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Status of white croaker *Micropogonias furnieri* exploited in southern Brazil according to alternative hypotheses of stock discreetness

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Abstract

The exploitation status of white croaker *Micropogonias furnieri* in southern Brazil is assessed using a production model constructed according to three hypotheses of stock discreetness: an isolated stock in southern Brazil; a straddling stock shared between Brazil and Uruguay; and a straddling stock shared among Brazil, Uruguay and Argentina. Estimates of virgin stock size and maximum sustainable yield were more sensitive to the hypothesis assumed correct, the posterior means varying respectively from 177,648 to 1,007,256 tonnes and from 7459 to 38,677 tonnes. Estimates of stock status in relation to management reference points were more robust to the uncertainties in stock discreetness and indicate that the species in currently overfished (biomass at 60% of B_{msy}) and under heavy overfishing (F between approximately 2 and 6 times higher than F_{msy}). Results suggest that the relative stability of catches in the region occurs at the expense of a steady decline in stock abundance and that concerted management actions by the three countries are needed to bring the stock to safer levels of exploitation.

Keywords: *Micropogonias furnieri*; Exploitation status; Production model; Straddling stock; Southern Brazil

1. Introduction

The estuary of Patos lagoon and shelf waters of southern Brazil comprise one of the most important Brazilian fishing grounds (Fig. 1). During the last 30 years fisheries in the region are going through a crisis caused by an excess fishing capacity and a continuous decline in yield and abundance of important fish stocks (Haimovici, 1997; Reis and D'Incao, 2000; Haimovici et al., 2006). Fisheries production reached a maximum in the early 1970s and since then shows a declining trend with substantial pluriannual oscillations. The peak of artisanal fisheries landings was reached in 1972 with 43.705 tonnes, while the reported landings in 2002 were 4.442 tonnes. Similarly, industrial fisheries landings declined from 83.698 tonnes in 1971 to 39.557 tonnes in 2002 (Haimovici et al., 2006; IBAMA—Brazilian Institute for the Environment and Renewable Natural Resources).

Over 50% of the total fisheries production in the region is supported by sciaenid species, being the white croaker *Micropogonias furnieri* one of the most abundant and important for local fisheries. The species has a broad distribution range, from Yucatan Peninsula (Mexico) to Golfo de San Matias (Argentina), and is fished mainly in coastal waters (<50 m) close to estuaries. In southern Brazil the species is the target of artisanal fisheries that operate in estuarine and shallow coastal waters using mainly gillnets and otter trawls (Reis et al., 1994), industrial pair trawlers, otter trawlers, double-rig trawlers and bottom gillneters that operate on the shelf (Haimovici, 1997) and more recently are also targeted by industrial purse-seiners.

The distribution of the species from southeastern Brazil to Argentina is continuous and genetic studies did not find evidences that support the existence of isolated populations throughout the region (Fig. 1; Maggioni et al., 1994; Levy et al., 1998). However morphological and life cycle char-

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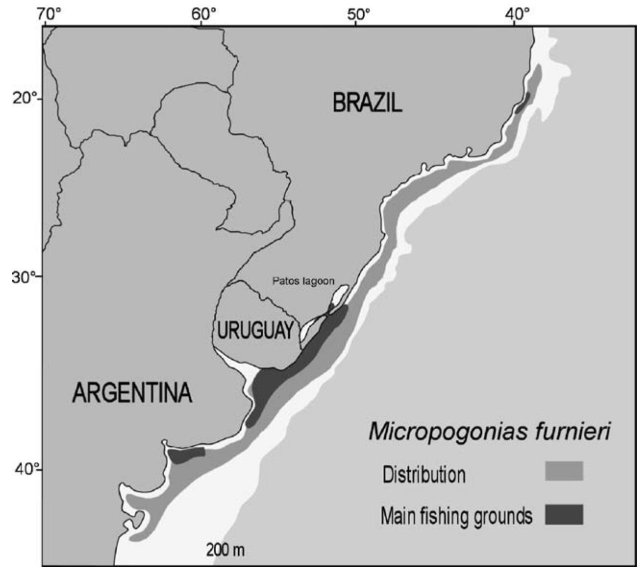

Fig. 1. Distribution and main fishing grounds of white croaker *Micropogonias furnieri* in southern Brazil, Uruguay and Argentina.

acteristics and historical trends in fisheries cpue indicate the existence of at least two stocks in southern Brazil, to the north and south of Cabo de Santa Marta Grande (29°S) (Vazzoler, 1971; Haimovici and Ignácio, 2005). On the other hand the separation between the stock fished in southern Brazil and the one(s) exploited in the Common Fishing Zone of Uruguay and Argentina is less conclusive (Figueroa et al., 1991). Growth and age composition of white croaker caught in southern Brazil suggests, for instance, that the stock that spawns off Uruguay during spring and summer uses the shelf waters of Rio Grande do Sul as feeding ground during the winter, when it is caught by Brazilian trawlers (Haimovici and Umpierre, 1996).

