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The artisanal fishery of *Cynoscion guatucupa* in Argentina: Exploring the possible causes of the collapse in Bahía Blanca estuary

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ABSTRACT

Cynoscion guatucupa Cuvier 1829 is a migratory pelagic fish species, which has a wide geographical distribution. It is the most important fishing resource for local communities in Bahía Blanca estuary and has been captured by artisanal fishermen since the 1900s. The industrial fleet has been fishing this species in the coastal area of Buenos Aires province since the 1950s, and, since 1970, landings have increased sharply. Between 2000 and 2004, the artisanal fishery in the estuarine waters of Bahía Blanca collapsed. Variations in total landings of the artisanal fleet might have arisen from the environmental variables within the estuary, fishing activity in the surrounding sea region, local pressure within the estuary and/or several other variables. Our results suggest that neither oceanographic parameters nor local pressure seem to have influenced the artisanal fishery of *C. guatucupa* in the estuarine region. Instead, this fishery seems to have been partially influenced by the increasing fishing pressure exerted by the industrial fishing fleet operating in open waters around the estuary. This study emphasizes the need to take into account fisheries data from both the estuarine environment and the surrounding sea region, particularly when designing management plans for the sustainable use of migrating fish resources.

1. Introduction

The striped weakfish, *Cynoscion guatucupa* Cuvier 1829, is a pelagic fish species, which has a wide geographical distribution, extending from Río de Janeiro (22°S) in Brazil, to the San Matías Gulf (43°S), in Argentina (Cousseau and Perrotta, 1998). This fish feeds on crustaceans on its early stages, and its diet shifts to pelagic fish as it develops into adulthood (Lopez Cazorla, 1996; Sardiña and Lopez Cazorla, 2005). *C. guatucupa* is a commercially important sciaenid found in estuarine, coastal and marine waters of Argentina, Uruguay and Brazil. Adults perform seasonal migrations, moving northward between autumn and spring (April–September), from the fishing grounds of Uruguay and Argentina to the coastal waters of southern Brazil and back southward in summer (Villwock de Miranda and Haimovici, 2007). The influence of oceanographic parameters is well documented for fish and known to influence the distribution and abundance patterns (Andrade and Garcia Eiras, 1999; Jaureguizar et al., 2003; Sunye and Servain, 1998). Lopez Cazorla (1996) reports such influence in the spawning movements of *C. guatucupa,* associating it with changes in temperature and salinity. Spawning occurs outside estuaries along the Argentinean coast, from spring to mid-autumn (Cassia, 1986; Lopez Cazorla, 2000). Small juveniles recruited since late spring in coastal waters (less than 25 m depth) move to deeper waters (25–50 m) in late autumn, when they reach a mean total length of 9.8 cm (age 0+). They remain there for the next 1–2 years before joining the adult stock's seasonal movements (Haimovici et al., 1996; Lopez Cazorla, 2000; Sardiña and Lopez Cazorla, 2005). The total length of adult fish ranges from 34 to 63 cm and the ages range from 3 to 23 years (Lopez Cazorla, 2000; Ruarte and Sáez, 2008).

The northern Argentine continental shelf (34–41°S) is a broad, shallow system between the coastal and the shelf break (200 m isobath). The homogeneous coastal zone is located south of 38°S (Lucas et al., 2005) and comprises the El Rincón area (ERA) (39 – 41°S). Bahía Blanca estuary (BBE) is located in the coastal region of the mentioned area, at 39°S (Fig. 1). Sciaenid fishes are dominant in these waters, *C. guatucupa* being the most important fishing resource, in social and economic terms, in these areas (Carozza and Fernandez Araoz, 2009; Lopez Cazorla, 2004).

Cynoscion guatucupa has been fished between 30°S and 41°S (Arena and Gamarra, 2000; Ruarte and Aubone, 2004; Vasconcellos et al., 2005; Yesaki and Bager, 1975). The annual commercial landings of the Argentinean fleet reached 5000 t in the early 1970's. After that, landings increased sharply to 20,000 – 48,000 t (Villwock de Miranda and Haimovici, 2007). In the decade between 1995 and 2004 total landings were on average 36,154 t, of which 28% were caught by the coastal bottom trawl and gill-net fisheries in South Brazil and 72% by the coastal otter trawl fishery of Uruguay and Argentina (Villwock de Miranda and Haimovici, 2007). The northern stock (from 35°S to 41°S) of Argentinean hake (*Merluccius hubbsi,* Marini

