SPATIAL CO-OCCURRENCE OF TWO SCIAENID SPECIES (*Micropogonias fuernieri* AND *Cynocion guatucupa*) SUBJECT TO FISHING IN THE RÍO DE LA PLATA AND OCEANIC COAST OF URUGUAY: ECOLOGICAL OR TECHNOLOGICAL INTERDEPENDENCE?

Walter NORBIS [1,2] and Oscar GALLI [1]

ABSTRACT

The whitemouth croaker (*Micropogonias furnieri*) and striped weakfish (*Cynoscion guatucupa*) are the most important resource of coastal fisheries in the Southwest Atlantic Ocean and particularly in the Rio de la Plata estuary. The aim of this study is to analyze the spatial and temporal co-occurrence of both species in relation to density estimates, length structure and immature-mature individuals using research vessel data from the spring of 1991-1995 and 2007. A positive tendency for co-occurrence and species overlap occurred in more than 53% of fishing trawls, either significantly or with predominance of whitemouth croaker or striped weakfish. Differences between the spatial distributions of both species during the spring in the study area were found for all years with the exception of 1992, a supposed consequence of increased river discharge related to El Niño/Southern Oscillation (ENSO) effects. In fishing hauls where significant species overlap occurred, length composition showed that whitemouth croaker adults spatially co-occurred with juveniles of striped weakfish. The nonrandom spatial segregation of both species as consequence of habitat heterogeneity and differential feeding habits did not support the ecological interdependence hypothesis. Rather, according to the trawler fleet that operates and directs the fishing effort directed towards these two target species, there may be evidence of technological interdependence. Fishing trawls may affect different length classes with different environmental requirements at different stages of their life history. These aspects should be considered when weighing different fisheries management options, related to the spawning areas and genetic management units of both species.

Keywords: *Whitemouth croaker; striped weakfish*; industrial fisheries; Río de la Plata estuary

CO-OCORRÊNCIA ESPACIAL DE DUAS ESPÉCIES DE SCIAENIDOS (*Micropogonias fuernieri* E *Cynoscion guatucupa*) SUJEITAS À PESCA NO RÍO DE LA PLATA E COSTA OCEÂNICA URUGUAIA: INTERDEPENDÊNCIA ECOLÓGICA OU TECNOLÓGICA?

RESUMO

A corvina (*Micropogonias furnieri*) e a pescada-olhuda(*Cynoscion guatucupa*) são os recursos mais importantes das pescas costeiras do OceanoAtlântico Sudoeste, em particular, no estuário do Rio de la Plata.O objetivo deste estudo foi analisar a co-ocorrência espacial e temporal de ambas espécies em relação às estimativas de densidade, estrutura de comprimento e indivíduos imaturos e maduros, usando dados de cruzeiros de pesquisa realizados entre a primavera de 1991 e 1995, e 2007. A tendência de co-ocorrência foi positiva, e a superposição das duas espécies ocorreu em mais de 53% dos lances de pesca, ora significante ou com predominância da corvina ou da pescada-olhuda. Foram encontradas diferenças significativas entre a distribuição espacial das duas espécies durante a primavera, na área de estudo, exceto para o ano 1992, supostamente como consequência do aumento da descarga de água doce, efeito do fenômeno El Niño/Oscilação Sul (ENOS). Nos lances de pesca onde ocorreu uma sobreposição destas duas espécies, a composição de tamanhos mostrou adultos de corvina co-ocorrendo com juvenis de pescada-olhuda. A segregação espacial destas duas espécies, que não se dá ao acaso, consequência da heterogeneidade de habitat e das diferenças de hábitos alimentares, não suporta a hipótese de interdependência ecológica. Em vez disso, de acordo com a frota de arrasteiros que opera e se dirige à captura destas duas espécies, podem haver evidências de interdependência tecnológica. Os arrastos de pesca podem estar tendo diferente efeito sobre diferentes classes de tamanho, com requerimentos ambientais distintos em

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[1] *Departamento de Biología Poblacional, Dirección Nacional de Recursos Acuáticos (DINARA), Ministerio de Ganadería Agricultura y Pesca (MGAP) - Constituyente 1497 – PC-11200 – Montevideo – Uruguay*

[2] *e-mail: wnorbis@dinara.gub.uy (correspondence author)*

diferentes momentos da sua história de vida. Estes aspectos devem ser considerados quando se comparam diferentes medidas de manejo pesqueiro, relacionadas às áreas de desova e a unidades genéticas das duas espécies.