Previous studies have attempted to assess the exploitation status of white croaker stocks. In southern Brazil Reis (1992) applied a length-based yield per recruit analysis to estimate exploitation rates by artisanal gillneters and industrial trawlers and Haimovici (1997) used trends in cpue to infer the status of the stock. Arena and Rey (2003) applied an equilibrium form of Schaeffer and Fox production models to data from Uruguayan fisheries in the Rio de la Plata and the Common Fishing Zone. Carozza and Hernández (2004) applied a discrete form of the Schaeffer production model to data from Argentinean fisheries in the Common Fishing Zone. In this paper we use a discrete form of the Schaeffer production model to assess the exploitation status of white croaker fished in southern Brazil considering three different hypotheses about the discreteness of the stocks. First that the stock in southern Brazil is isolated from the one(s) fished off Uruguay and Argentina; second that the Brazilian and Uruguayan catches are from the same stock; and third that the catches from the three countries are from the same straddling stock. The assessment employs a Bayesian approach to parameter estimation because it provides a framework suitable for data-limited situations by which it is possible to combine the available data with prior information about the population dynamics of the species.

2. Material and methods

2.1. Assessment model

The discrete form of the Schaefer model was used

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{k}\right) - C_{t-1} \tag{1}$$

where B_t is the estimated biomass at time t, r is the intrinsic rate of population growth, k corresponds to the unfished stock size and C_t is the catch measured in tons per year ($F_t = C_t/B_t$). Model parameters were estimated using a Bayesian approach that combines prior probabilities and the likelihood of parameter values. Likelihoods were estimated using an observation-error estimator that evaluates the fit between predicted and observed time series of cpue data (Y_t), where

$$Y_t = q_i B_t^{(1-b)} \tag{2}$$

q is the catchability coefficient of fleet i and b is a parameter that describes whether the relationship between cpue (Y) and biomass is linear; cpue will be linearly proportional to stock biomass with $b = 0$. The observation-error estimator is based on the assumptions that the population dynamics Eq. (1) is deterministic, that all errors occur in the relationship between biomass and cpue, and that the error is multiplicative and log-normal with a constant coefficient of variation ($Y = q_i B^{(1-b)} e^{\varepsilon}$; $\varepsilon = N(0;\sigma^2)$) (Polacheck et al., 1993).

2.2. Fisheries data

Catch data from 1976 to 2002 were obtained from IBAMA for Brazil, from the Dirección Nacional de Pesca (DINARA) for Uruguay and from the Secretaria de Agricultura Ganaderia Pesca y Alimentacion (SAGPyA) for Argentina. Catch per unit of effort (tonnes days^{-1}) data of the pair trawling fishery operating in the port of Rio Grande between 1976 and 2002 (Haimovici et al., 2006) were used as an index of abundance in southern Brazil. No adjustments were made to the cpue data from southern Brazil because the power of the boats, the harvest technologies and the fishing areas changed very little during the time period of the analysis (Haimovici et al., 1989; Haimovici et al., 2006). Catch per unit of effort (tonnes h^{-1}) data of Uruguayan pair trawlers from 1986 and 2002 were used as an index of abundance for the white croaker exploited in the Rio de la Plata and the Common Fishing Zone (Arena and Rey, 2003). Catch per unit of effort (tonnes h^{-1}) data of Argentinean trawlers from 1989 to 2002 were used as an index of abundance for white croaker exploited along the Argentinean coast of the Common Fishing Zone (Carozza and Hernández, 2004). Annual data by country are presented in Table 1 and Fig. 2.

