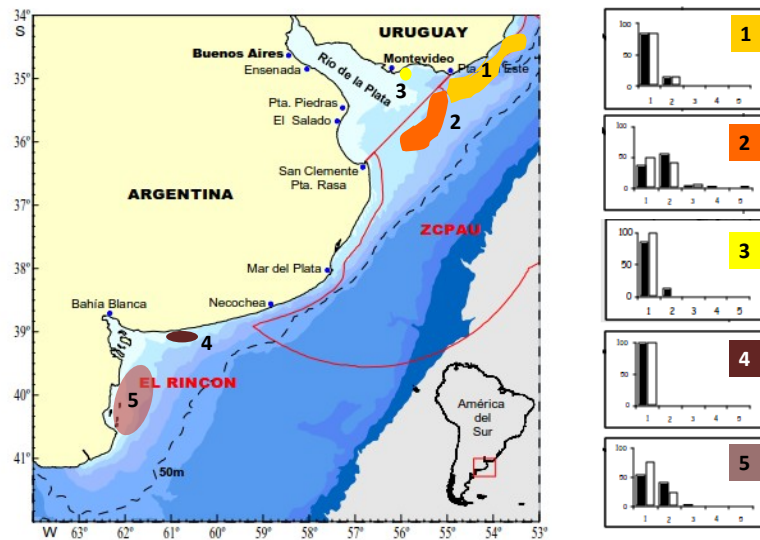
Figure 3. Stages of maturity composition of *Cynoscion guatucupa* for the different zones considered. Black bars: males; white bars: females. Modified from Militelli (2004, 2007).

Feeding

The striped weakfish occupies tertiary and quaternary consumer levels in the trophic chain, with a degree of cannibalism, seasonal variations in diet and an ichthyophagous tendency of adult individuals. The juvenile stages are preferably carcinogens and the basic component of their diet in the Mar del Plata area is *Peisos petrunkewitchi* (Ciechomski and Ehrlich, 1977). The adult specimens have a preference for fish, mainly *E. anchoita* and *A. marinii* and *A. longinaris* (shrimp) and *P. muelleri* (shrimp), especially when there is not enough availability of anchovy (Cordo, 1986).

Garcia (2012) analyzed the feeding habits of *C. guatucupa* through the stomach content of specimens between 38° 30'S - 41° 30'S, covering the ZCP and the El Rincon area during 2004 and 2005. Were identified 39 prey items, corresponding to 4 Phyla. Using the Relative Abundance Index (IRI), determined that the most important item (72.53% IRI) in the diet of the striped weakfish was the fish, followed by the crustaceans (27.44% IRI); with smaller values polychaetes and mollusks were also found (0.2% IRI). Pelagic fish had the greatest contribution to the diet, with *Engraulis anchoita* (75.02% IRI) being the dominant prey, throughout the annual cycle in both areas. Other fish identified were the horse mackerel (*Trachurus lathami*, 2.56% IRI) and the anchovy (*Anchoa marinii*, 0.56% IRI). Within the crustaceans, *Peisos petrunkevitchi* (11.75% IRI) was the most important and in second place was the shrimp (*Artemesia longinaris*, 0.81% IRI) and the shrimp (*Pleoticus muelleri*, 0.51% IRI) [link 13]. No differences between sexes were found in the diet analysis. The food strategy was that of a predator specialist in pelagic fish. The trophic level of the striped weakfish (4.01) was that of a tertiary consumer. Likewise, highly significant differences were found when comparing the diet between the specimens from both study areas. In the ZCP a greater degree of ichthyophagy was observed with respect to the southern zone, which had a preponderantly carcinogenic diet in juveniles and ichthyophagous adults. The amplitude of the trophic niche was limited in the northern sector and broad in the southern sector, maintaining this difference in the two regions by also discriminating values between sexes and sizes. The existence of overlap in the diet was found among all the size groups for the northern zone, while in the southern zone, there was no overlap between the smaller and larger groups.

López Cazorla (1996), analyzing individuals from the Bahia Blanca estuary area, determined that the group of crustaceans constitutes the main item, both in adult and juvenile individuals. Likewise, Sardiña and Lopez Cazorla (2005) verified ontogenetic changes of diet in juvenile individuals in this same area. The first was observed when reaching a TL close to 4 cm, which implied a change in the type of prey, from demersal-pelagic (mysidáceos) to demersal benthic (*Peisos petrunkevitchi*). The second change occurs when reaching an LT of 8 cm, showing a progressive increase in ichthyophagia (*E. anchoita*).

In the Brazilian southeast, Lucerna *et al*., (2000) found that the main prey of the striped weakfish were the fish, crustaceans and occasionally squid. The seasonal variation in the diet, related to the availability of prey in the area confirmed the opportunistic feeding of this species. Although anchovy was an important component of the diet throughout the year, *A. longinaris* predominated in autumn, *Umbrina canosai* in winter, and *Trachurus latami* and eufáusidos in spring. During the summer, *C. guatucupa* was mainly fed on *Artemesia longinaris* and *Paralonchurus brasiliensis* and, to a lesser extent, on anchovy, and also cases of cannibalism were observed on juvenile individuals.

Natural mortality

The values of M obtained by the different methods fluctuated between 0.23 and 0.41 year-1 for females and 0.23 and 0.42 year-1 for males. Pauly's method, considering the von Bertalanffy growth parameters and an average temperature of 16.5 ºC gave an estimate of M = 0.41 yr^{-1} for females and 0.42 yr^{-1} for males. With a temperature range of 13.1 to 21.8 the average values of M were 0.42 $year^{-1}$ in all cases. The methods of Hoenig and Alagaraja taking the maximum age observed (10 for males and 14 years for females) indicated the values of M in 0.25 and 0.27 $year^{-1}$ for females and M = 0.38 and 0, 42 $year^{-1}$ for males respectively. With the estimated maximum expected longevity ($A_{0.95}$) M values of 0.32 for males and 0.35 $year^{-1}$ for females were obtained.

Distribution of the species in the area of the Treaty

Habitat

The area of the Treaty constitutes an area recognized for its high biological productivity. It is a hydrologically complex and dynamic habitat with marked horizontal and vertical density gradients [link 14] [link 15]. Forces of this variability are linked to the seasonal and inter-annual changes of the Rio de la Plata discharges, the seasonal regimes of the winds strongly associated to the latitudinal variations of the South Atlantic high-pressure cell, the nearness of the shelf with the Brazil and Malvinas currents as well as the contribution of nutrients from the southwest of the area transported by the Subantarctic waters of the Argentine shelf.

In the area of the Treaty, the coastal habitat of the species is limited topographically by the isobath 50-60 m, which separates the coastal regime from the continental shelf. In relation to the water masses Negri *et al*. 2016 [link 16] they indicate that waters of sub-Antarctic origin flow south of 38° S, and to the north of 36.5° S diluted waters by the discharge of the Rio de la Plata and waters of subtropical origin are added, principally in summer. Subantarctic Shelf Water, transported from the south, extend parallel to the bathymetry with SW-NE direction with salinity between 33.5 and 34.2 ups.

In the Subantarctic Shelf Water there are three components: the external one with salinity between 33.7 and 34.2 ups, which is located in the outer of the continental shelf; in the middle on the central shelf with lowest salinity resulting from the contribution of diluted waters by continental runoff in the south of the continent; and the coastal one with relatively high salinity values (S> 33.8 ups), coming from the east of El Rincon and originating in the interior of the Golfo San Matías due to the effect of restricted circulation and the predominance of evaporation over local precipitation. The Subtropical waters present are the Tropical Water and the South Atlantic Central Water, transported to the south by the Brazil current, which predominate during the summer and autumn. The Rio de la Plata water is mixed with continental shelf waters, forming a low - salinity layer over the Subantarctic and Subtropical Water, induces a high vertical stratification, isolating the deep layer.

The topography, together with the contributions of continental water and the modifications due to the exchange with the atmosphere, generate a complex ecological and oceanographic system. In the Rio de la Plata, the Barra del Indio constitutes a geomorphological barrier that divides the area internal and external. The internal corresponds with the river discharge and the external to a mixohaline regime where the intrusion of shelf water along the bottom, in the form of a salt wedge, generates a two-layered structure with a strong vertical stratification that decreased towards the outside of the Rio de la Plata. The interfaces between the mentioned regimes originate two salinity fronts, the bottom one as the boundary between the fluvial regime and the mixohaline, and the surface one as the boundary between the mixohaline regime and the shelf waters.

The entrance to the platform of the diluted water of the Rio de la Plata and its seasonal variation influences the shelf ecosystem modifying the physical-chemical properties of the area, the concentration of nutrients and the biological productivity. The distribution of surface salinity varies seasonally and is forced by winds and continental discharge. In autumn-winter the winds are continental and fresh water discharge reaches maximum values. In that period, there is a drift of water coming from the discharge of the Rio de la Plata in the northeast direction along the Uruguay coast. In spring summer, they show an extension in south-easterly direction, towards the Argentina coast, as a consequence of the oceanic winds and a minimum in the continental discharge. There are also areas whose waters are locally modified by continental contributions, which promote the formation of fronts in the coastal littoral, of importance due to their biological implications.

Areas of concentration and size structure

In the Treaty area, the greatest abundance of the species is 50 m deep (Macchi 1998). In winter it concentrates in deep waters, while in autumn and spring it moves to shallower waters, close to the coast, probably in a movement associated with reproduction.

From the analysis of research cruises conducted during 1998 and 1999 in the spring and summer, it emerged that the highest concentrations of this species were recorded north of the ZCP (Punta del Este and El Chuy) between 25 and 100 m. This area was characterized by high densities of juvenile between 10 cm and 30 cm TL (individuals from 1 year to 3 years). Within the Rio de la Plata, Bahia Samborombón and the Mar del Plata, low densities were found. In El Rincon the highest densities were located forward of Bahia Blanca, being the highest percentage of adult individuals.

Jaureguizar *et al.* (2006) and Jaureguizar and Guerrero (2009) found a temporal space pattern in the abundance of age classes correlated with environmental variables. Although the juveniles (<3 years) predominated in the ZCP throughout the year, its observed seasonal changes in abundance. Age class 0+ predominated in autumn while in winter and spring they were 1+ individual. Individuals> 4+ were abundant in winter and early spring. The structure of the juvenile population of striped weakfish was associated with low salinities, this occurs when the wind forces fresh water from the Rio de la Plata to the coastal marine area, while adults were associated with high salinities. The authors conclude that the short-term environmental synoptic condition has a greater influence on the distribution and population structure of *C. guatucupa* than long-term environmental variability.