Palavras chave: *Corvina;* pescada-olhuda; pesca industrial; estuário Río de la Plata

INTRODUCTION

Fish communities are an important organizational level to consider in resource assessments because they are directly impacted by fishing. Many species within the community are directly targeted by fishing activities while others are affected indirectly as by-catch and discard (ROCHET and TRENKEL, 2003).

A holistic approach to fisheries management involves assessment of ecological and technological interdependencies, as well as the influences of the physical environment. An ecological interdependence is defined by the occurrence of a competitive or predator-prey relationship between two stocks (or species) (ANDERSON, 1975a, b; MITCHELL, 1982; MESTERTON-GIBBONS, 1996; SEIJO *et al.*, 1997). A technological interdependence occurs when fleets with different fishing power and/or wear types operate on different components of a single stock or on different target species, affecting their abundance in a dissimilar form (HUPPERT, 1979; MAY,1984; CLARK, 1985).

The whitemouth croaker is a demersal benthic marine species that is widely distributed along the western Atlantic coast from Mexico (20ºN) to Argentina (41ºS) (ISAAC, 1988). It is a multiple spawner that spawn in the inner part of the Rio de la Plata estuary and Uruguayan Atlantic coast from October to March (Austral spring-summer) (MACCHI *et al*., 1996; 2003; VIZZIANO, 2002).

The striped weakfish is a demersal bentho-pelagic fish found in South American Atlantic waters with a distribution ranging from Rio de Janeiro (22º54´S), Brazil, to northern Patagonia, Argentina (43ºS) (COUSSEAU and PERROTTA, 2004; MENEZES *et al*., 2003). The striped weakfish is a partial spawning species (CASSIA, 1986; MACCHI, 1998) that spawns in the spring-summer in the ocean off the coast of Punta del Este (35º15'S – 54º50'W), Uruguay (MACCHI, 1998; MILITELLI and MACCHI, 2006). Juveniles occur in high densities in the coastal zone of the Uruguayan shelf (RUARTE *et al*., 2005).

Two species may not interact by displaying different habitat preferences or colonizing different sites independently. Species co-occurrence patterns and habitat heterogeneity could explain non-random species spatial distribution (ULRICH, 2004). Fish assemblages in the Rio de la Plata estuary and Uruguayan Atlantic coast are comprised of species that may have different environmental requirements (JAUREGUIZAR *et al*., 2003; 2004; LORENZO *et al*., 2011). Two dominant species of sciaenid fishes, the whitemouth croaker (*Micropogonias furnieri*) and striped weakfish (*Cynoscion guatucupa*) may be considered as co-occurring as they are both found in variable abundance in species assemblages in this region (LORENZO *et al*., 2011). Total fisheries production from the coastal regions of South Brazil, Uruguay and Argentina (depths<50 m) is principally comprised of three sciaenid species: whitemouth croaker, striped weakfish and argentine croaker (*Umbrina canosai*) (VASCONSELLOS and HAIMOVICI, 2006; NORBIS *et al*., 2006; VILLWOCKDE MIRANDA and HAIMOVICI, 2007). The whitemouth croaker and the striped weakfish represented by landing of more than 30,000 tons per year in the last 10 years for Uruguayan and Argentinean fisheries (CAROZZA *et al*., 2004; RUARTE *et al*., 2004; NORBIS *et al*., 2006).

The degree of spatial and temporal co-occurrence in the Río de la Plata region would determine whether fishing activity targeting the whitemouth croaker also result in the catch of striped weakfish. Whitemouth croaker fishing occurs year – round until reaching an annual catch quota established by the Joint Technical Commission for the Maritime Front (Argentina – Uruguay). When the annual catch quota is reached (generally in spring, October – December) the industrial fishing fleet change the target species (to striped weakfish), according to market demand. In turn, fishing activity directed at the striped weakfish during the spring may also affect the whitemouth croaker. In the region there is no background to analyze two species that are captured by the same fleet and can change as the target species. The aim of this study is to analyze the spatial and temporal co-occurrence of whitemouth croaker and striped weakfish, in the Rio de la Plata estuary (Southwest Atlantic Ocean), in order to evaluate the ecological or technological interdependencies, and analyse the length structure and size at maturity during spawning season of both species.