Table 1
Catch and cpue data used in the assessment of the white croaker

Year	Catches (tonnes)			Cpue		
	Southern Brazil	Uruguay	Argentina	Southern Brazil (tonnes day^{-1})	Uruguay (tonnes h^{-1})	Argentina (tonnes h^{-1})
1976	11397	9434	5175	1.03		
1977	16582	11921	3955	1.32		
1978	15081	13980	4544	0.93		
1979	14003	25827	4391	1.03		
1980	16547	31623	6518	1.30		
1981	14625	25913	13657	1.02		
1982	15182	26930	16760	1.12		
1983	15369	24842	18159	0.70		
1984	12799	24246	5311	0.65		
1985	15291	19324	4065	0.53		
1986	15642	24393	11006	0.50	1.04	
1987	13719	28173	8893	0.37	1.51	
1988	7665	25914	11345		1.85	
1989	9504	23993	6019	0.32	1.34	0.03
1990	12840	17488	6398	0.36	1.08	0.06
1991	14667	26510	4659	0.42	0.90	0.16
1992	13779	28271	10619	0.31	0.80	0.13
1993	15452	25804	12700	0.30	0.91	0.11
1994	19562	29012	19100	0.11	0.99	0.05
1995	13196	29513	30200	0.11	1.14	0.15
1996	14839	25745	23500	0.18	0.91	0.10
1997	13452	23743	26100	0.20	0.73	0.13
1998	15697	22253	9151	0.25	0.78	0.03
1999	8266	14650	6728	0.26	0.81	0.04
2000	9672	24146	5253	0.22	0.76	0.03
2001	14712	27322	4479	0.23	0.78	0.04
2002	17561	25550	3352	0.23	0.65	0.04

IBAMA; DINARA; SAGPyA: Haimovici et al. (2006), Arena and Rey (2003), Carozza and Hernández (2004).

2.3. Parameter estimation

To reduce the number of parameters to be estimated we assumed that the biomass at the beginning of the time series (B_0) is equal to k. Although this assumption can be misleading if the stock is already depleted at the first year of the time series (Hilborn and Walters, 1992), it has been shown that a better performance of the estimation procedure is obtained by assuming so than trying to estimate k and B_0 independently (Polacheck et al., 1993). In the case of white croaker exploited in southern Brazil, the assumption of B_0 equal to k is acceptable because before 1976 industrial fishing was less intense, artisanal fisheries were restricted to the estuary of Patos Lagoon and hence fishing mortality was at a low level (Yesaki and Bager, 1975; Kalikoski and Vasconcellos, 2003). In addition we tested a range of possible scenarios for B_0/k without much difference in the estimated management parameters. Therefore we opted to show only the results for the scenario of $B_0 = k$.

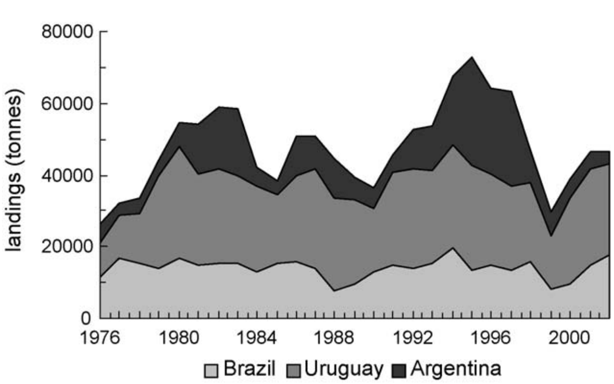

Fig. 2. Landings of white croaker in southern Brazil, Uruguay and Argentina (sources IBAMA, DINARA, SAGPyA).

Also to reduce the number of parameters we fixed parameter b to zero when fitting the model to data from Uruguay and Argentina. As these data cover a shorter time period and a narrower range of stock abundances as compared to the Brazilian data, the assumption of constant proportionality between stock biomass and the cpue of Uruguay and Argentina is less likely to affect the performance of the model to fit the data.

The likelihood function used for the estimation is

$$L(D\backslash\underset{\sim}{\theta}) = \prod_t \frac{1}{\sigma Y_t\sqrt{2\pi}} \exp\left(-\frac{1}{2\sigma^2}(\ln Y_t - \ln(qB_t^{1-b})^2\right) \quad (3)$$

When the model was fitted to data from more than one fleet the total likelihood was computed as the product of the likelihoods of the individual set of observations. The posterior probability distribution for each alternative parameter value was computed by combining prior information with the estimated likelihoods using Bayes rule.