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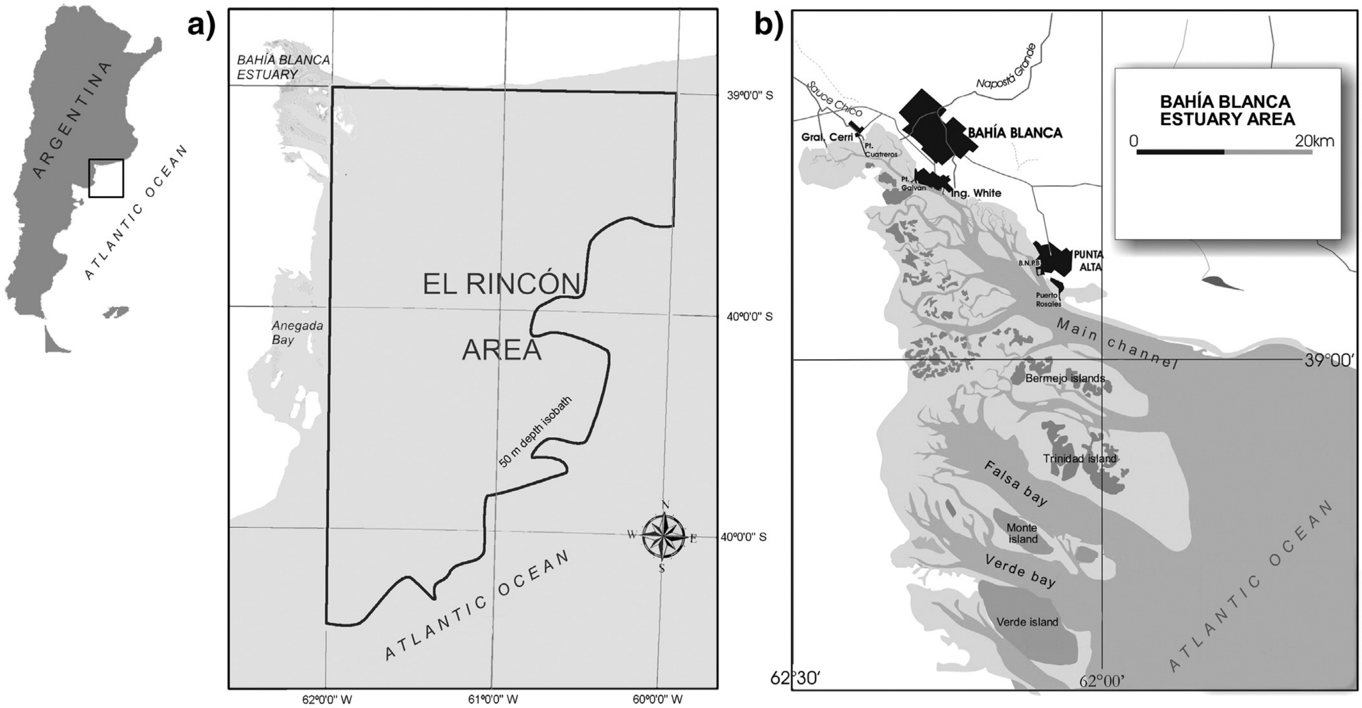

Fig. 1. Study areas. a) El Rincón, Argentina and b) Bahía Blanca estuary.

1933) has also been fished intensely by the industrial fleet of Argentina. Within the period 1986–1998, effort applied to its capture increased sharply, with yields that dropped from ~2300 kg/h to ~500 kg/h (Aubone et al., 2004). Population biomass decreased in the same fashion, with a sharp drop from 1986 to 1989 and another, more pronounced decrease, from 1991 to 1999. In 1992 a fishing closure was implemented when *M. hubbsi* juveniles stock dropped dangerously (Aubone et al., 2004). Part of the industrial fleet kept fishing *M. hubbsi* around the closed area, but an important fraction of these ships started operating at 34–41°S, targeting other species of less commercial value and abundance, such as *C. guatucupa* (Ruarte et al., 2004). From 1992 to 1998 the number of industrial vessels targeting striped weakfish at the northern continental shelf of Argentina has doubled, and the amount of effort measured in fishing hours has quadruplicated (Ruarte et al., 2000).

The artisanal fishery in BBE has been carried out since the beginning of 1900. Between 1972 and 1992, catches of *C. guatucupa* reached 50% of the total annual landings. However, at the end of the 1990s, these percentages dropped to 15%. Between 2000 and 2004, the artisanal fishery in the south of the Buenos Aires province collapsed. Coincidentally, from 2004, the government implemented fishing closures in ERA as a reaction to the increasing landings from ERA and the decrease in biomass of *C. guatucupa* and several other species (Carozza and Fernández Aráoz, 2009).