The specific analysis of the distribution by age group in the spring of 2007 marked the prevalence of age 0 individuals in a range of 30 to 37 m depth between Punta del Este and Chuy. Although the distribution for age group 1, 2 and 3 was similar to the previous one, they had higher density of individuals north of 35ºS at depths between 45 and 65 m. From age 4, concentrations predominated compared to Punta del Este at depths of less than 20 m. It should be noted that it was from this age that a difference in concentrations was found by sex, with females predominating in number up to age 7+ [link 17].

Spawning and breeding in the Treaty area

In the Treaty area, spawning of this species is always located in saline waters (values higher than 30 ups), mainly in a small area off the coast of Punta del Este (Macchi and Acha 1998, Militelli and Macchi 2006). With the aim of describing the spawning strategy of the sciaenid in the coastal waters of Argentina, Militelli *et al*. (2013) analyzed the influence of environmental factors on the spawning. During the peak of the reproductive period, spawning females were mainly located in waters with mean temperature values of 15.2° C in the range of 13.1 to 18.5° C and average salinity of 33.4 ups (between 31.9 and 34.2 ups) characteristic of marine waters of the coastal region. The spawning females were concentrated mainly in a reduced area with salinity values between 33 and 34 ups and a temperature that varied between 19 and 22 ° C (Fig. 4). These results agree with López Cazorla (2000) who described the spawning of the striped weakfish in the El Rincon area, particularly in the Bahia Blanca estuary. This author concludes that the spawning takes place in the external zone of the estuary and that their eggs and larvae are transferred to the inner zone of the same by the tidal currents, using it as a breeding area up to an average size of 12 cm. From there the juveniles migrate again to the marine environment.

Batch fecundity was estimated for March 2000 between 14,500 to 208,000 hydrated oocytes and was positively correlated with total length and ovary-free female weight. These values showed a power function of total length and linear function of ovary-free body weight, similar to that reported by Macchi (1998). Relative fecundity estimated for the 3 years sampled ranged between 37 and 276 hydrated oocytes/g. During December 2003, fecundity values were significantly lower than those obtained in March 2000 and 2001. However, in December the oocyte dry weight was greater than in March, when the spawning activity of striped weakfish decreases.

Figure 4. Spatial distribution of sciaenid spawning females (a) at the time of peak spawning activity and (b) at the end of the spawning season. Modified from Militelli *et al.* 2013.
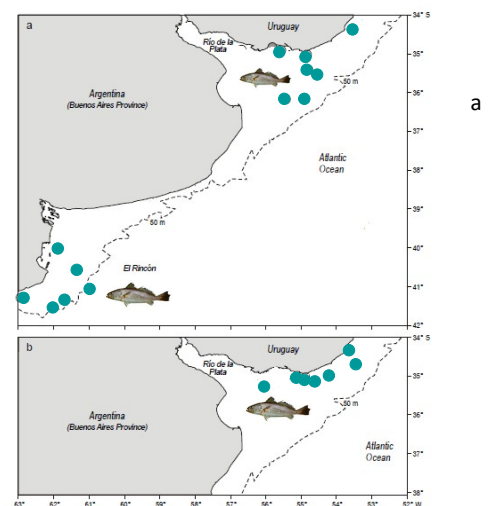
Fishery Indicators

Striped weakfish is a resource exploited by Brazil, Uruguay and Argentina. In Brazil, nearly all landing is made in Rio Grande do Sul, being landed by the industrial fleet mode pair and otter trawlers and gillnet throughout the year (Haimovici 1997) and the medium-scale coastal fleet with gillnets during the winter months. Between 2009 and 2011 the landed volumes averaged 6,000 t (MPA 2012).

In Uruguay, striped weakfish landings occupy the third place and it is considered the second most important species among the coastal demersal resources of the Treaty area, after the whitemouth croaker (*Micropogonias furnieri*). It is catches mainly by the industrial fleet pair bottom trawl nets (Cordo 1986, Nion 1998). The coastal Uruguayan industrial trawls fleet Category B operate with bottom trawls, either independently using gates, or the pair trawlers. The average length of these vessels are 23 m in length,

129 GRT and 415 HP. Currently there is no industrial fleet whose target species is the catch of whiting, a situation that was recorded until 2001.

In Argentine, the largest landing of this species occurs in the port of Mar del Plata, by the bottom trawl fleet with gates and the drag net to the couple (Ruarte *et al.,* 2004). The coastal fleet denominated Ic (lengths between 18 and 25 m) is the one of greater activity on the striped weakfish in particular. Landings from the fishing fleet to the couple increased, becoming one of the preferred modalities for the coastal fleet, reaching more than 50% of the catches in the ZCP as of 2010. The main area and the fishing season of the Argentine fleet are in the Rincon, the Faro San Antonio area and the Uruguayan coast, there being a peak in the catches in the winter-spring period (Ruarte and Rico 2014, Ruarte 2015).

The landings of this species made by the Uruguayan fleet between 2000 and 2003 exceeded the volumes of Argentine catch by averaging 10,800 and 2,500 tons respectively. Between 2004 and 2008, the landings of both countries stabilized at approximately 10,000 tons. From this year, the catch by Argentina doubled to that made by the Uruguayan fleet (Figure 8). In 2014, there was a slight increase in the Uruguayan fleet and a decrease in the landing in Argentina compared to 2013. Although in 2015 Argentine increased the catch of this species, in 2016 it decreased to 3,300 tons in 2019. Uruguay increased 76% of the catch in 2019 compared to 2015 (Figure 5).
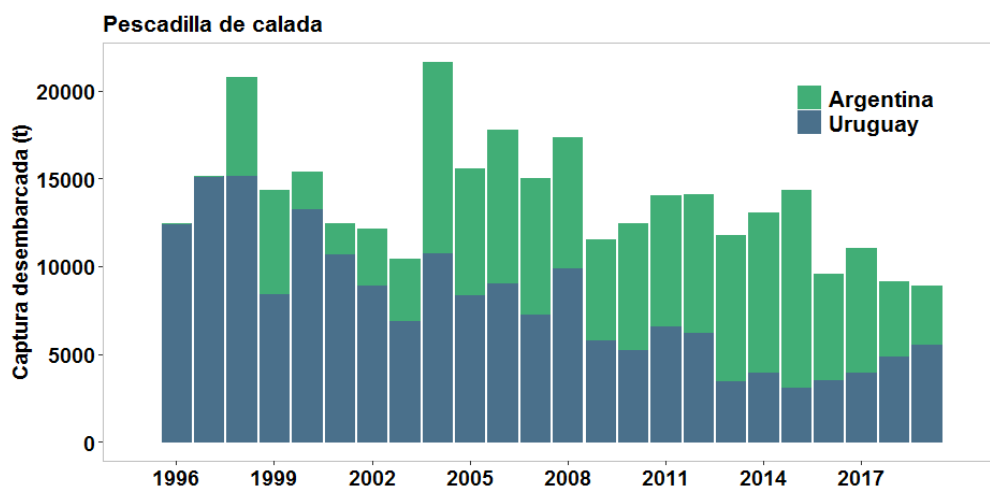
Figure 5. Striped weakfish landings from Uruguay and Argentina (north of 39º S). Period 1996-2019.

The monthly distribution of striped weakfish landings by the Argentine fleet from 2016 was not as marked as in previous years (Figure 6). The Uruguayan fleet showed an increase between April and September. The low landing volume recorded in 2013 corresponds to the total stop of activity of the coastal fleet in May and June.
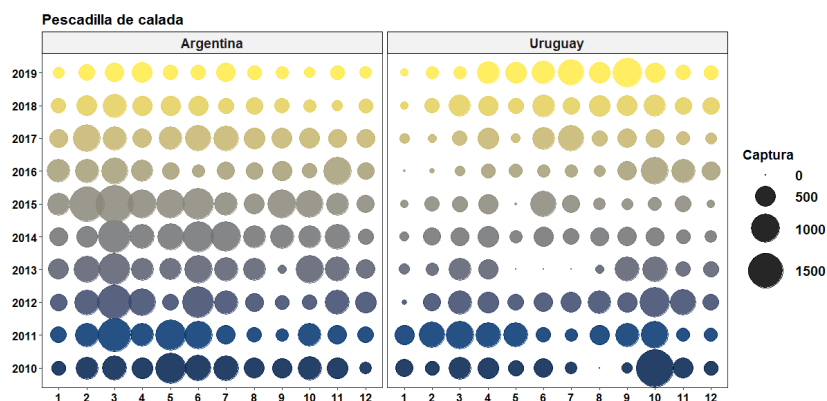

Figure 6. Monthly trend of the catch (t) of striped weakfish and fishing effort (h)of the Uruguayan coastal fleet in the years 2012 to 2016.