Table 2
Prior probability distributions for model parameters

Parameter	Prior distributions
r	(1) U [0.01, 1.5] (2) N [0.238, 0.09] (3) $r = 0.238$
k	U [100, 10^7]
$\log q$ (Brazil)	U [−20, 20]
b (Brazil)	U [−1, 1]
$\log q$ (Uruguay)	U [−20, 20]
$\log q$ (Argentina)	U [−20, 20]

Different scenarios for the prior probability distributions of model parameters were tested (Table 2). We assumed uniform priors for k (U[100, 10^7]), b(U[−1, 1]) and for $\ln q$ (U[−20, 20]). As discussed by Punt and Hilborn (2001), by being very broad, these priors supply very little information about the values of these parameters. For parameter r we tested three different scenarios. First we placed uniform probability distribution for r (U[0.01, 1.5]), representing a wide range of possible parameters for marine fish populations. Second we used a Leslie matrix projection method (McAllister et al., 2001) to compute more informative (normal) prior distribution for r (N[0.238, 0.09]), using as input parameters the natural mortality rate M (U[0.1, 0.25 year^{-1}], Haimovici, 1997), the age at maturity (1 year in estuaries, 3 years in coastal waters and longevity 35 years) (Castello, 1982; Haimovici, 1997), and the maximum annual reproductive rate (α) for Scianidae ($\ln\alpha = N$ [1.88, 0.28]; Myers et al., 1999). Lastly we assumed that r was known and equals to 0.238, i.e., the expected r from the life history parameters described above. Parameter σ was treated as known and fixed at 0.4, as in Punt and Hilborn (2001).

The computation of posterior probabilities was carried out using a Markov Chain Monte Carlo method implemented in an Excel spreadsheet (Punt and Hilborn, 2001). The vectors for each parameter were plotted to look for obvious patterns of lack of convergence of the chain. The chains were also assessed for indication of lack of convergence using the Geweke test (Geweke, 1992). The Geweke test compares the mean of the first 10% of the chain with that of the last 50% for equality. A Z-score is computed and it is interpreted to indicate lack of convergence if it falls outside the interval −2.32 and 2.32 (where 99% of the density of a standard normal distribution lies). The Geweke test was performed using the package CODA for R (Plummer et al., 2005). At least 100,000 runs were necessary to find convergence in parameter estimates. For more complex scenarios, with a larger number of parameters to be estimated, it was necessary to use longer chains (>300,000 runs). In each simulation the first 20,000 runs were disregarded as a "burn in" period and select the parameter vectors after every 40th run as the basis to construct the posterior distributions.

Three management reference points were estimated based on this analysis. The maximum sustainable yield (msy), the ratio between the current fishing mortality and the fishing mortality at msy (F/F_{msy}) and the ratio between current biomass and the biomass at msy (B/B_{msy}). These parameters are used to compare the expected productivity of the stocks and their exploitation status, i.e., if there is overfishing occurring ($F/F_{msy} > 1$) and if the stocks is overfished ($B/B_{msy} < 1$).

3. Results and discussion

Parameter estimation was strongly influenced by the longer time-series of cpue data from Brazil that shows a continuous declining trend of stock abundance, meaning that fisheries have been steadily depleting a large and relatively unproductive stock (Fig. 3). Best fit models were obtained under the scenario of increasing catchability with stock size for the Brazilian fleet (mean b between −0.464 and −0.490; Table 3). Such relationship would explain the sequence of high cpue values in the beginning of the time-series (Fig. 2), which could have been caused by fleets targeting dense aggregations of the species that were probably present in the area during the early development phase of industrial trawling (Vazzoler, 1991; Haimovici et al., 1989). The cpue plots also