A time series of fisheries data can provide a picture of the exploitation history of a species, and can help indicate possible causes of a fishery's collapse. Several studies try to unravel the causes of fisheries collapses, using different methods and arrive at different conclusions, depending on the target species' biology, life history, location, environmental variables, and human impact, among others (see Eero et al., 2007; Frank et al., 2005; Lotze, 2007; MacKenzie and Myers, 2007; Maynou et al., 2011; Poulsen et al., 2007). For example, herring (Genus *Clupea*) populations of an estuary in Denmark has been shown to have been depleted by unchecked fishing, while the eel and whitefish fisheries operating in the same waters collapsed when the ecological regime shifted from a brackish to a salt water environment following the North Sea breach of Agger Tange (Poulsen et al., 2007). The herring fishery's decline in the White Sea was also associated with an increase in fishing effort (Lajus et al., 2007). Conversely, Eero et al. (2007) suggest that ecological and biological variables have an important role in the fluctuations of catches of Baltic cod (*Gadus morhua*). The causes of the decline of Atlantic bluefin tuna are unclear, but MacKenzie and Myers (2007) conclude that temperature related shifts were not the cause of the reduction in the number of this species, and note its important ecological role in the ecosystem as a top predator. Removal of a top predator such as this might generate, or originate from a trophic cascade, that can generate disruptions through the whole trophic chain (Frank et al., 2005). Models have been created, based on existing data (i.e. Andersen and Pedersen, 2009 based mainly on fisheries on the Baltic Sea) trying to predict this effect, and how a particular fishery can cause the collapse of a non-target species. It is then vital to explore the causes and background of a fishery collapse, not only as a way to understand the origin and causes of the problem, but also to contribute to future management approaches.

Based on the bibliographic information, we hypothesize that the observed decrease in the *C. guatucupa* stocks in BBE is a consequence of the increase in the industrial fisheries activity in ERA, the changes in temperature in BBE and/or the changes in Salinity in BBE. In order to test this hypothesis, our objectives were to estimate landings, fishing effort and catch per unit effort of *C. guatucupa*, during the period 1992–2009 for each area, and compare these results from the artisanal and industrial fisheries operating in BBE and ERA respectively, and the oceanographic variables that might also influence the variations in *C. guatucupa* landings.

2. Materials and methods

2.1. Study area

The Bahía Blanca estuary is located between 38° 45′ and 39° 25′ S and 61° 15′ and 62° 30′ W (Fig. 1). It consists of a main channel as well as several secondary channels, separating inner islands and wide tidal flats (Piccolo and Perillo, 1990). The estuary has a surface area of ~2300 km^2, covering an area of 1900 km^2 at high tide and of

740 km^2 at low tide. The tidal regime is semidiurnal, with an amplitude of ~4 m. This is a shallow estuary, with a mean depth of approximately 10 m (Perillo et al., 2004), is highly turbid due to the predominance of fine sediment and the turbulence of the waters (Cuadrado et al., 2004). The estuary's behaviour throughout the year varies with the fresh water discharges from rivers and creeks of limited flow, giving rise to a low and variable runoff. On the northern shore, the estuary receives freshwater from two main water bodies, the Sauce Chico river and the Napostá Grande creek, with mean annual discharges of 1.9 $m^3\ s^{-1}$ and 0.8 $m^3\ s^{-1}$ respectively (Perillo et al., 2004). Water temperature has a mean annual value of 13 °C and varies seasonally, with highest values in summer (21.6 °C; December–February) and lowest values in winter (8.5 °C; June–August) (Perillo et al., 2004). The estuary is classified as a salt marsh and is seasonally mixed, vertically homogeneous and with a tendency towards hypersalinity in summer (Hoffmeyer, 1994).

The area known as El Rincón is located between 39°S and 41° 30′ S and it extends from the coast to a 50 m depth not including the estuarine area (Fig. 1). From an oceanographic point of view, this area is divided into two main domains, the coastal or inner shelf and the outer shelf. The coastal waters, delimited by the 40 m isobath, are generally homogeneous (Martos and Piccolo, 1988) with temperatures between 14 and 16 °C and salinities ranging from 33 to 33.8 in both seasons (Lucas et al., 2005).

To improve the understanding, conservation and management of the exploited striped weakfish population in the homogenous coastal zone, we evaluate the relationship between the fishery data from the artisanal fleet operating in BBE with the fishery activity of the industrial coastal fleet operating in ERA and BBE oceanographic variables available from 1992 to 2009.