Figure 7 shows the distribution by square of the average catch between 2010 and 2019 for the Uruguayan fishing fleet. The area of greatest concentration of catches is the Rio de la Plata region in fishing grid 355 and 356, given that this fleet is directed at *M. furnieri*. In the coastal oceanic region the fishing grid 344 and 354 stand out, which do not exceed an average of 1,200 t for this period.
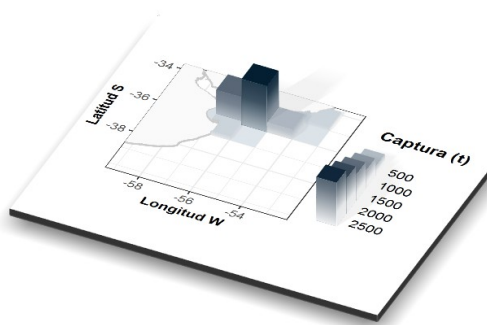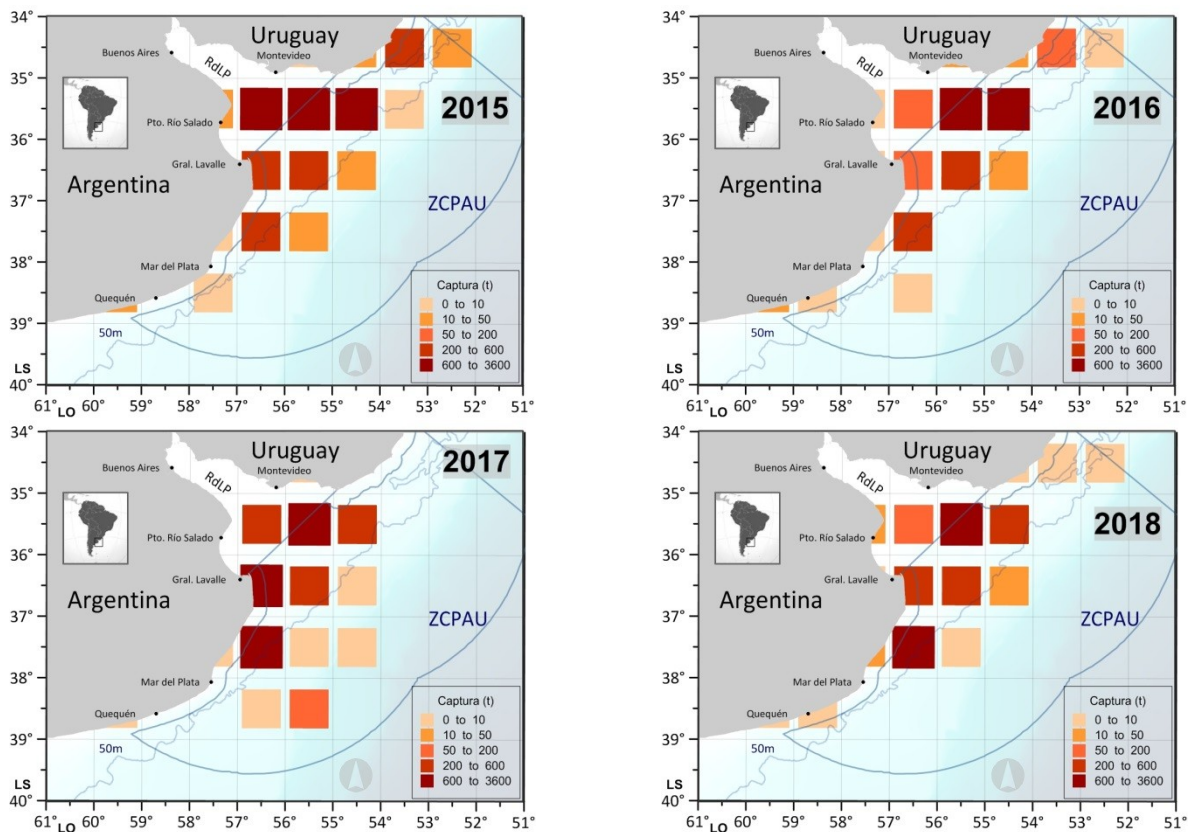
Figure 7. Striped weakfish average catches of the Uruguayan fleet Category B.
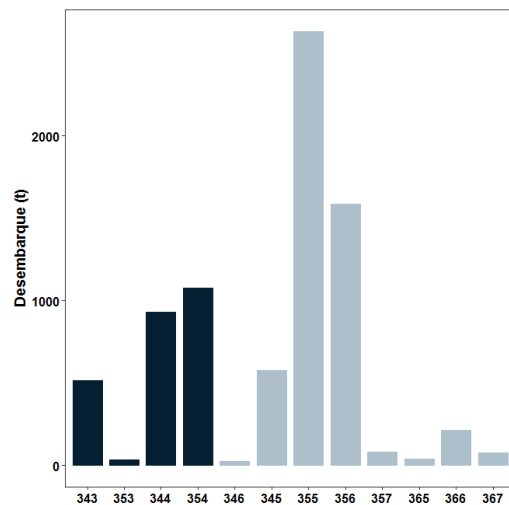
Figure 7. Continue. Striped weakfish average catches (tons) per fishing grid. 2010- 2019.

The distribution of the whiting catch by fishing grid is shown in Figure 8.

Figure 8. Annual landings (tons) of striped weakfish by the Argentine fleet by fishing grid in the Treaty area.

Relative abundance indices

CPUE standardization was performed using a Generalized Linear Model), which allows incorporating the most important factors and interactions that generate changes in the CPUE.

Argentine industrial fleet

The factors considered that were included in the GLM were: Year; four- months, demersal pair trawling.

Two models were formulated:

(a) **Model (CPUE A kg/day):** *ln (CPUE$_{ijkl}$) = μ + Year$_i$ + four- months + Pair trawling$_k$ + (Year * four- months)$_{ij}$ + ϵ_{ijkl}*

(b) **Model (CPUE A kg/hour VMS***)*

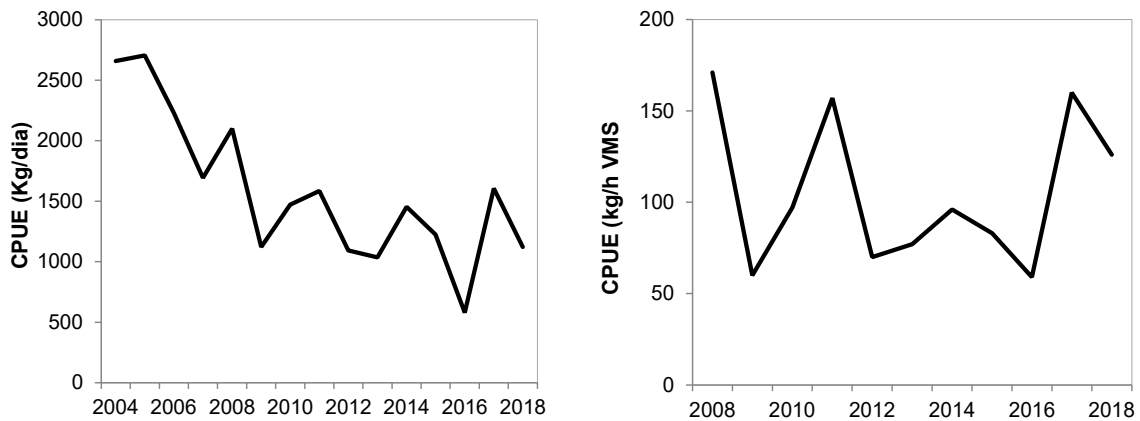The trends of each of these indices are presented in the Figure 9.

Figure 9. Standardized annual CPUE (kg/day). Period 2004-2018 (left panel) and CPUE (kg/h$_{VMS}$). Period 2008-2018 (right panel).

An index derived from research cruises of coastal demersal species carried out by Argentine vessels in the study area in spring was also used (Table 2). These were carried out with a stratified random design and the average densities of the years 1994, 1998, 1999, 2003 and 2013 were used.

Table 2. Average densities (t/mn^2) of *C. guatucupa* estimated from data from spring research vessel surveys.

Code research vessel surveys	Year	Average Density t/mn^2
EH 13/94	1994	9,6
EH 10/98	1998	9,0
EH 09/99	1999	9,4
EH 06/03	2003	5,8
EH 06/13	2013	5,2

Uruguayan industrial fleet

For the Uruguayan industrial fleet, the General Linear Models (GLM) were applied using as basic data the CPUE values corresponding to the haul-to-haul of each tide, expressed in kilograms per trawl hour. To estimate the CPUE, catch data (t) of striped weakfish from the Uruguayan commercial fleet and fishing effort (hs) of the same were used in the period 2002-2018. The models considered the following factors and interactions of the first order:

Model U: ln(CPUE) = μ + Year$_i$ + Trimester$_j$ + Fishing grid $_k$ + Vessel$_l$ + (Year:Trimester)$_{ij}$ + (Trimester: Fishing grid)$_{jk + ijkl}$

The annual mean values of the abundance series according to the models estimated in the GLM are presented in Figure 10.
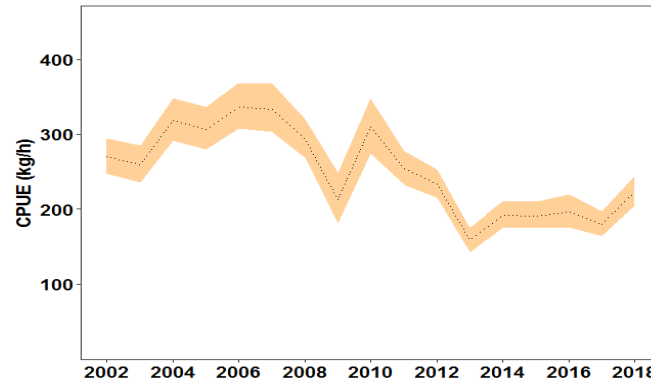
Figure 10 Annual trend of the CPUE (kg/h) of the Uruguayan fleet.

Status of fishery resource

1. Surplus production model

Surplus production models provide simple descriptions of harvested populations, in terms of annual biomass levels (Bt), the intrinsic growth rate (r), the carrying capacity of the environment (K) and the efficiency of fishing gear (q), (Hilborn and Walters, 1992; Polacheck *et al*., 1993).

The surplus production model (Schaefer, 1954) was used to determine indicators of stock productivity. The parameters of the model, its uncertainty and the performance indicators of the management strategy were estimated with Bayesian methods.

The Schaefer (1954) form of the surplus production function is

$$B_{t+1} = \left[B_t + rB_t \left(1 - \frac{B_t}{k} \right) - C_t \right]$$

Where Bt, Ct , and g(Bt) denote biomass at the start of year t, catch during year t, and the surplus production function, respectively.

The annual catch is treated as a fixed constant. A common, although simplifying assumption is that the relative abundance index is directly proportional to the biomass.

$$I_t = qB_t \exp(\varepsilon_t)$$

where catchability parameter *q*.

Bayesian nonlinear state–space model

The parameters of the model, its uncertainty and the management strategy indicators were estimated with Bayesian methods. These methods allow using in simple way previous information on the parameters to construct the prior distributions. In this statistical framework, the probability of the hypothesis given the data or posterior probability distribution Pr {Hi / dada} was estimated with the following equation:

$$Pr\{H_i/data\} = \frac{L\{data/H_i\}Prior\{H_i\}}{\sum_j L\{data/H_j\}Prior\{H_j\}}$$

The incorporating uncertainty in the natural variability underlying the annual biomass dynamics transitions (process error) and uncertainty in the observed abundance indices due to measurement and sampling error (observation error) is possible calculate using a state–space model (Meyer and Millar, 1999). State–space models relate times series observations {CPUEt} to unobserved "states" {B_t} through a stochastic observation model for CPUE$_t$ given B$_t$. The states are assumed to follow a stochastic transition model. We assumed lognormal error structures and used a reparametrization (P$_t$ = B$_t$/K) by expressing the annual biomass as a proportion of carrying capacity as in Millar and Meyer (1999a) to speed mixing (i.e., sampling over the support of the posterior distribution) of the Gibbs sampler. The state equations are rewritten as:

$$\begin{cases} P_1|\sigma^2 = exp(u_1) \\ P_t|P_{t-1}, r, K, \sigma^2 = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right) exp(u_t) \\ CPUE_t|P_t, q, \tau^2 = (qKP_t) exp(v_t) \end{cases}$$

where u_t are i.i.d. normal with mean 0 and variance σ^2 and v_t are iid normal with mean 0 and variance τ^2.