MATERIALS AND METHODS

Individuals of the whitemouth croaker (*M. furnieri*) and striped weakfish (*C. guatucupa*) were collected off the Uruguayan oceanic coast and in the Río de la Plata estuary during research cruises aboard the R/V "Aldebarán" (operated by DINARA, Uruguay) in the spring (October to December) of 1991-1995 and 2007 (Figure 1), to verify the spatial consistency of species distributions during the spring and to test if their distribution patterns were maintained after 12 years. Trawl stations were placed using a stratified random sample design, defined by depth and latitude (EHRHARDT *et al.*, 1977). At each sampling location, a 30 min haul was conducted at a towing speed of approximately 3 knots during daylight. A high-opening 'Engel' type net with a100 mm (stretched mesh) cod end was used. We recorded date, geographic position, depth, total catch weight and number of individuals for each species. For each individual fish, total length (TL) was measured to the nearest centimeter and maturity stages were determined macroscopically according to a maturity key adopted from VIZZIANO (2002) for sciaenid fishes.

In order to compare the catch of whitemouth croaker and striped weakfish only hauls with both species were considered for analyses and the data were transformed logarithmically. Trends of co-occurrence between the catch of two species were analyzed using the reduced major axis (RMA) method, considering the major axis (first eigenvalue) as a measure of trend (LEGENDRE and LEGENDRE, 2012). This method measures the variability along the major and minor axes, and was considered the most appropriate given the dispersion characteristics of the data. The percentage of overlap between species for each year was analyzed using the Schoener index (SCHOENER, 1970), which ranges from 0 (no overlap) to 1 (total overlap). Species overlap is considered to be significant when the index value exceeds 0.6 (WALLACE, 1981).

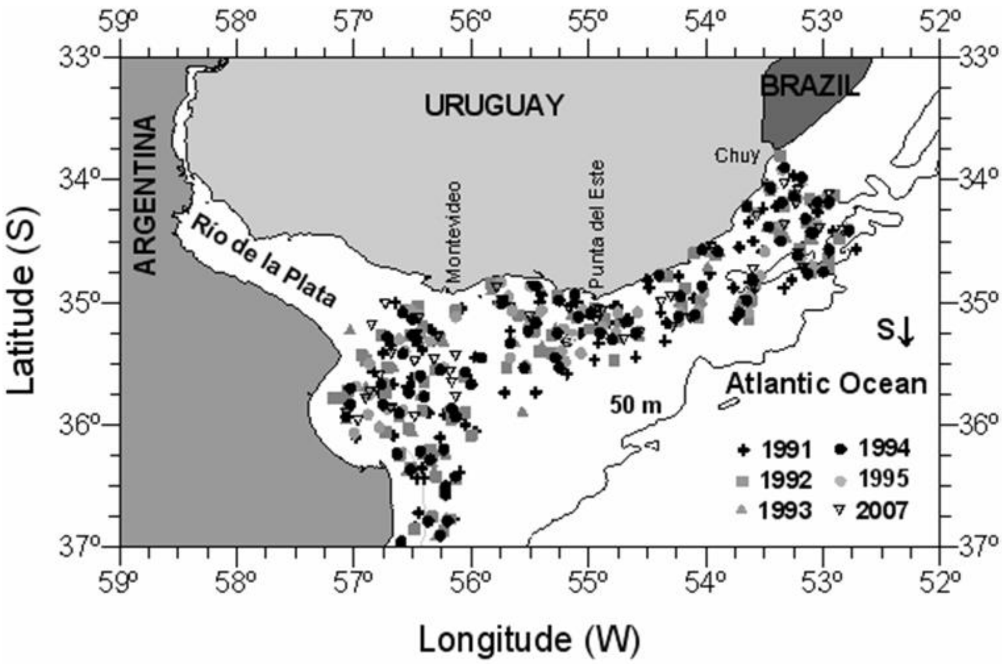

Figure 1. Map of the study area showing bathymetric contours and the research fishing trawls realized by R/V "Aldebarán" in spring.