2.2. Fleet characteristics and fisheries data

Fishing boats of the artisanal fleet operating in BBE use shrimp nets. These nets are funnel shaped and present lateral wings, a central bag and three different mesh sizes. In the wing area, the outstretched mesh size is 60 mm. In the bag, the mesh opening is 40 mm from the mouth to the mid portion. On the last portion of the bag, the stretched mesh size is 20 mm. This seine-type net is used to catch shrimp, prawns and striped weakfish. These nets are placed at anchor by small boats (12 m long, 3.5 m wide and 1.5 m deep).

Data about catches in BBE during 1992–1998 were provided by the *Cooperativa Pesquera Whitense* (White's Fishery Cooperative), a cooperative organization formed by local fishermen. This organization closed in 1999 due to the artisanal fisheries collapse. From 1999 to 2009, data were obtained from the landing records of the *Dirección Nacional de Pesca y Acuicultura* (DNPyA) (Argentine's Bureau of Fisheries and Aquaculture) the national entity that regulates and manages fishing and agricultural activities.

The catch records for *C. guatucupa* were taken from the daily landings of each boat. The unit of effort *f* was a fishing day per boat. Then we estimated the annual catch per unit effort (CPUE) expressed in kg day^{-1}.

Catch (C) and effort (*f*) data during fishing hours in ERA were obtained from the landing records of the DNPyA. Based on an estimation of CPUE for the striped weakfish by Perrotta and Ruarte (2009, 2007) and taking into account that CPUE = C/*f*, we estimated the annual effort value as: *f* = C/CPUE for the period 1992–2009.

2.3. Oceanographic variables

Water temperature (T) and salinity (S) measurements were taken from Ingeniero White port (Fig. 1) by means of a multisensory Horiba U10 (R. H. Freije, *Universidad Nacional del Sur, Argentina,* pers. comm.) with fortnightly frequency. Mean annual ± standard deviation T and S for BBE were calculated for the 1992 to 2009 period.

2.4. Data analysis

Variations in total landing in BBE might arise from both the environmental variables within the estuary and/or fishing activity in ERA. In order to assess the significance of inter-annual variations in the oceanographic parameters an ANOVA test was performed. When significant differences were found, a Tukey honestly significant difference (HSD) analysis was carried out to identify the years with significantly different T or S. Data on landings from BBE were used in a multivariate regression model as a dependant variable, with landings in ERA and mean annual T and S in BBE as explanatory variables. This allows us to evaluate the effect of these variables on *C. guatucupa* landings on BBE. The minimum adequate model was obtained through stepwise model simplifications. Non-normality and heteroscedasticity were not detected using an ordered residuals against normal scores plot, standardized residuals against fitted values plot and Barlett's test of homogeneity of variances. The maximum fitted model for the multiple regression was:

$$\text{Lan. BBE} \sim \text{Lan. ERA}^{*}\text{T}^{*}\text{S} + (\text{Lan. ERA})^2 + \text{T}^2 + \text{S}^2 \quad (1)$$

Where: Lan. BBE are landings in BBE, Lan. ERA are landings in ERA, T is temperature and S is salinity in BBE. This model represents both the effects of each independent variable and its interactions (denoted by the '*'), as well as the possible quadratic effects of each of them to the landings in BBE.

In order to assess the possible variations between the artisanal fisheries activity in BBE and the industrial fleet activity of ERA, polynomial models (first, second and third order) were fitted to total landings, effort and CPUE data from BBE and ERA against year. Data on CPUE and effort presented a somewhat sinusoidal distribution shape that suggested the use of polynomial models of higher than 2nd order. An *F* test was conducted to assess the significance of fit. To explore overfitting that might arise when using polynomial models (Crawley, 2007), Akaike's information criterion (AIC) was employed, calculated as:

$$\text{AIC} = -2 \times \text{LL} + 2(\text{p} + 1) \quad (2)$$

Where: LL is the log-likelihood value of the model, p is the number of parameters in the model and 1 is added for the estimated variance.

The selected models were then compared with an ANOVA to test the significance of variations between areas ($P < 0.05$).

Statistical analysis and calculations were performed using R statistical software (R Development Core Team, 2009).

3. Results

The maximum artisanal catch in BBE during the period analyzed was 189.6 t in 1992. After this year, catches decreased up to a minimum of 0.6 t in 2001–2004 (mean landing = 1.45 t +/− 0.8 t). Catches seem to increase steadily since 2004 reaching 61 t for 2009 (mean landing = 39 t +/− 19.2 t) (Table 1). Conversely, landings in ERA increased from the 1992–1993 period (mean landing = 2632 t +/−762.2 t) to higher values between 1994 and 2002 (mean landing = 6662.1 t +/−2621.5 t) where the highest landing was 9623 t in 2001. Since 2003, landings dropped to lower values (mean landing = 4304.6 t +/−991.9 t) (Table 1).