Bayesian inference is then based on the posterior distribution of the unobservable given the data. In the sequel, its will denote the probability density function of a parameter q by p(q). We assume that the parameters *K*, *r*, *q*, σ^2, and τ^2 are independent a priori. By a successive application of Bayes theorem and conditional independence of subsequent states, the joint prior density is given by

$$P\left(K, r, q, \tau^2, \sigma^2, P_1, ..., P_N / CPUE_1, ..., CPUE_N\right) \propto \dot{c}\dot{c}P\left(K, r, q, \tau^2, \sigma^2, P_1, ..., P_N\right)P\left(CPUE_1, ..., CPUE_N / K, r, q, \tau^2, \sigma^2, P_1, ..., P_N\right)$$

$$P\left(K, r, q, \tau^2, \sigma^2, P_1, ..., P_N\right) = P(K)P(r)P(q)P(\tau^2)P(\sigma^2)P(P_1, ..., P_N)$$

$$P\left(P_1, ..., P_N\right) = P(P_1/\sigma^2)\prod_{t=2}^{t=N} P\left(P_t/P_{t-1}, K, r, \sigma^2\right)$$

Because of the conditional independence assumption of the relative abundance indices given the unobserved states, the sampling distribution is:

$$P\left(CPUE_1, ..., CPUE_N / K, r, q, \tau^2, \sigma^2, P_1, ..., P_N\right) = \prod_{t=1}^{t=N} P\left(CPUE_t/q, \tau^2, P_t\right)$$

Then, by Bayes theorem, the joint posterior distribution of the unobservable given the data, p(K, r, q, σ^2, τ^2, P_1,..., P_N| $CPUE_1$,...,$CPUE_N$), is proportional to the joint posterior distribution of all unobservable and observables:

$$P\left(K, r, q, \tau^2, \sigma^2, P_1, ..., P_N / CPUE_1, ..., CPUE_N\right) \propto \dot{c}\dot{c}P(K)P(r)P(q)P(\tau^2)P(\sigma^2)P(P_1/\sigma^2)\prod_{t=2}^{t=N} P\left(P_t/P_{t-1}, K, r, \sigma^2\right)\prod_{t=1}^{t=N} P\left(CPUE_t/q, \tau^2, P_t\right)$$

A no-informative prior is chosen for q. Lognormal prior distributions for K, r and inverse-gamma for σ^2, τ^2 are specified using biological knowledge.

The posterior probability distribution of carrying capacity, the intrinsic growth rate, catchability coefficient, σ^2, τ^2, the current biomass was estimated. The posterior probability distributions of the parameters were estimated with simulations of the Markov-Monte Carlo chains (MCMC). A total of 100,000 simulations were made using the OpenBUGS software with an initial "*burn-in*" period of 50,000 iterations.

Results

Figure 11 shows Schaefer model fit to the CPUE (kg/h) data.
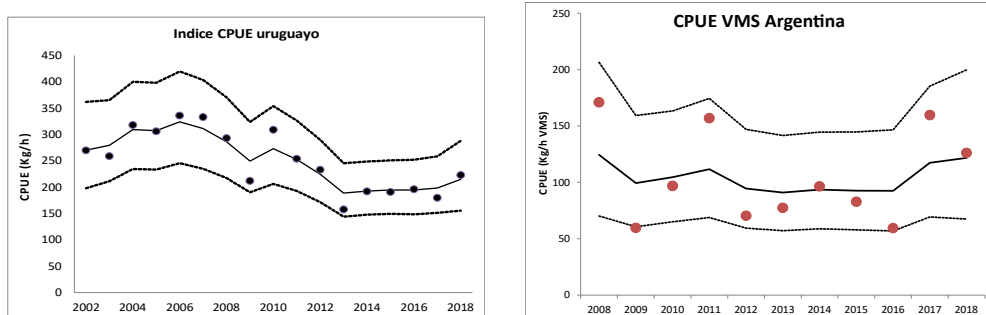
Figure 11. Trend of the standardized CPUE (kg/h) CPUE (kg/h$_{VMS}$).

K estimates were 249,200 tons (IP95% from 153,800 to 378,800 tons) for the Argentine CPUE series and 204,300 tons (IP95% from 165,000 to 240,600 tons) for the Uruguayan CPUE series. The results of the model fit indicated that the whiting stock in 2019 would be reduced to 66% and 54% of the virgin condition for each CPUE series respectively (Table 3, Figures 12 and 13). The estimates of total biomass in 2019 were 168,000 tons for the model with Argentine CPUE series and 112,200 tons with Uruguayan fleet CPUE.

Table 3. Parameter estimated Surplus Model: MSY: Maximum sustainable yield, CR*2019*: replacement yield, stock biomass giving MSY (B_{MSY}), B_{2019}, biomass estimated to 2019, B_{2019}/B_{MSY}: ratio of final-year biomass to biomass at MSY, B_{2019}/K: ratio of final-year biomass to carrying capacity, F_{MSY} fishing mortality rate at MSY.

| Índice VMS argentino				
	Media	**Mediana**	**2,5%**	**97,5%**
RMS	23.890	22.950	14.830	37.710
CR_{2019}	15.610	17.070	9802	31.700
B_{2019}	168.000	157.800	48.680	342.500
B_{RMS}	124.600	120.600	76.890	189.400
B_{2019}/B_{RMS}	1,336	1,353	0,4402	2,173
B_{2019}/K	0,6678	0,6766	0,2201	1,087
F_{2018}	0,1029	0,08547	0,03434	0,2726
F_{RMS}	0,1931	0,1923	0,1465	0,2416
Índice CPUE uruguayo				
	Media	**Mediana**	**2,5%**	**97,5%**
RMS	19.610	19.370	15.760	23.850
CR_{2019}	17.150	17.260	12.770	21.630
B_{2019}	112.200	109.800	59.550	168.000
B_{RMS}	102.100	103.300	82.500	120.300
B_{2019}/B_{RMS}	1,088	1,096	0,6358	1,523
B_{2019}/K	0,5442	0,5479	0,3179	0,7616
F_{2018}	0,1409	0,125	0,07928	0,2258
F_{RMS}	0,1929	0,1922	0,1623	0,2252
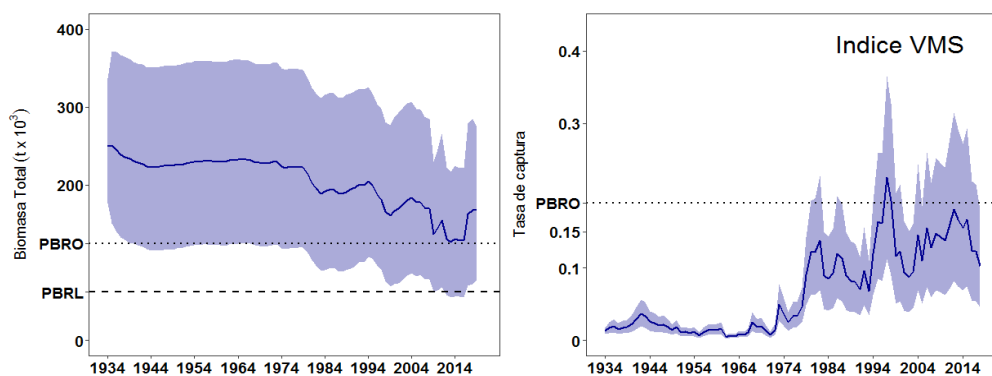
Figure 12. Trend of total biomass and fishing mortality estimated from the surplus model. The band indicates the 95% confidence interval. Argentine fleet CPUE. Horizontal line indicates PBRO and PBRL.
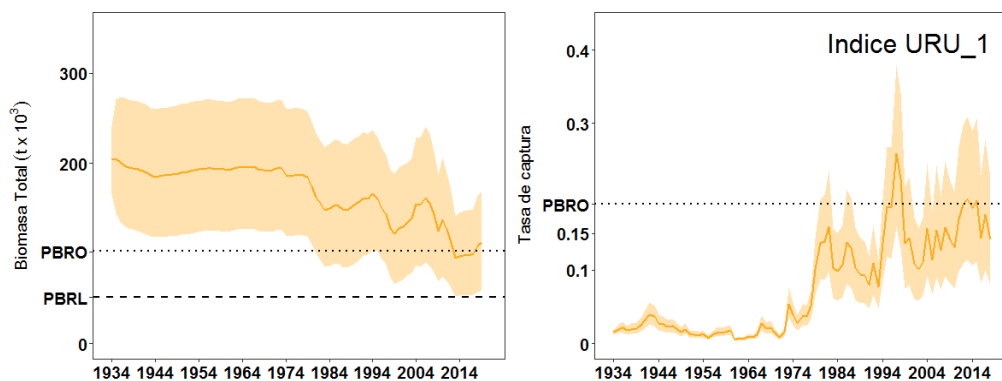
Figure 13. Trend of total biomass and fishing mortality estimated from the surplus model. The band indicates the 95% confidence interval. Uruguayan fleet CPUE. Horizontal line indicates PBRO and PBRL.

For each of the fitted models, the total biomass values in the year 2018 were higher than those corresponding to the optimal biomass values (Figure 14).
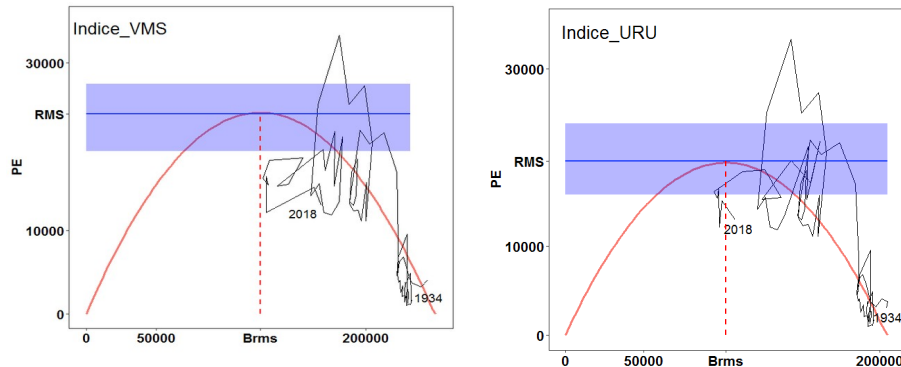
Figure 14. Surplus production curves and estimated catch trends as a function of biomass for the Schaefer model during the period 1934-2018. MSY estimates are shown with 95% confidence intervals (shaded areas).