Syrjala's test (SYRJALA, 1996) was used for analysed the spatial association between species. The null hypothesis predicts no difference in the distribution of the two species across the study area, while the alternative hypothesis predicts an unspecified difference between species in their underlying distributions (SYRJALA, 1996). Syrjala's test is a randomization test based on the Cramer von Mises statistic extended to bivariate distributions. The Syrjala test implemented by DELA CRUZ (2008) was performed by using the R software, Version 2.11.1 (R DEVELOPMENT CORE TEAM, 2010).

To compute size-at-maturity (*i.e.,* size at which 50% of the sampled individuals of each species were mature; T_{L50}), a logistic model was fitted to the binomial dataset (immature = 0, mature = 1) as:

$$y = \left[1 + e^{(\beta_0 + \beta_1 x)}\right] - 1,$$

where:

y was the percentage of mature individuals and *x* the TL class; $\hat{\beta}_0$ and $\hat{\beta}_1$ parameters estimated by maximum likelihood.

T_{L50} was calculated as (KING, 2007):

$$T_{L50} = \frac{-\hat{\beta}_0}{\hat{\beta}_1}$$

The analytical 100(1-α)% confidence interval was defined by:

$$\frac{1}{\beta_1}\left(-\beta_0 \pm z_{\frac{\alpha}{2}} \upsilon(T_{L50})\right)$$

where:

$z_{\alpha/2}$ is a quantile of the normal distribution and υ is the square root of the analytical variance of the logit link function (ROA *et al.*, 1999). The median maturity TL was used to separate immature (< T_{L50}) and mature (≥ T_{L50}) individuals.

RESULTS

All of the first eigenvalues were positive coefficients and explained more than 68% of the total variability for the co-ocurrence between species, except for the spring 1991 (Table 1). Thus, the relationship between catch of the whitemouth croaker and striped weakfish showed a positive tendency for most years (Figure 2). However, the determination coefficient (r^2) values were low and the catches of striped weakfish explain little the catches of whitemouth croaker (Table 1).

Table 1. Eigenvalues (λ),percentage of variance explained for each eingenvalue, correlation coefficients (r) and determination coefficient (r^2) for the relationship between logarithm of whitemouth croaker and striped weakfish research fishing trawls catches.

Years	λ_1	λ_2	$\%\lambda_1$	$\%\lambda_2$	r	r^2
1991	2.10	1.56	57.37	42.63	0.21	0.05
1992	3.03	0.92	76.70	23.29	0.48	0.23
1993	3.55	1.34	72.60	27.39	0.22	0.05
1994	3.14	1.44	68.62	31.38	0.20	0.04
1995	3.72	1.21	75.40	24.60	0.23	0.07
2007	4.06	0.91	81.66	18.34	0.42	0.18

For all years analyzed for both species, temporal consistency in spatial distribution was found. The percent of total fishing hauls that captured only whitemouth croaker or striped weakfish were 13-37% and 6-22%, respectively (Table 2). Fishing hauls in which only whitemouth croaker was caught usually occurred in the Rio de la Plata estuary and occasionally outside the coastal area off Punta del Este. However, fishing hauls without whitemouth croaker present (*i.e.,* only with striped weakfish) were restricted to the East of the study area, between 34º and 35ºS at depths below 50 m.

According to the Schoener index, species overlap occurred in more than 53% of fishing trawls, significantly (values greater than 60%) or with predominance of whitemouth croaker or striped weakfish (Table 2).