Mean annual temperature and salinity in BBE oscillated between 13.9 and 16.3 °C and 29.4 and 37.8 respectively. We found significant variations in salinity ($P < 0.01$) and not in temperature (P: 0.995) throughout the years considered. Despite that, oceanographic parameters did not show any defined trend (Table 1).

Environmental variables (T and S) had no significant effect on *C. guatucupa* landings at BBE, neither as lineal, quadratic or interaction terms. The landings of this species at ERA, as a lineal term, were the only explanatory variable that showed a significant effect on the striped

Table 1
Data on landings in Bahía Blanca estuary (Lan. BBE) and El Rincón area (Lan. ERA), temperature (T) and salinity (S) in Bahía Blanca estuary. Different lower case letters represent significant differences (P < 0.05) between the salinity of each year.

Year	Lan. BBE(Kg)	Lan. ERA(Tn.)	T (°C)	S	
1992	189.7	3171	14.9 ± 5.7	31.4 ± 2.2	a
1993	83.7	2093	15.2 ± 5.6	32.0 ± 4.9	ab
1994	27.8	5522	16.0 ± 5.7	35.0 ± 1.6	c
1995	37.4	5515	15.2 ± 5.8	35.3 ± 1.1	cd
1996	27.9	6606	15.8 ± 4.9	36.2 ± 2.1	df
1997	13.7	6030	14.7 ± 5.0	32.5 ± 3.0	ab
1998	6.9	7246	15.3 ± 4.6	32.7 ± 1.7	abc
1999	33.1	5680	14.9 ± 5.7	35.4 ± 1.0	cd
2000	148.6	7323	15.3 ± 5.6	33.9 ± 2.5	bd
2001	2.6	9623	15.6 ± 5.5	29.4 ± 4.6	a
2002	1.7	7075	14.0 ± 5.5	31.0 ± 3.0	abc
2003	0.7	3632	14.9 ± 5.2	33.1 ± 1.2	ab
2004	0.9	4937	16.3 ± 5.6	32.8 ± 2.4	abc
2005	15.0	3193	15.5 ± 5.2	33.9 ± 1.8	bcde
2006	24.6	3924	16.3 ± 5.2	34.7 ± 1.0	bd
2007	52.5	5417	14.6 ± 6.1	32.2 ± 2.8	ae
2008	41.0	5454	16.0 ± 5.7	35.9 ± 1.1	d
2009	61.7	3575	15.7 ± 5.3	37.9 ± 2.3	f

weakfish landings at BBE. Through stepwise deletion of non significant terms, the minimum adequate model found was:

$$\text{Lan. BBE} \sim 63700 \text{ kg-}0,007\text{xLan. ERA} \quad (3)$$

This model is significant (*P*: 0.037) with d. f. = 14 and explains 79.2% of the variation in the landings of BBE. The standard error is 1690 kg for the estimate of the intercept and 2.9×10^{-4} for the slope.

Landings of each area show high correlation coefficients and significant fit with second order polynomial models (r >70%, *P*: 0.0032) and significant differences between them (*P*: 0.0032) (Fig. 2a). Deviance values for landing models show that the second order polynomial presents a better fit (Table 2). This suggests that when catches in ERA increased, catches in BBE decreased.

Effort applied in BBE decreased from 1992 to 2000 (mean $f =$ 583.6 +/− 271.6), from 2001 up to 2004 it remained low and constant (mean $f =$ 15.5 +/− 2.5) and since 2005 a slight recovery was observed (mean $f =$ 159.4 +/− 72.9). Effort in ERA increased in the 1996 to 2001 period (mean $f =$ 96,871.6 +/− 32,168.5) from the lower values of 1992 to 1995 (mean $f =$ 50,322.7 +/− 21,964.1). From 2002, effort dropped considerably, remaining low since 2003, although a slightly positive trend can be observed until 2009 (mean $f =$ 25,577. 3+/− 2403.8) (Fig. 2b). Effort of each area showed significant fit with the third order polynomial model and high correlation coefficients (r > 60%; *P*: 0.004). Deviance values for effort models show that the third order polynomial represents the best fit for ERA data, and a similar deviance for second and third order polynomial models fitted to BBE data (Table 2). Effort curve comparisons presented significant differences between areas (*P*: 0.00016) (Fig. 2b).