2   Integrated age - structured model.

An integrated age - structured model was applied in the *Stock Synthesis* (SS3). Stock Synthesis provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population and with multiple stock sub-areas. Selectivity can be cast as age specific only, size-specific in the observations only, or size-specific with the ability to catch the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Some SS features include ageing error, growth estimation, spawner-recruitment relationship, movement between areas. SS is most flexible in its ability to utilize a wide diversity of age, size, and aggregate data from fisheries and surveys. The ADMB C++ software in which SS3 is written searches for the set of parameter values that maximize the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian and MCMC methods. A management layer is also included in the model allowing uncertainty in estimated parameters to be propagated to the management quantities, thus facilitating a description of the risk of various possible management scenarios, including forecasts of possible annual catch limits. The structure of Stock Synthesis allows for building of simple to complex models depending upon the data available.

The basic information used in the application of the age-structured models is detailed below:

- 12 age classes, with the last class corresponding to a plus group (12+);
- Individual growth parameters of Von Bertalanffy: Linf = 53,37; k = 0,25; t0: -0,099.
- Instantaneous rate of natural mortality (M) 0.30
- Parameters of the length-weight relationship: = 0,0152 and b = 2,8662.
- Ratio mature females to age group: 0,0016 0,0129 0,0984 0,4763 0,8834 0,9844 0,9981 0,9998 1 1 1 1 1.
- Age distributions from the samplings of Argentine fleet: data of 1982, 2004, 2009, period 2010-2017.
- Length distributions from annual landing samples in 1874-2018.
- Reporter catch: official fishing statistics, the annual landings declared of striped weakfish between 1874 and 2018

The basic assumptions considered in the models were the following:

- von Bertalanffy growth curve
- Beverton and Holt's yield per recruit models, including annual LogNormal error variability take into account a deviation of 0.4. The R_0 parameter (recruitment at the beginning of the period) was estimated in the model and different exercises were performed according to the value of the *h* (steepness) parameter. This last parameter was estimated using a priori information (normal distribution, mean value of h = 0.8). The a priori information for the estimation of the parameter h was estimated from biological information of the species using the method of Mangel *et al*., (2009).
- The year 1874 (year of the founding of Mar del Plata city) was considered, year that is considered a structure in equilibrium of the population and the beginning of the model.
- The vulnerability or selection pattern was considered logistic for both indices of abundance. These patterns were estimated in two periods: 1874-1969, 1970-1999 and 2000-2018.
- Minimum observation error in the total catches of the species (CV = 0.01).
- Proportional relationship between biomass and indices (fleet and cruises), with an error of type LogNormal

- Coefficient of variation associated with the fleet index. Period 2004-2016: this value arises from considering an average CV of 0.3 and the standard annual errors of the GLM used to estimate the index, in order to re-escalate the variability of the CV.
- Coefficient of variation associated with the research vessel surveys indices with an average CV of 0.2

The final models were as follows:

	Model 1	Model 2	Model 3	Model 4	Model 5
Argentine fleet	kg/day	kg/ day		kg/ day	
	Kg/h_vms	Kg/h_vms	kg/h_vms		
Research vessel surveys indices	+	+	+	+	+
Uruguayan fleet					kg/h
h	h=0,8	h=0,7	h=0,8	h=0,8	h=0,8

Results

Figures 15 to 19 show the fit of the indices of abundance, the trends of total and spawning biomass, recruitment, stock-recruitment relationship, instantaneous rates of fishing mortality, vulnerability patterns and the fit to the lengths and ages distributions for each exercise performed. The main results for each of the models are presented in Table 6.
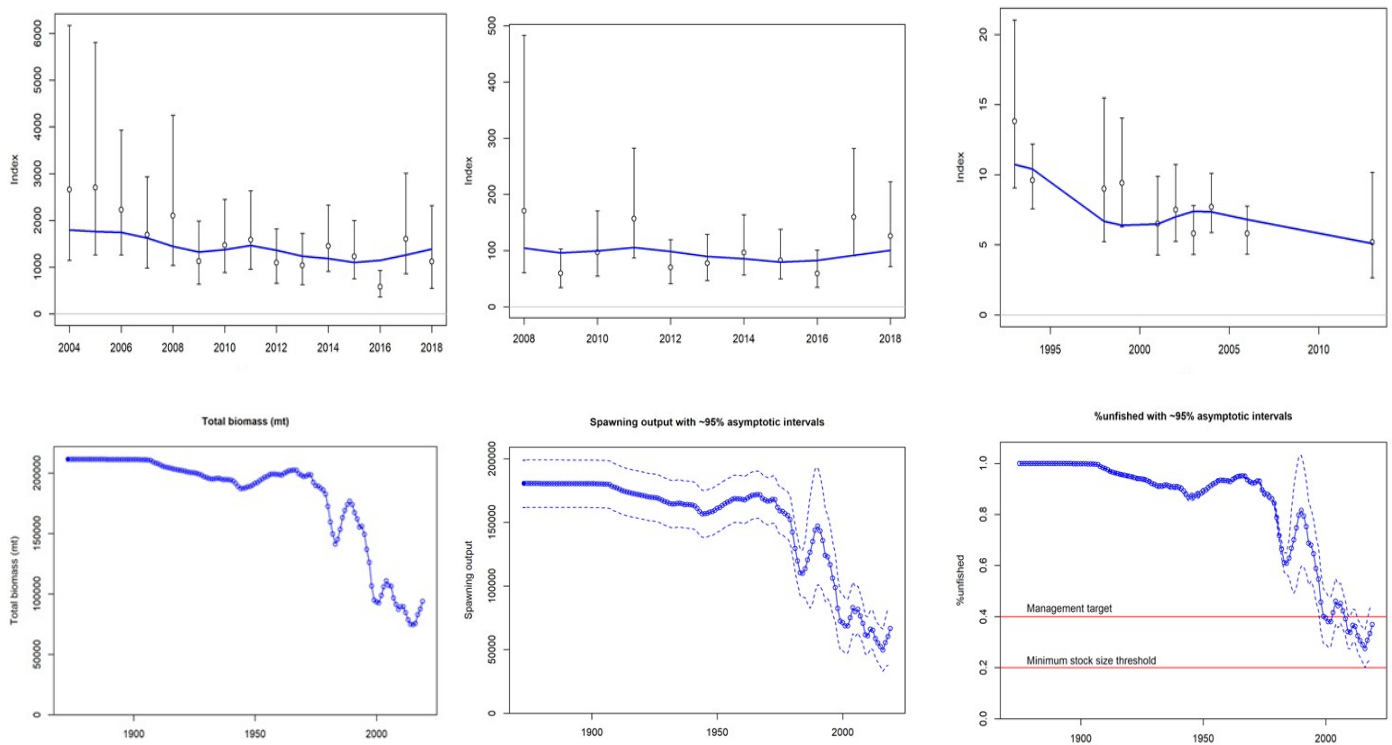
Figure 15. Model M1. Fit to the index; trend of total and spawning biomass, recruitment (with associated uncertainty) and stock-recruit relationship.
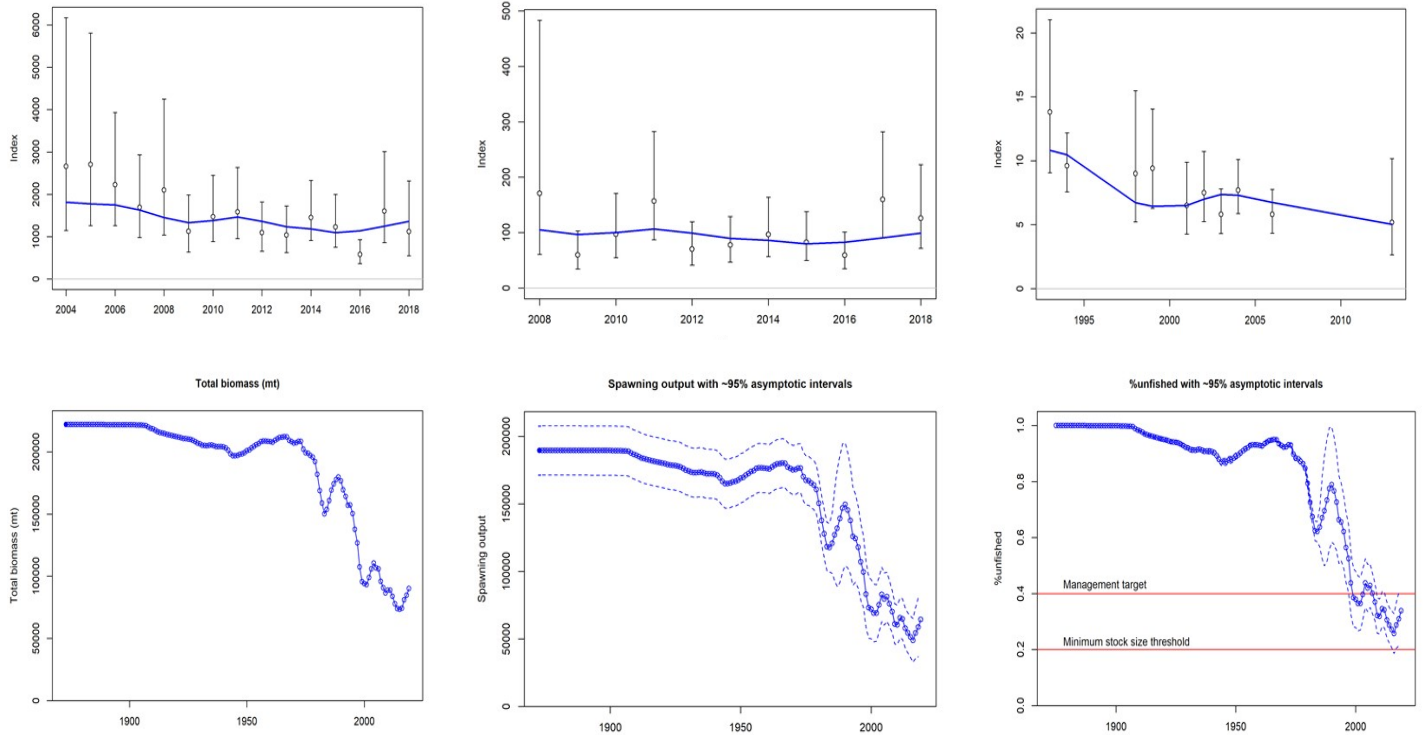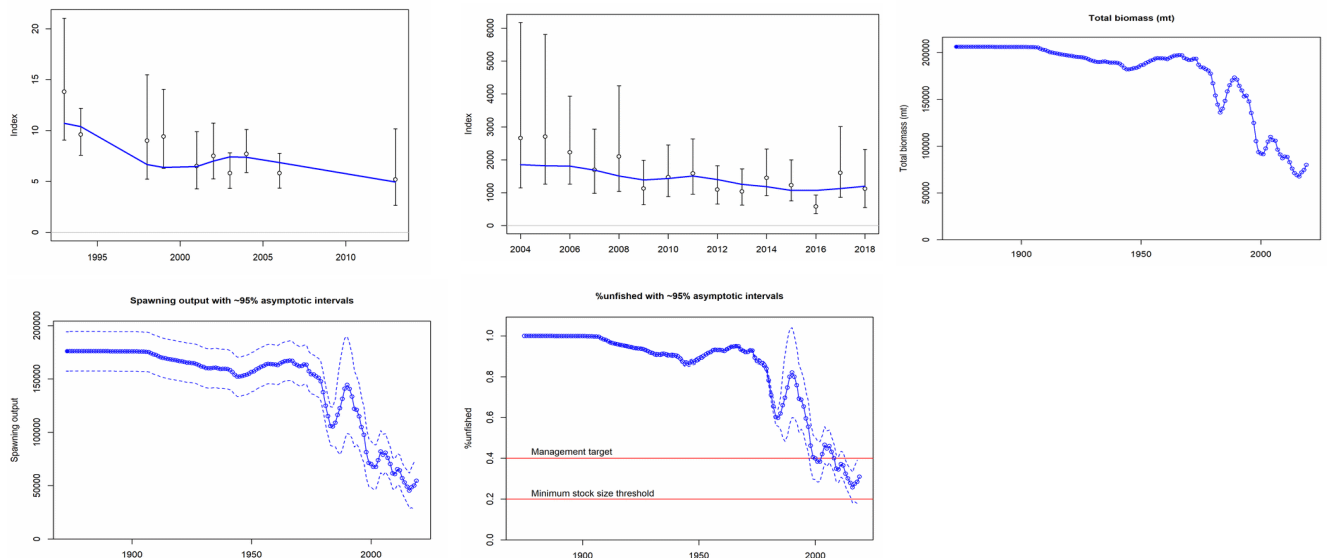
Figura 16. Model M2. Fit to the index; trend of total and spawning biomass, recruitment (with associated uncertainty) and stock-recruit relationship.
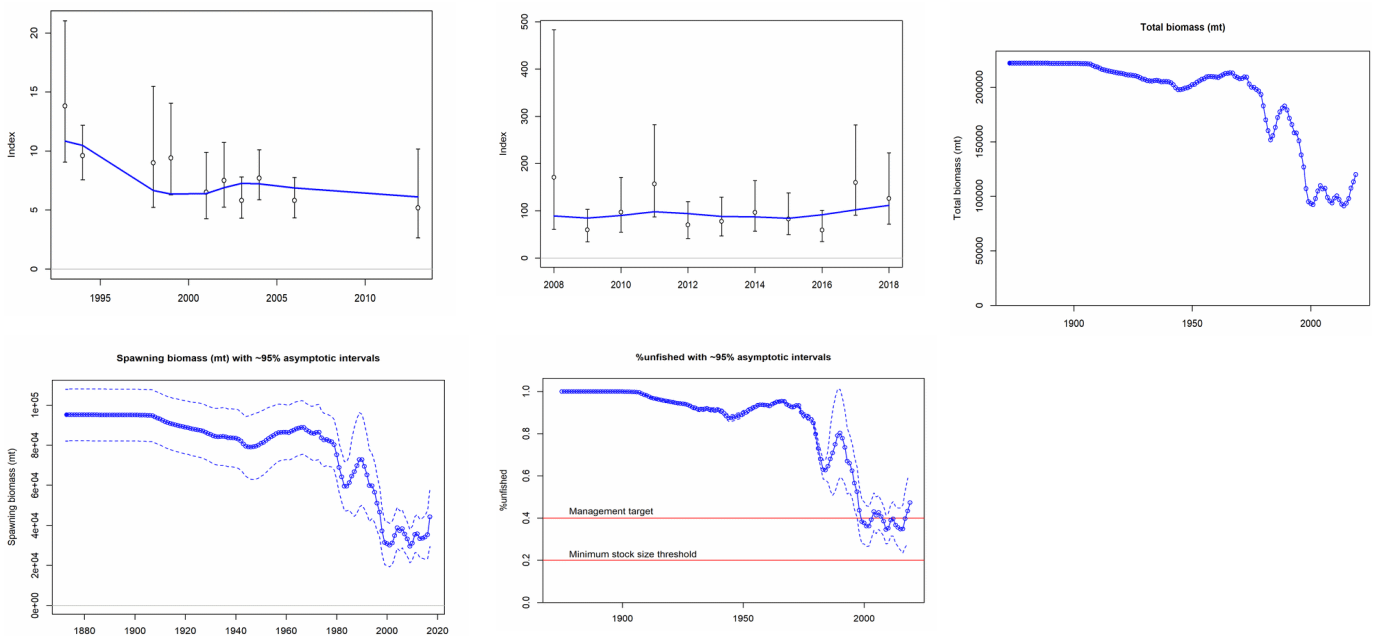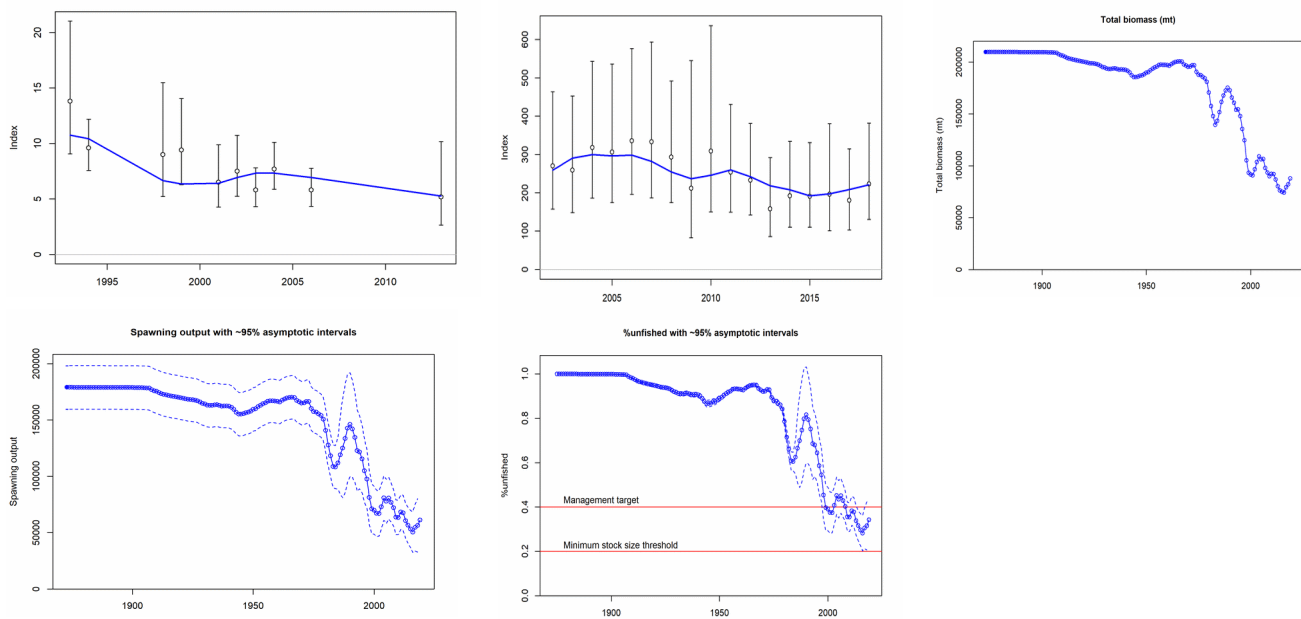