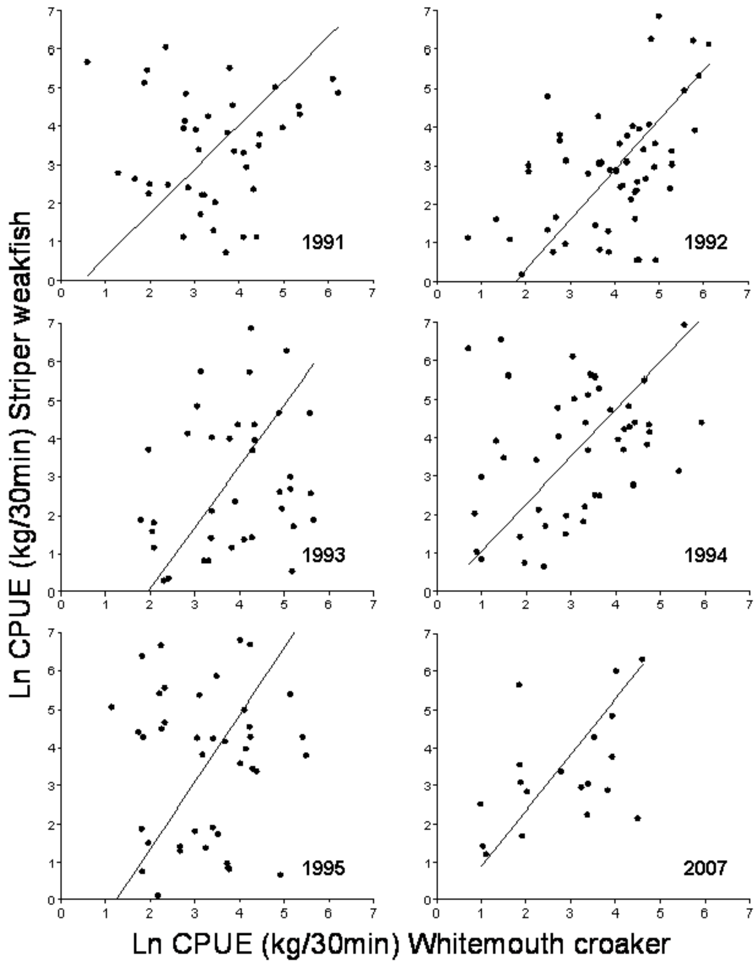

Figure 2. Biplot of co-occurrence of the two species by hauls and trend lines determined by the first eigenvalue of reduced mayor axis method.

Table 2. Number of fishing hauls (NFH) by years for Spring and percentage of hauls with significantly overlap, with predominance of whitemouth croaker or striped weakfish, and with the presence of only one species.

Year	NFH	Significant overlap	Predominance of whitemouth croaker	Predominates of striped weakfish	Only whitemouth croaker	Only striped weakfish
1991	75	29.3	12.0	12.0	37.3	9.3
1992	84	27.4	34.5	4.8	21.4	11.9
1993	77	15.6	24.7	9.1	37.7	13.0
1994	80	25.0	13.8	20.0	28.8	12.5
1995	65	20.0	21.5	21.5	30.8	6.2
2007	55	29.1	27.3	9.1	12.7	21.8

The significant overlap and the overlap with a predominance of either species covered a large area of the Rio de la Plata estuary as well as the Uruguayan oceanic coast between Punta del Este and Chuy at depths <50 m (Figure 3). The spatial distribution of whitemouth croaker and striped weakfish in the study area (Syrjala's test) significantly differed among the springs of 1991, 1993, 1994, 1995 and 2007, but was similar for 1992 (Table 3).