In BBE there was a steady drop in CPUE from 1992 to 1994, and this decrease continued until 1998 (mean CPUE = 72.56 kg day^{-1} +/− 66.6 kg day^{-1}). On 1999, CPUE peaked at 265 kg day^{-1} and then dropped again until 2003 (mean CPUE = 97.9 kg day^{-1} +/− 47.2 kg day^{-1}). Starting on 2004, there was a net increase of the CPUE (mean CPUE = 247 kg day^{-1} +/− 189.5 kg day^{-1}) (Fig. 2c). Yields in ERA increased after 1993. Up to 2001, it oscillated but remained around the same average values (mean CPUE = 70.6 kg h^{-1} +/− 23.6 kg h^{-1}). CPUE between 2002 and 2009 presented an important increase (mean CPUE = 163.8 kg h^{-1} +/− 25.3 kg h^{-1}). Third order polynomial models showed a significant fit (r >60%; $P < 0.05$) for the CPUE of each area and were significantly different from each other ($P < 0.05$) (Fig. 2c). Deviance values for CPUE models show that the third order polynomial presents the best fit (Table 2).

First order polynomial models had larger AIC reflecting their poor fit to the data, as also suggested by the *F* test.

4. Discussion

The temperature and salinity range registered during the study period in BBE were within the reported ranges for the normal behaviour of *C. guatucupa* (Jaureguizar et al., 2006; Lopez Cazorla, 1987).

Shifts in environmental variables such as temperature (Henderson and Nepszy, 1988; Serns, 1982; Staggs and Otis, 1996), salinity (Bishop and Bishop, 1973; Green, 1970; Visser and Parkinson, 1975), and nutrient levels (Leach et al., 1977; Persson et al., 1992; Quirós, 1990, 1998), as well as anthropogenic impacts may change the size and dynamic balance of fish populations (Schlosser, 1991). We failed to detect a relationship between the key environmental variables of salinity and temperature and the landings of *C. guatucupa* by the artisanal fleet of BBE. A similar result was reported for bluefin tuna (*Thunnus thynnus*) by Schick et al. (2004) in the Gulf of Maine, where neither salinity nor temperature influenced the landings of tunas. However, other authors have reported certain influences of physicochemical parameters on the abundance or landings of fish. Sunye and Servain (1998) found that salinity influenced the landings of sardine in southern Brazil, but did not find an influence from temperature on the landings. Andrade and Garcia Eiras (1999) found that temperature affects CPUE of skipjack tuna (*Katsuwonus pelamis*) on the coast of the south of Brazil.

It is widely recognised that small-scale fisheries play a significant role in providing an important source of food to people, contributing to poverty reduction and to sustainable development in several areas of the world (FAO, 2005). In particular, developing countries greatly benefit from this type of fishery, as they constitute the main source of both food and income for people living along the coast (Blaber et al., 2000). The artisanal fishery of BBE has economic, historical and cultural importance. The local population uses the marine environment for livelihood. At present, traditional fishing methodologies are still used (Lopez Cazorla, 2004). Artisanal fisheries, however, may also impact fish stocks. Pinnegar and Engelhard (2008) presented a series of cases in which artisanal fisheries have produced degradation of ecosystems through the removal of slow-growing, late-maturing fish. While *C. guatucupa* is neither late-maturing nor slow-growing, the artisanal fleet of BBE fished almost 200 tons of this species in 1992; hence the decline of the species might be partially influenced by local pressure.

The collapse of *C. guatucupa* landings in BBE that we studied was possibly influenced by the overfishing of the resource by the industrial trawling fleet in ERA that had larger landings than the artisanal fleets. The loss of the resource to the artisanal fishers in BBE and the consequent socio-economic problems this triggered are not isolated cases. An example of industrial and artisanal fisheries interaction, close geographically to the present study, was presented by Vasconcellos et al. (2005) in Brazil. In this country, modern industrial fleets started operating during the 1950s, fishing various species of osteichthyes. The landings of these trawlers sharply increased up to an average of 50,000 tons per year, which produced symptoms of severe degradation for several fish stocks in the 1980s, 30 years later.

In Argentinean waters, fishing activity in ERA has increased to significantly higher values from 1992 (Ruarte et al., 2004), and recent data shows a decrease in biomass and mean size for many species that are taken in the coastal multispecific fisheries (Carozza and Fernández-Aráoz, 2009).