Figura 17. Model M3. Fit to the index; trend of total and spawning biomass, recruitment (with associated uncertainty) and stock-recruit relationship.

Figura 18. Model M4. Fit to the index; trend of total and spawning biomass, recruitment (with associated uncertainty) and stock-recruit relationship.

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Figura 19. Model M5. Fit to the index; trend of total and spawning biomass, recruitment (with associated uncertainty) and stock-recruit relationship

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The total biomass in 2018 resulting from the application of the integrated stock assessment models with the different indices of abundance were estimated between 84.704 and 87.444 tons and the spawning biomass between 58.626 y 60.137 tons. The ratio between the spawning biomass in 2018 and the virgin spawning biomass varied between 0.21 and 0.40 according to the index use (Table 4).

Table 4. Main results obtained from the fit of the integrated models. *h*: 'steepness' of the stock–recruit relationship; Biomass final year (B$_{2016}$), Virgin Biomass (VB), Spawning Biomass final year (SSB$_{2018}$), Virgin Spawn Biomass (SSBV), Depletion: relationship between SSB$_{2018}$/SSBV, f$_{2018}$: proportional factor of the annual fishing mortality rate in 2018 for each of the models.

Model	M1	M2	M3	M4	M5
	CPUE A kg/day kg/h_vms Research vessel surveys indices		CPUE A kg/h_vms Research vessel surveys indices	CPUE A kg/ day Research vessel surveys indices	CPUE U kg/h Research vessel surveys indices
	h=0,8	h=0,7	h=0,8	h=0,8	h=0,8
VB	211.403	222.063	221.991	206.125	209.555
B$_{2018}$	87.444	84.704	113.218	74.449	82.067
SSBV	180.525	189.628	189.567	176.018	178.948
SSB$_{2018}$	60.137	58.626	82.132	50.031	56.435
B$_{2018}$/VB	0,41	0,38	0,51	0,36	0,39
SSB$_{2018}$/ SSBV	0,33	0,31	0,43	0,28	0,31
f$_{2018}$	0,21	0,21	0,15	0,25	0,22

Risk analysis and biomass projections

Surplus production model

Projections of total biomass from 2019 to 2033 at constant catch are presented in Figure 20. For all catches considered the total biomass estimated with the Argentinean indices remains above the PBRO. While with the Uruguayan CPUE fit, with catches greater than 19,000 t the biomass would fall below the B$_{MSY}$. With catches of 17,000 t, a long-term recovery of the biomass is observed in this case.
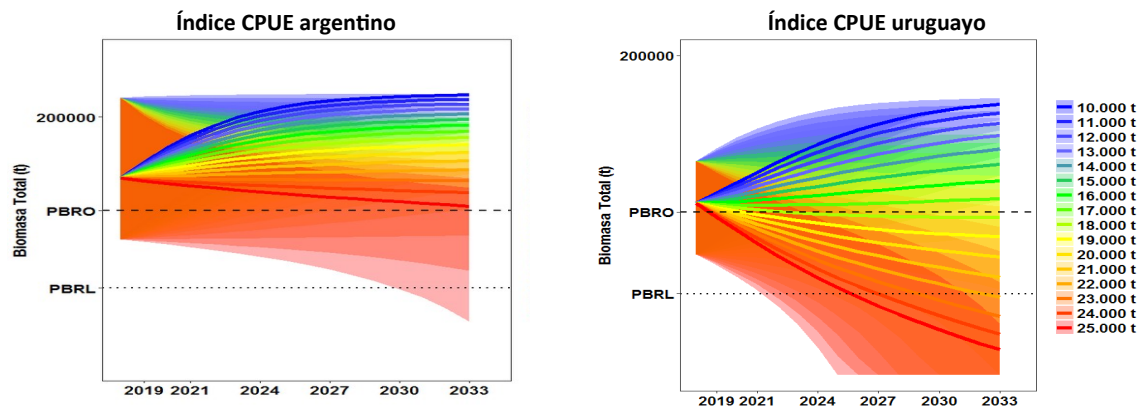
Figure 20. Total biomass values projected for striped weakfish. Constant catch,