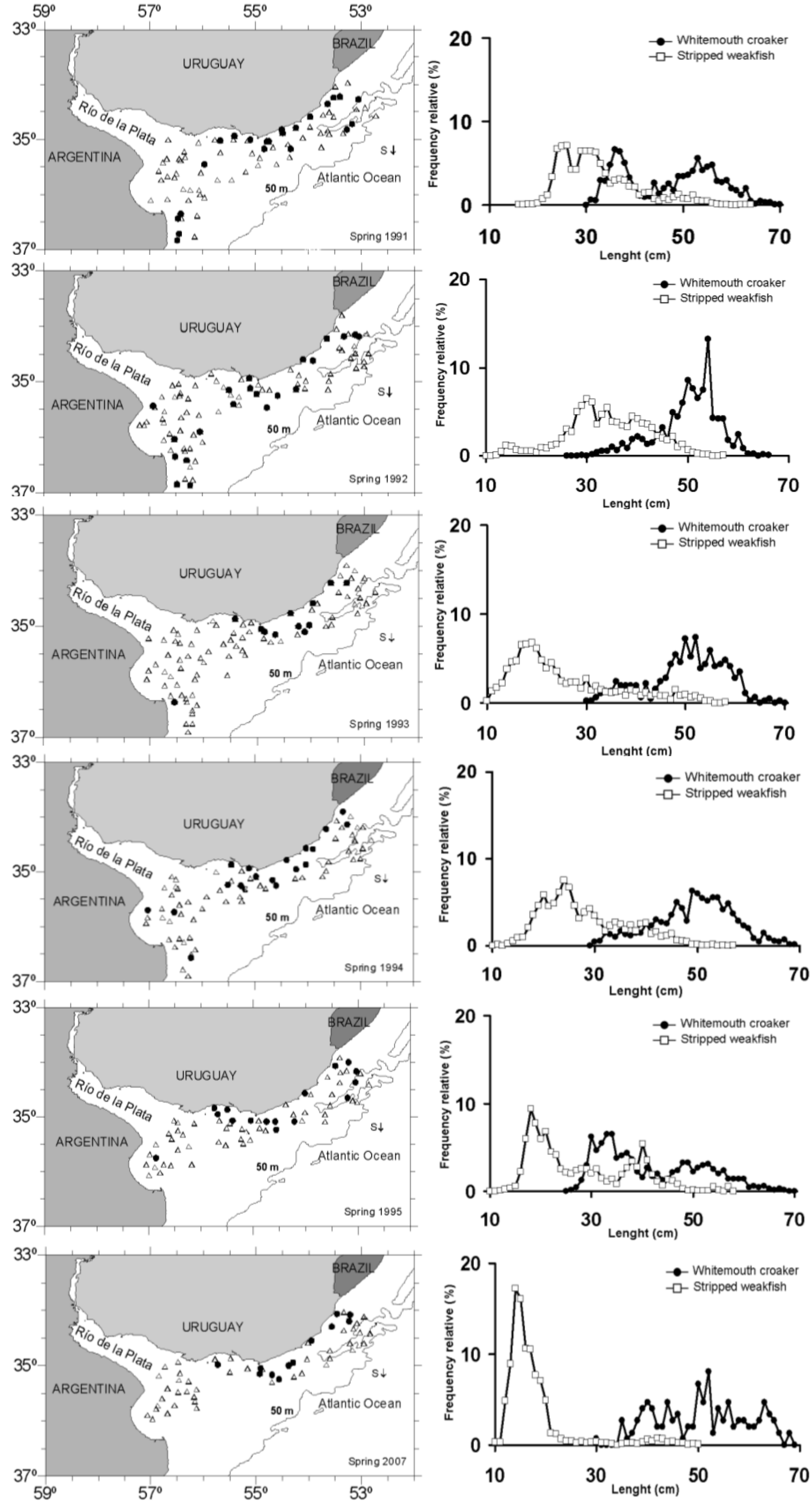

Figure 3. Spatial distribution of research fishing trawl and length composition of whitemouth croaker and striped weakfish for significant fishing trawl overlap for spring (years: 1991 to 1995 and 2007) (dark point: significant overlap; triangle: non significant overlap).

Table 3. Results of Syrjala´s test (Ψ) for spatial distribution of species (*= significant differences).

	Ψ	p
Spring 1991	4.66	0.01*
Spring 1992	0.29	0.40
Spring 1993	6.73	0.03*
Spring 1994	5.88	0.03*
Spring 1995	5.17	0.01*
Spring 2007	6.27	0.03*

The size-at-maturity calculated for each species varied from 31.9 to 35.9 cm TL for whitemouth croaker and 29.9 to 34.5 cm TL for striped weakfish (Table 4). In 2007, the size at maturity is smaller for both species (Table 4). Length composition for fishing hauls where significant species overlap occurred showed that adults of whitemouth croaker (principally individuals >32 cm TL - mature individuals) spatially co-occurred with juveniles of striped weakfish (principally less than 29 cm TL) (Figure 3 and 4), except in the spring of 1991 and 1992 (Figure3).