Alterations in the composition of species in a particular area, fishery collapse, shifts in the reproductive behaviour and species extinction, have been mentioned by several authors as possible outcomes of overfishing (Baum et al., 2003; Jackson et al., 2001; Jennings and Kaiser, 1998; Myers and Worm, 2005; Pauly et al., 1998). Overfishing has a great ecological impact on aquatic environments, evidenced by discards of both juvenile of target species and species of no or reduced

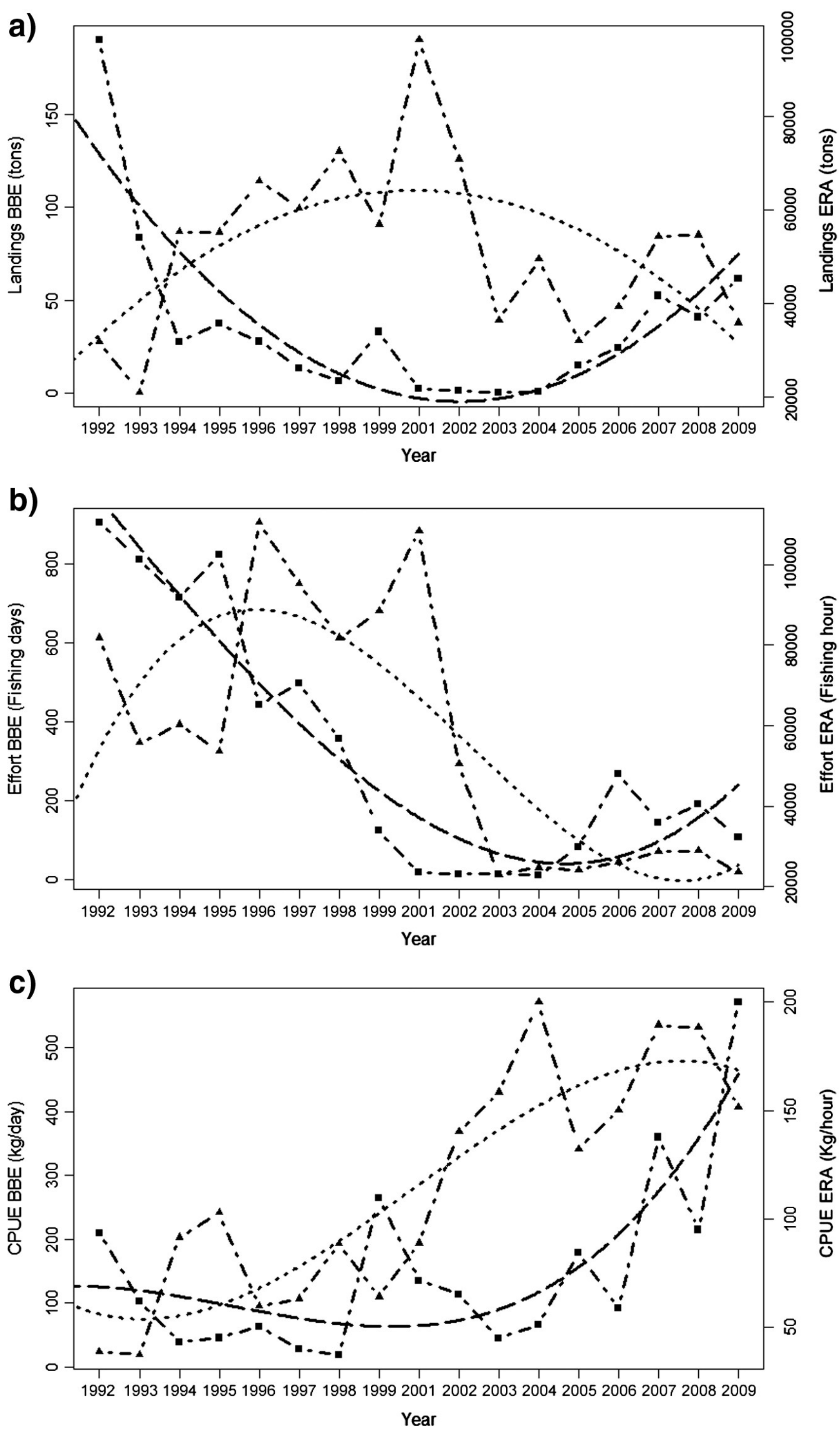

Fig. 2. Reported landings of *Cynoscion guatucupa* (a), effort (b), CPUE (c) and model estimates for Bahía Blanca Estuary (BBE) and El Rincón Area (ERA) from 1992 to 2009. Data and model estimates for BBE are presented with boxes and a dashed line, and for ERA with triangles and a pointed line.

Table 2
Akaike's information criterion for the models fitted (first, second and third order polynomial models) to the data on landings (Lan), fishing effort (Eff.) and capture per unit of effort (CPUE) in Bahía Blanca estuary (BBE) and El Rincón area (ERA).