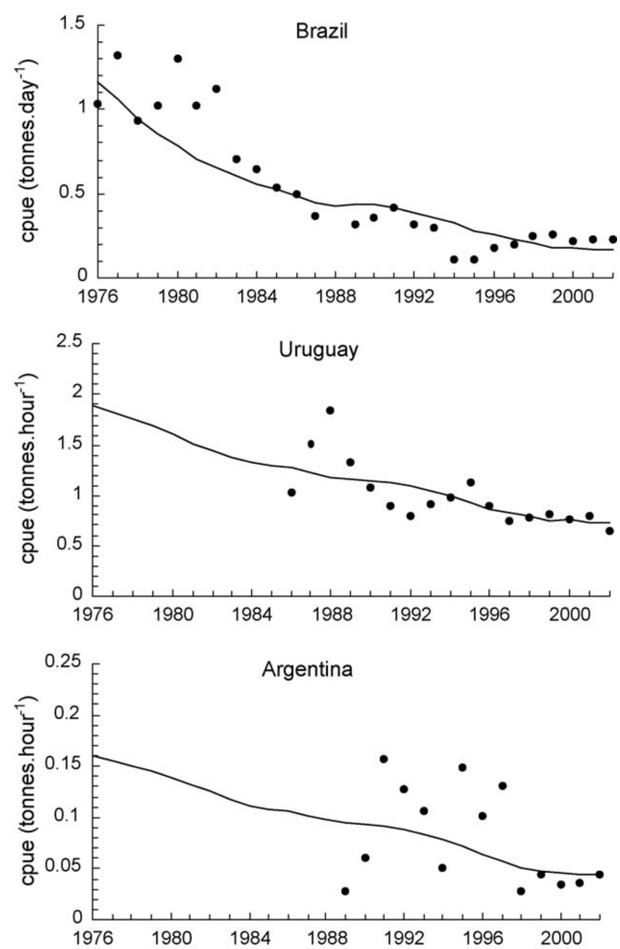

Fig. 3. Best fit models to time series of cpue of trawlers in Brazil, Uruguay and Argentina.

Table 3
Summary of posterior probability distributions of model parameters with the diagnostic statistics for the MCMC chain

	Mean	Fixed r 95% probability	Geweke	Mean	Uniform r 95% probability	Geweke	Mean	Normal r 95% probability	Geweke
Brazil data only									
r	0.238	–	–	0.131	0.017, 0.309	−2.020	0.136	0.014, 0.295	−0.638
k	177648	170699, 187069	0.824	274994	146644, 439439	2.268	268043	152002 445805	−0.015
log q Br	−17.922	−19.907, −13.617	−1.984	−18.235	−19.922, −15.457	0.021	−18.656	−19.947, −15.200	1.805
b	−0.490	−0.662, −0.123	−2.013	−0.464	−0.639, −0.259	1.216	−0.494	−0.639, −0.225	1.837
Brazil and Uruguay data									
r	0.238	–	–	0.146	0.015 0.434	1.197	0.174	0.024 0.344	−2.122
k	491669	473468, 518102	−2.133	742464	314010, 1202496	−1.407	640572	378891, 1092585	1.985
log q Br	−18.399	−19.893, −14.147	2.298	−18.166	−19.888, −13.431	1.680	−18.496	−19.981, −14.333	2.233
b	−0.402	−0.533, −0.069	2.287	−0.345	−0.536, 0.0123	2.051	−0.387	−0.533, −0.061	1.477
log q Ur	−5.411	−5.680, −5.157	2.039	−5.774	−6.451, −5.035	−1.214	−5.701	−6.481, −5.056	2.277
Brazil, Uruguay and Argentina data									
r	0.238	–	–	0.129	0.0152, 0.339	−2.013	0.131	0.006, 0.305	−0.890
k	650039	623819, 688438	−1.723	1007256	502924, 1591692	1.332	995860	543860, 1684836	0.596
log q Br	−18.459	−19.940, −15.732	1.563	−18.338	−19.879, −15.174	2.256	−18.548	−19.907, −15.291	−0.533
b	−0.371	−0.483, −0.162	1.566	−0.321	−0.071, −0.493	2.216	−0.337	−0.478, −0.098	−0.778
log q Ur	−5.750	−5.497, −6.025	1.363	−6.151	−6.781, −5.463	−1.242	−6.149	−6.805, −5.516	−0.628
log q Ar	−15.285	−15.573, −15.014	0.859	−15.677	−16.315, −14.991	−1.322	−15.676	−15.044, −16.350	0.732

show that there are some systematic trends in residuals in the three time series. We speculate that these systematic trends may be due to process errors caused by some environmental factors that could be affecting, for instance, stock productivity throughout the distribution of the species. The exact nature of these trends need be evaluated in the context of past trends in oceanographic processes and of indicators of changes in stock productivity (e.g. recruitment and growth rates).