Projections made with different fishing mortality rates indicate that levels of F less than or equal to the F$_{MSY}$ allow the biomass to reach its optimum level in the long term (Figures 21 and 22). It is this level of catch that determines a risk of 0.5 of exceeding the PBRO associated with the biomass in the mid-term. The catches associated with MSY (0.18) ranged from 21,998 to 19,944 ton in the projected period.
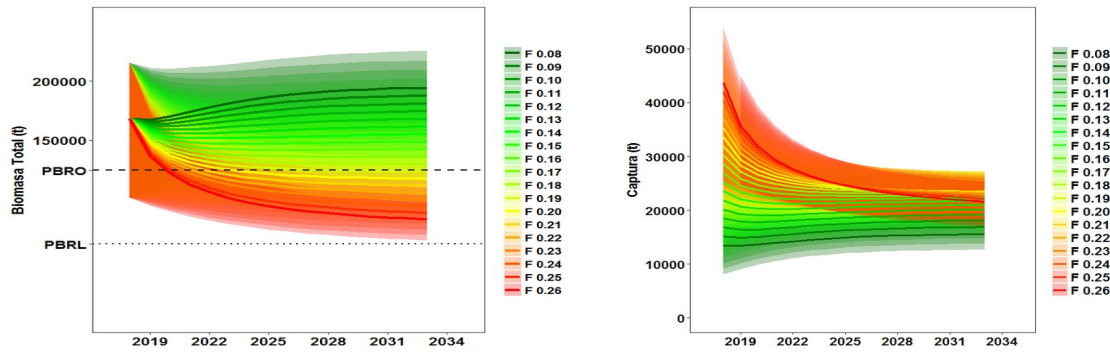
Figure 21. Argentine CPUE $_{VMS}$ indice. Projections of total biomass and trend of catch at constant exploitation rate (between 0.10 and 0.26).
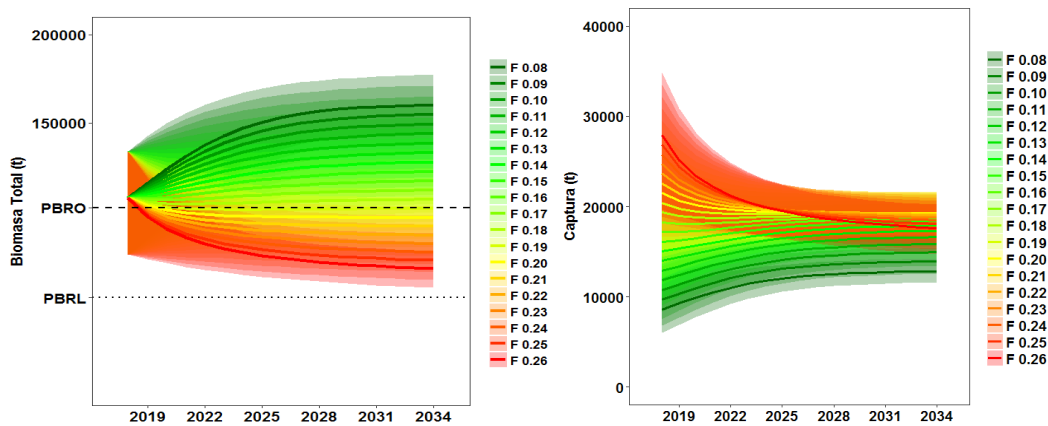

Figura 22 Uruguayan CPUE indice. Projections of total biomass and trend of catch at constant exploitation rate (between 0.10 and 0.26).

2. Age – structured model

Based on the results of the stock assessment, projections of abundance and yields were made under a long-term management objective that allows reaching an abundance of reproductive equal to or greater than 30% of the spawning biomass existing at the beginning of the exploitation (virgin spawning biomass, SSBV).

To measure sustainability in the long term (15 years), different extraction levels were simulated, based on different factors that multiply the selection pattern to obtain instantaneous fishing mortality rates by age.

In order to measure the risk, simulations were carried out starting from the state of the resource at the beginning of 2018. The proportionality of the annual fishing mortality rate, the total biomass, the number of individuals by age, the weight by age to start of the year, the average weight by age and the selection pattern resulting from the adjustment of the model. The spawning biomass and the mean, minimum (R_{min}) and maximum (R_{max}) recruitment value of the whole period were also used. Uncertainty was incorporated into the analysis by randomly generating recruitment values in each simulation, based on the mean value and deviation estimated in the diagnosis under the assumption of a LogNormal distribution. In this way, the CBA is determined, which allows the population to be kept at such levels that the risk of reaching the PBRO defined above is lower than 10% and 50%.

The projections at constant fishing mortality from the different models and series used with the associated uncertainty are presented in Figure 23.
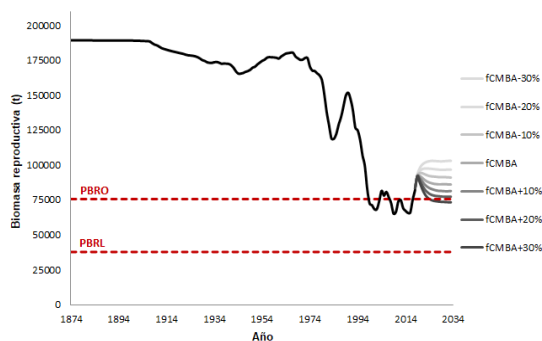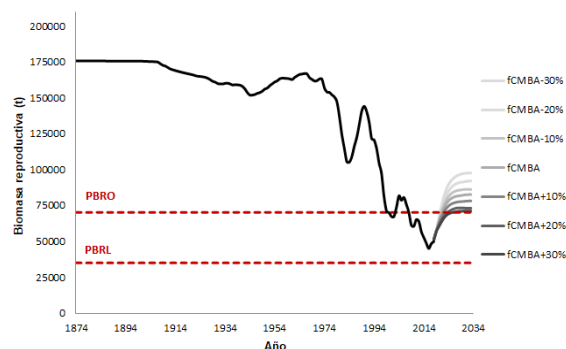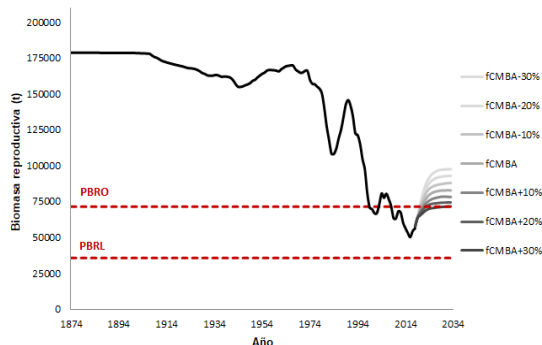
Model 1
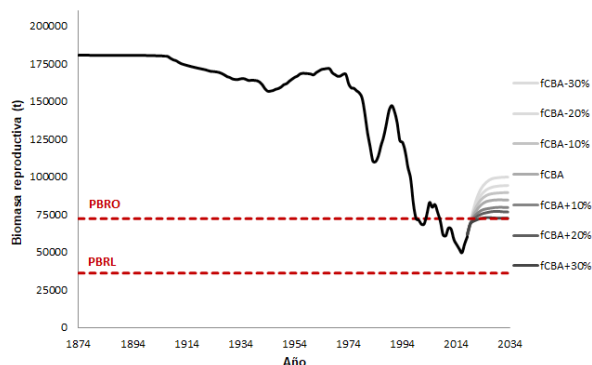
Model 2
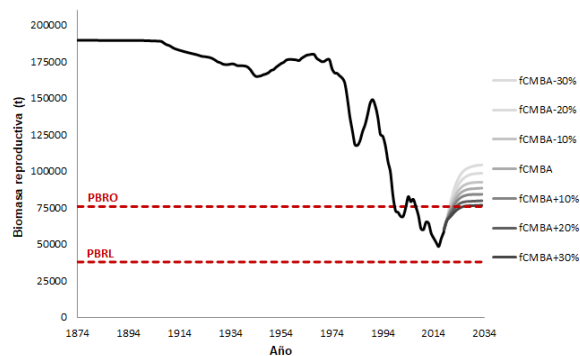
Model 3

Model 4

Model 5

Figure 23. Projections of spawning biomass trends from Models 1 to 5 applying the fishing mortality rate associated with the estimate of CBA (f $_{CMBA}$) and increases and decreases of 10, 20 and 30% of this value.