Table 4. Size-at-maturity (cm) and confidence interval calculated by species by year for spring.

Year	Whitemouth croaker	Striped weakfish
1991	34.8 ± 0.04	31.8 ± 0.01
1992	35.9 ± 0.05	31.6 ± 0.01
1993	34.9 ± 0.04	30.2 ± 0.05
1994	34.9 ± 0.04	34.5 ± 0.01
1995	33.5 ± 0.03	30.8 ± 0.01
2007	31.9 ± 0.10	29.9 ± 0.02

DISCUSSION

A positive tendency in the co-occurrence of the whitemouth croaker and the striped weakfish and a small percentage of the catch of striped weakfish explained by the catch of the whitemouth croaker were found. In addition, there was a significant overlap between species (striped weakfish juveniles with whitemouth croaker adults) or an overlap with a predominance of either species, as well as differences between the spatial distributions of both species during the spring in the study area. Low co-occurrence could reflect habitat segregation (GOTELLI *et al.*, 1997, GOTELLI and MC CABE, 2002), and may explain why species present little overlap. The observed differences in spatial distribution support the hypothesis that these species have distinct habitat preferences and that environmental factors play an important role in habitat differentiation. Three spatially and temporally distinct fish assemblages (internal and external estuarine and inner continental shelf) were persistent over time from 1975 to 1995 (LORENZO *et al.*, 2011). The whitemouth croaker has 100% persistence in the internal estuarine assemblage, an area with most shallow waters (ranging 3 to 19 m deep), a range in temperature of 16 to 20ºC and salinity between 13.5 and 22.5. Striped weakfish typically displayed high density and persistence in the Uruguayan coastal assemblage, located on the inner continental shelf in the Uruguayan Atlantic coast at depths of 17 to 40 m, with a temperature between 12 and 18 ºC and salinity ranging from 28.9 and 33.1. Both species belong to the external estuarine assemblage with low density and high persistence (LORENZO *et al.*, 2011). The similarity found in spatial distribution in the spring of 1992 could be a consequence of strong river discharge related to El Niño/Southern Oscillation (ENSO) effects during that year. The spring-summer rainfall in the South American Atlantic is correlated with ENSO variability (DÍAZ *et al.*, 1998; MONTECINOS *et al.*, 2000). A positive trend in high rainfall levels and high river run-offs of the Paraná and Uruguay Rivers has been reported for the region (GARCÍA and VARGAS, 1998; GENTA *et al.*, 1998) correlated with negative South Oscilation Index years (El Niño), and increases in river discharge related to ENSO strongly influence salinity, turbidity, volume and temperature of the Rio de la Plata (MECHOSO and PEREZ-IRIBARREN, 1992; PISCIOTTANO *et al.*, 1994; NAGY *et al.*, 2002).

The whitemouth croaker is an opportunistic benthic predator that feeds principally on crustaceans (crabs) and polychaetes (PUIG, 1986; SANCHEZ *et al.*, 1991; MASELLO *et al.*, 2002). The striped weakfish is an opportunistic predator, with necto-pelagic and benthic habits and a diet that varies with ontogenetic development. Young fishes feed in the water column on zooplankton and, as they grow larger, the fish feed on pelagic fishes (*Engraulis anchoita, Trachurus lathami*) and crustaceans (*Peisos petrunkevitchi, Artemesia longinaris*) (LOPEZ CAZORLA, 1996; SARDIÑA and LOPEZ CAZORLA, 2005; GARCÍA, 2007). According to their feeding habits and prey types, both species may not display trophic interactions.

Whitemouth croaker have two separate spawning areas during the reproductive season, one in association with the turbidity front at the head of the salt wedge intrusion of the estuary, with low bottom salinity and warm temperatures (ACHA *et al*., 1999; MACCHI *et al*., 2003; PUIG and MESONES, 2005; JAUREGUIZAR *et al*., 2008) and the other in marine coastal waters of high bottom salinity and low temperatures (MACCHI *et al*., 2003; PUIG and MESONES, 2005). The existence of at least two genetic stocks (PEREIRA *et al*., 2009; D'ANATRO *et al*., 2011), suggests the existence of two management units in the study area. Striped weakfish spawn inshore (depth <10 m) in marine coastal waters of high bottom salinity (33-34 ups) and low temperatures (MILITELLI and MACCHI, 2006; JAUREGUIZAR *et al*., 2006; JAUREGUIZAR and GUERRERO, 2009) and the studies on morphometric and genetic differentiation for suggest that only one management unit is present in the study area (SABADIN *et al*., 2010).