The assessment of the status of the white croaker was based on a production model because of its suitability for situations when only catch and cpue data are available. Despite the fact that they are very simple, production models have been shown to provide very similar results to age-structured models and in some times better estimates of policy parameters even when age-structured data is available (Ludwig and Walters, 1985; Hilborn and Walters, 1992). One implicit assumption of production models is that harvest selectivity does not change over time. Changes in harvest selectivity would impact the results of the assessment in two ways. First by changing the proportion of the stock vulnerable to exploitation and, consequently, invalidating the assumptions of constant catchability. In this context changes in the harvest selectivity of trawl fisheries would be critical for the assessment because trawl cpue was used as index of abundance. There is no reason to believe that the harvest selectivity of trawlers has changed as the power of the boats, harvest technologies, fishing areas by the pair trawlers that land in Rio Grande have changed very little over time (Haimovici et al., 1989; Haimovici et al., 2006). The other possible effect of changes in harvest selectivity would be to change the size structure of the stock and its intrinsic rate of growth. This effect would be subjacent to the density-dependent changes in the stock growth rate, which is captured by the Schaefer model as $dB/dt = (r(K - B))/K$. The latter effect seems to be more relevant to the white croaker as changes in growth rate of the species were evident in southern Brazil with the decline in stock abundance resulting from intense exploitation (Haimovici and Ignácio, 2005). These observed density-dependent changes in growth rates suggest that the choice for a production model is particularly adequate in this case to describe the dynamic of the stock.

Table 3 shows the estimated parameters according to the hypothesis of stock discreteness and the assumptions about prior probability distributions for parameter r. Overall the model tends to estimate lower r values than expected for the species, based on its biological parameters and the approach used to estimate r described in the methods. Consequently the model tends to estimate higher k values to compensate for the estimated low productivity of the stock. This result is normally obtained when applying production models to "one-way trip" time series of cpue data with low contrast in exploitation rates and stock abundance (Hilborn and Walters, 1992). Adding more informative priors for r helped increase slightly the estimated r values in all cases, although the estimates remained below the expected intrinsic rate of increase obtained based on the species life history characteristics ($r = 0.238$). This difference reflects on the one hand that the likelihood of parameter r has a very narrow distribution biased towards the lower range of r values. On the other hand it indicates that the probability of r has only a small influence on the overall posterior probability of model parameters computed by the MCMC method, i.e., the model performance in fitting the data is not very sensitive to the value of r because of the poor contrast in the data time series.

The estimated virgin stock size (k) and msy were more sensitive to the hypotheses about stock discreteness (Tables 3 and 4). If the hypothesis of a Brazilian stock is assumed true, the posterior mean of parameter k is estimated between 177,648 and 274,994 tonnes and msy between 7459 and 10,570 tonnes year^{-1}. On the other hand, adding data from Uruguay and Argentina, under the assumption of a single stock south of 29°S, leads to an estimated k between 650,039 and 1,007,256 tonnes and msy between 26,549 and 38,677 tonnes year^{-1}. There are no independent biomass estimates for the same areas to compare with the assessment carried out in the present study. The total biomass of demersal bony fish in southern Brazil in the early 1970s was estimated between 257,000 and 406,000 tonnes (Yesaki et al., 1976), being the white croaker one of the most abundant species. Haimovici et al. (1996) estimated, using the swept area method, an average biomass of white croaker of ca. 20,000 tonnes during the early 1980s in an area in southern Brazil from 30° 43′S and 33° 45′S. This biomass is likely to be an underestimate for a stock in southern Brazil, considering that: the reported catches in the period (when the stock was considered moderately exploited) were in the order of 15,000 tonnes year^{-1}; and that the survey area was relatively small compared to the distribution area of the stock, especially considering the migratory behavior of the species. Carozza and Hernández (2004) estimated a virgin stock size of ca. 700,000 tonnes in the Argentinean and Uruguayan Common Fishing Zone using a likelihood approach to estimate parameters of a production model. Their estimate is in the same order of magnitude obtained in the present study under the assumption of a single stock shared among Brazil, Uruguay and Argentina.