Kobe plot

Even with the variability in the CBA estimates obtained by the different models, which showed a recovery of the resource, a catch of 19,000 t would allow the stock to be maintained at a biomass level close to or higher than the PBRO. Under this exploitation scenario, in some cases, the F values would be higher than those associated with the PBRO, but lower than those corresponding to the PBRL. The projections at constant F associated with this catch value are presented for the age-structured models (Figure 24) and for the global model-adjusted cases (Figure 25).
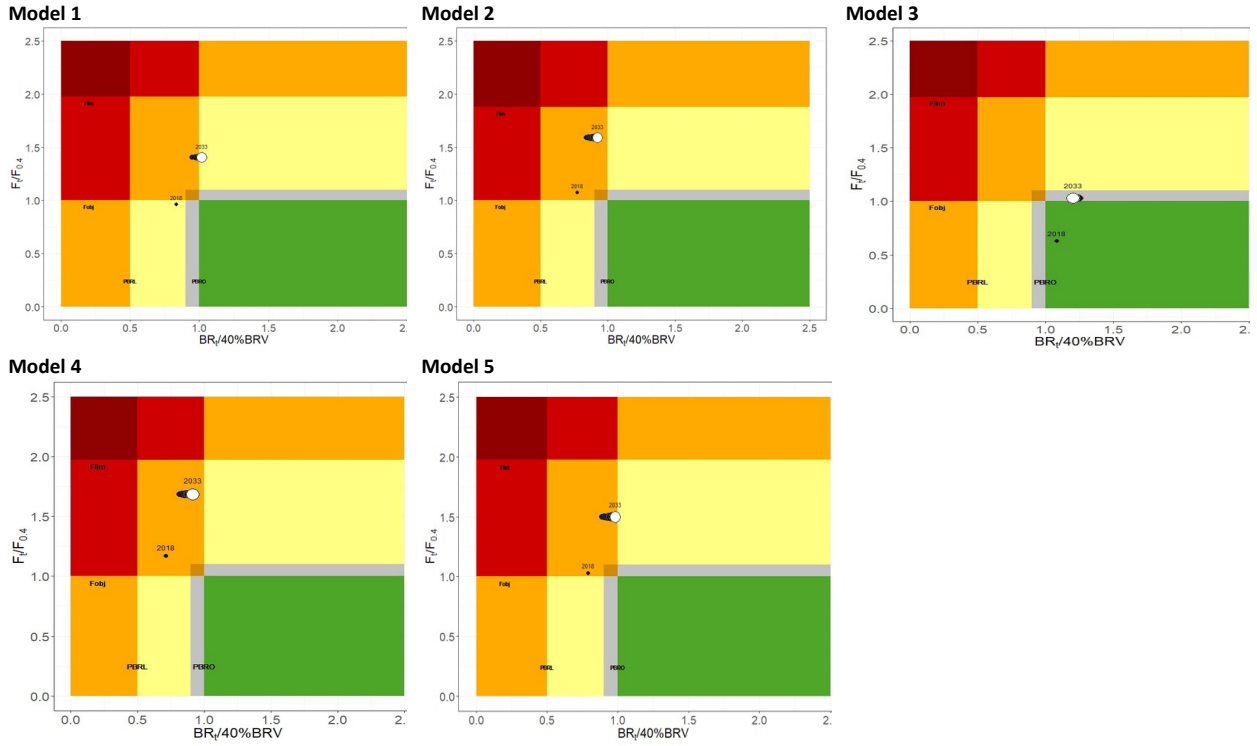
Figure 24. Kobe plot. Projections associated with the scenario of constant f equal to f corresponding to 19,000 t of catch in 2019. The points correspond to the population status in the initial and final year of the projection.
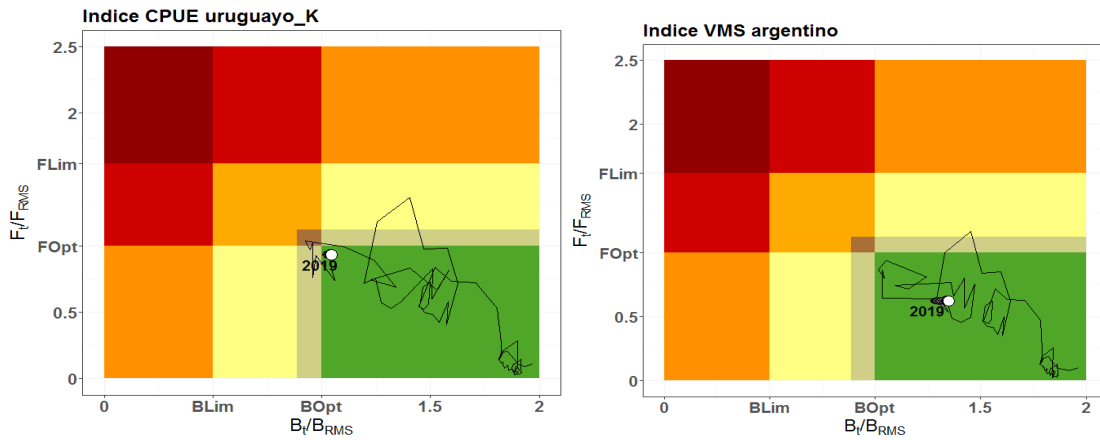

Figure 25. Kobe plot. Projections associated with the scenario of constant f equal to f corresponding to 19,000 t of catch in 2019.

Synthesis of the results and management

After reviewing the different abundance series available and assess the different models and fits, the GT- COSTERO agreed to base the recommendations on CBA for the establishment of TACs for stripped weakfish in 2019 and 2020, in the values presented in the table follow:

CBA 2019-2020

	Age – structured model *										Surplus production model **	
Model***	M1		M2		M 3		M 4		M5		M4a	M5a
Risk	10%	50%	10%	50%	10%	50%	10%	50%	10%	50%	**50%**	**50%**
2019	15.575	19.765	13.784	17.655	12.957	16.599	21.344	25.780	14.641	18.368	27.082	24.815
2020	16.385	19.926	14.72	18.149	14.187	17.416	21.076	24.682	15.679	18.847	25.688	24.133

	M1	M2	M3	M4	M5			
VB	211.403	222.063	221.991	206.125	209.555	B_{2019}	168.000	112.200
B_{2018}	87.444	84.704	113.218	74.449	82.067	B_{MSY}	124.600	102.100
SSBV	180.525	189.628	189.567	176.018	178.948	B_{2019}/B_{MSY}	1,336	1,088
SSB_{2018}	60.137	58.626	82.132	50.031	56.435	B_{2019}/K	0,6678	0,5442
B_{2018}/VB	0,41	0,38	0,51	0,36	0,39	F_{2018}	0,1029	0,1409
$SSB_{2018}/SSBV$	0,33	0,31	0,43	0,28	0,31	F_{MSY}	0,1931	0,1929
f_{2018}	0,21	0,21	0,15	0,25	0,22			

* Biomass final year (B_{2018}), Virgin Biomass (BV), Spawning Biomass final year (SSB_{2018}), Virgin Spawning Biomass (SSBV).
** Surplus model: Maximum Sustainable Yield (MSY), Fishing mortality at MSY (F_{MSY}), Biomass at MSY (B_{MSY}), carrying capacity (K)

Current management measures

- Resolución CTMFM Nº 5/99 Pescadilla. Norma estableciendo talla mínima de desembarque
- Resolución CTMFM Nº 10/00 (Modifica Art. 1 Resol. 7/97). Corvina, pescadilla y otras especies demersales. Norma modificando eslora máxima/total de buques autorizados a operar en un sector de la Zona Común de Pesca.
- Resolución Conjunta CARP-CTMFM Nº 02/06. Norma estableciendo criterios a tener en cuenta para la investigación de los recursos corvina y pescadilla, a fin de dictar las resoluciones de manera conjunta que sean convenientes.
- Resolución Conjunta CARP - CTMFM Nº 01/19. Norma estableciendo la captura total permisible para la especie pescadilla (*Cynoscion guatucupa*) en el área del Tratado para los años 2019 y 2020, en el área geográfica del Tratado del Río de la Plata y su Frente Marítimo.

Trade

The stripped weakfish is marketed fresh in the domestic market and frozen in the external.

Argentine stripped weakfish exports between 2011 and 2015 averaged 14,800 tons and remained relatively stable until 2015. Although the lowest export volume was recorded in 2016 (7,989 tons), from that year onwards, a slight increase begins to reach 9,633 tons in 2019. The contribution of whiting to total exports of fishery products did not exceed 3.5% between 2011 and 2019 (Figure 26).

The average price per ton of Argentine exports of stripped weakfish fell between 2011 and 2019, reaching values, expressed in US dollars (USD) FOB, of 1,424 and 1,407, respectively. In 2011, stripped weakfish exports had a value of USD 19,049,000, equivalent to 1.3% of the total exported in fishery products while, in 2019, the exports value (USD 13,555,000) it contributed 0.72% to the total exported.
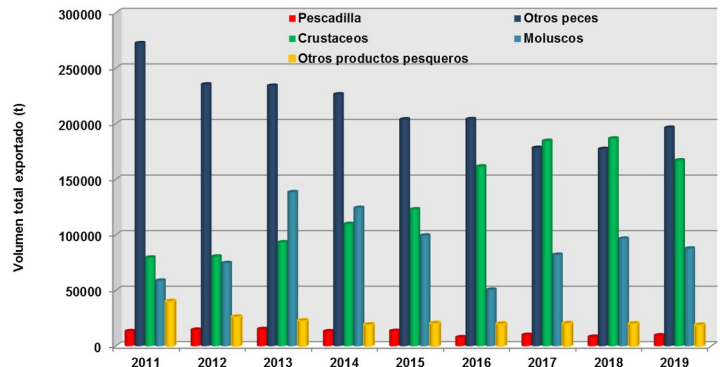

Figure 26. Stripped weakfish contribution to the total volume (t) of fishery products exported by Argentine between 2011 and 2019.

The main destinations of Argentine exports of stripped weakfish in 2019 were Cameroon, China and USA, which together account for almost 77% of the total exports. The export volumes, price and destination of each of these products vary as indicated in the report prepared by the *Dirección de Economía Pesquera de la SSPyA* of Argentine. For example, whole stripped weakfish was exported mainly to Cameroon (6,809 tons at an average price of USD 1.274) while frozen fillets were exported to the USA (578 tons, average price USD 3,067) [link 18].

The *Boletín Estadístico Pesquero* prepared by [DINARA] from data from the *Dirección Nacional de Aduanas del Uruguay*, indicates that, as of 2012, the stripped weakfish decreased to the contribution of exports from the fishing sector as a whole from 6 to 3 % in 2014. This is equivalent to a decrease in export volume from 4,877 to 1,999 tons respectively (Figure 27). In 2012, the export of this species had a value of USD 8,060,000 while in 2015, this value decreased to USD 2,741,000. From that year, it increases systematically to reach 3,545 tons exported at a value of USD 5,336,000 in 2018.
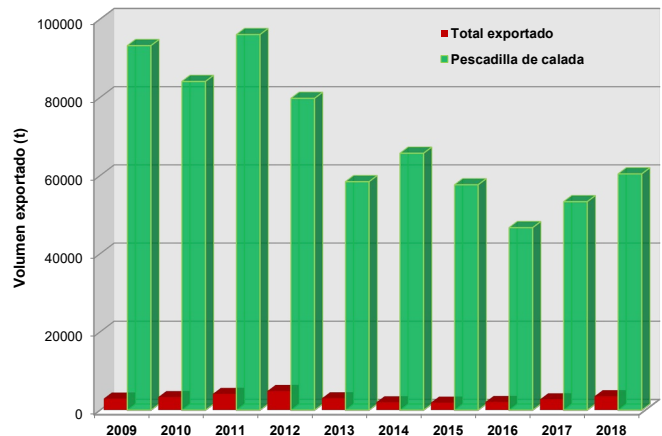

Figure 27 Stripped weakfish contribution to the total volume (t) of fishery products exported by Uruguay between 2009 and 2018.

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