Significant co-occurrence of striped weakfish juveniles and whitemouth croaker adults in marine coastal waters may be associated with similar environmental conditions. This is likely a consequence of spatial segregation among striped weakfish according to size, with nursery grounds located on the inner continental shelves along the Uruguayan Atlantic coast (EHRHARDT *et al.*, 1977, 1979; COUSSEAU *et al*., 1986; RUARTE *et al.*, 2005).

Bottom trawls by coastal fisheries affect groups of species (LORENZO *et al*., 2011), and management decisions regarding changes in target species by the fleet (*e.g.,* whitemouth croaker for striped weakfish) could have no effect on the resource to be protected. The Uruguayan trawl fleet targets the whitemouth croaker but also captures striped weakfish. If the target species were striped weakfish, this would also affect the whitemouth croaker due to the co-occurrence of both species in 60% of the fishing hauls in the study area. Research fishing hauls that were solely comprised of striped weakfish accounted for less than 15% of the total, and were principally located off the Uruguayan Atlantic coast, in correspondence with juvenile nursery grounds (RUARTE *et al*., 2005).

This study shows that there is a non-random species spatial distribution as consequence of habitat heterogeneity. Both species have a wide distribution and a tendency to co-occur. However, fishing efforts would affect different length classes with different environmental requirements, at different stages of their life history. These aspects should be taken into account when considering different management options. The whitemouth croaker fisheries in the Argentine Uruguayan Common Fishing Zone has been declared as fully exploited and closed so as to not allow increased fishing effort (MGAP- INAPE, 1997). Bottom trawling by industrial fishing within 5 nautical miles of the coastline is prohibited, with the exception of artisanal fisheries that operate with gillnets and bottom lines (NORBIS, 1995; NORBIS and VEROCAI, 2002). A shared fishing area occurs between 7 nm and 12 nm offshore, where artisanal and industrial fleets operate and has been characterized as a technological interdependence by HORTA and DEFEO (2012). Despite the trend of co-occurrence of both species, their non-random spatial distribution and difference in feeding habits do not support the hypothesis of ecological interdependence. However, the two species analyzed showed some spatial segregation and could be affected by a trawling fleet that allocates fishing effort towards these two species as target species. According to HUPPERT (1979), MAY (1984), CLARK (1985), and SEIJO *et al*., (1997), this constitutes a technological interdependence whereby a fleet catches spatially co-occurring species that are not ecologically interdependent. The control of the industrial fishing fleets, data collected from different fishing grounds with geographic and environmental homogeneity characteristic, and different fishing intensities can be employed to define optimal operational strategies and sustainable yields per unit of area (CLARK, 1982; HILBORN and WALTERS, 1987; POLOVINA, 1989; MURAWSKI and FINN, 1989; SEIJO *et al.*, 1997).

The whitemouth croaker spawning stock located on inner continental shelf in the Uruguayan Atlantic coast may not be affected by fishing trawls during the summer due to a seasonally banned area for the protection of young striped weakfish (RUARTE *et al*.,2005). To protect the genetic management units of both species, the results of this study suggests that two seasonally protected areas for spawning individuals during the spawning season (October to March) would contribute to the conservation of both species. More studies on the regional migration patterns using tagging are necessary in order to understand the distribution and dynamics of these populations and management of mixed stock fisheries.

CONCLUSIONS

Both species analyzed have a tendency to co-occur and temporal consistency in spatial distribution was found. Their non-random spatial distribution and difference in feeding habits do not support the hypothesis of ecological interdependence. However, both species could be affected by a trawling fleet that allocates fishing effort towards these two species as target species. In this sense the trawling coastal fisheries in the Argentinean – Uruguayan Fishing Common Zone constitutes a technological interdependence.

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