Models	Lan. BBE	Lan. ERA	Eff. BBE	Eff. ERA	CPUE BBE	CPUE ERA
1st order	415.65	543.93	231.04	396.02	216.22	168.05
2nd order	392.86	536.32	215.15	395.22	209.11	166.09
3rd order	396.77	538.64	215.34	392.89	209.07	166.07

commercial value (i.e., bycatch) and by degradation of the benthic environment produced by bottom trawls (Pauly, 2002). It is possible that the BBE stock's collapse has been influenced by many of these factors. Trophic cascades have been shown to be triggered when the abundance of marine predators is depleted, causing disruptions in the ecosystem that might impact on the abundance of other organisms (Andersen and Pedersen, 2009; Casini et al., 2008; Frank et al., 2005). In the case of *C. guatucupa*, information on the feeding ecology of the species could help determine if there is such effect on this species. Lopez Cazorla (1996) determined the food composition of *C. guatucupa*, and

Sardiña and Lopez Cazorla (2005) studied the feeding of this species in three ontogenetic stages. Prey composition between these two studies doesn't seem qualitatively different; hence if there has been a trophic cascade, it might have not affected this particular species. Migratory behaviour of the species could have also been disrupted or changed by intense fishing. There is no published study on migratory behaviour for *C. guatucupa*, although the species has been found by researchers (Lopez Cazorla, 1987, 1996, 2000, 2004; Sardiña and Lopez Cazorla, 2005) and the fishermen of BBE throughout the years analyzed, and the salinity and temperature of the estuary, known to trigger the ingress into the estuary from the surrounding coastal water, have remained mostly constant through the years. Whether there is a decrease in the number of migrant individuals is unknown. Degradation of the benthic community might also play some role in the decrease of the stock's biomass, despite the species being a pelagic feeder, as it may disrupt the ecosystem as a whole.

For *C. guatucupa*, the first scientific results pinpointing the decrease in the yields of the artisanal fleet fishing this species in BBE were presented by Lopez Cazorla (2004). Carozza et al. (2004) mention that since 2000 there was an increase in landings of several coastal species at ERA, especially during the reproductive season of most of them. Additionally, Aubone et al. (2006) mentioned that from 1995 to 2006, biomass of *C. guatucupa* stocks south to the 39°S was severely depleted. These facts triggered the implementation of reproductive closures in ERA from 2004 (Fig. 1). This measure seems to have had certain positive effects on *C. guatucupa* landings since 2005 in both ERA and BBE (Fig. 2a); however, Pauly et al. (2002) mention that this management measure alone is not enough to rebuild the stock of an overfished species. *C. guatucupa* stocks needs to be recovered before a sustainable fishery of this species can be implemented.

As a consequence of the mentioned closures, the coastal industrial fleet moved to the southeast of the closed area, increasing the landings of mackerel (*Scomber japonicus,* Houttuyn, 1782) since 2007, as shown in the results presented by Garciarena and Buratti (2012).

Part of the fleet that originally targeted *M. hubbsi*, as explained in the introduction, joined the coastal fleet already fishing *C. guatucupa* and then part of this fleet shifted to *S. japonicus.* This fishing strategy has important ecosystem consequences as the sequential changes in fishing resources, decreasing from higher to lower TL species (*M. hubbsi,* TL: 4.08; *C. guatucupa*: 3.7, Vögler et al., 2009; *S. japonicus* TL: 3.1, Faith et al., 2004), shift the mean TL of the community to lower values. Pauly (2002) considers this “fishing down marine food webs” strategy to cause severe ecosystem disruptions. Fishing effort should be distributed among the available areas and species, instead of concentrated sequentially on a few highly economically profitable species in order to protect the individual fish resources available and the ecosystem as a whole.

It is then vital to predict, or at least detect, when overfishing is taking place, in order to limit the activity or supply corrective management measures (Thurstan and Roberts, 2010). Coastal areas are characterized by their sensitivity, complexity, as transition and interaction zones between the terrestrial and marine environment. They are exposed to environmental changes and anthropogenic activity (Elliott and Quintino, 2007). This makes these environments useful for detecting ecological disturbances on a broader scale in a timely fashion (Coll et al., 2008; Hilborn, 2007).

In our study we have not detected oceanographic variations in BBE that could explain the collapse of the artisanal fishery of *C. guatucupa* in BBE. However, we found a possible explanation for this change from fishing on the high sea fishing grounds of ERA. This suggests that the landings of the artisanal fleet operating in BBE were affected by the increasing fishing pressure exerted by the industrial fishing fleet of ERA. Our study emphasizes the need to take into account catch and effort data from both the estuarine environment and the surrounding sea region, particularly when designing management plans for the conservation of migrating fish resources.

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