Table 4
Summary of estimated policy parameters for white croaker according to the origin of the data used in the estimation and the type of prior information on parameter r of the Schaeffer model

Hypothesis	MSY (tonnes year^{-1})	F_{2002}/F_{msy}	B_{2002}/B_{msy}
Brazil			
$r = 0.238$	10570 (10156–11130)	2.8 (1.9–4.3)	0.6 (0.4–0.8)
Uniform r	7459 (1842–11441)	5.4 (2.1–18.7)	0.6 (0.4–0.8)
Normal r	7818 (1541–11340)	6.5 (2.1–19.3)	0.6 (0.4–0.8)
Brazil and Uruguay			
$r = 0.238$	29254 (28171–30827)	2.4 (1.7–3.4)	0.6 (0.4–0.8)
Uniform r	20486 (4580–34117)	5.3 (1.7–19.4)	0.6 (0.4–0.8)
Normal r	24398 (6658–32818)	4.5 (1.6–13.9)	0.6 (0.4–0.8)
Brazil, Uruguay and Argentina			
$r = 0.238$	38677 (37117–40962)	1.9 (1.4–2.6)	0.6 (0.4–0.8)
Uniform r	26549 (6003–42879)	3.8 (1.5–13.2	0.6 (0.4–0.8))
Normal r	28052 (7313–41709)	3.3 (1.5–10.9)	0.6 (0.5–0.8)

Parameter values for the mean and 95% probability intervals are provided for each estimation scenario.

The predicted values for management parameters are much less sensitive to the hypothesis assumed true (Table 4), and indicate that the species is currently overfished (B at ca. 60% of B_{msy}) and under heavy overfishing (F between approximately 2 and 6 times the F_{msy}). These results are corroborated by the assessment carried by Carozza and Hernández (2004) that showed that the biomass of the stock of white croaker exploited in Common Fishing Zone is 43% of the optimal biomass, and recommended that catches be reduced to allow the recovery of the stock. Similarly, the average fishing mortality rate of ca. 0.2 year^{-1} estimated for southern Brazil during the last 5 years of the time-series is comparable to an independent estimate obtained using catch curve ($F = 0.22$ year^{-1}; Haimovici and Ignácio, 2005). Haimovici and Ignácio (2005) concluded that the current exploitation rate of white croaker is unsustainable and that a marked decline in catches is expected in the near future. These assessments contradict the conclusion of Arena and Rey (2003) that the stability of Uruguayan fisheries yield in recent years signals that the stock is currently fully fished but not yet overfished. Our evaluation is that their conclusion was influenced by the use of an equilibrium form of the production model which tends to overestimate surplus production and underestimate the magnitude of stock decline (Hilborn and Walters, 1992; Polacheck et al., 1993).

Total catches of white croaker by the three countries have oscillated between 26,006 and 72,908 tonnes but have maintained an average of 47,987 tonnes from 1976 to 2002 (Table 1, Fig. 2), which is above the most optimist estimates of msy (Table 4). That does not include the portion of the catches that is illegally harvested and not reported to the official agencies. This problem can be particularly important in Brazil as it is well known locally that a considerable amount of the landings, particularly of artisanals, is not sold to the local fishing industries (monitored by fishery agencies) but to middle men at the landing ports.

As it is suggested in this study, historical catches could have been sustained only by a large virgin stock size that has been fished at increasing levels of fishing mortality. The marked decline in cpue indicates that catches have in fact being maintained relatively stable at the expenses of increasing fishing effort with time, specially of the gillnet fishery that is more efficient in terms of fuel consumption. These results support the conclusion that the current exploitation rates are unsustainable and that, if this situation continues, the fisheries south of 29°S are very likely to experience a decline in catches in the future. According to the model presented in this paper if the current exploitation rate is maintained, irrespective of the hypothesis about stock discreteness, the stock of white croaker is likely to reach in the short-medium term

(1–10 years) a critical threshold to the biological sustainability of the fishery.

There are no target or limit reference points applied for the management of this species in the region. In this paper we opted to use two common reference points ($F_{\text{current}}/F_{\text{msy}}$ and $B_{\text{current}}/B_{\text{msy}}$), used for instance by ICCAT and by FAO in the evaluation of the status of stocks, but we deliberately avoided discussing their role as target or reference points in the management of the white croaker. It is a discussion to be held with managers and fisheries stakeholders and depended exclusively on their willingness to accept risk. Most often these reference points are used as targets while smaller fractions of B_{msy}, (e.g. 50% of B_{msy}) are used as limit reference points to indicate the need to decrease fishing pressure so as to avoid the risk of stock collapse. The available information indicates that the stock of white croaker exploited in the Southwest Atlantic are probably very close to such a threshold and more conservative fishing strategies need to be employed for the sustainability of the fishery. Concerted management actions in all three countries, ideally by joint efforts, are needed to maintain the stock at safer levels of exploitation.

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