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THE FISHERY EXPLOITATION OF ACOUPA WEAKFISH OFF SÃO PAULO COAST, SOUTHEASTERN BRAZIL*

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ABSTRACT

The Acoupa weakfish *Cynoscion acoupa* (Lacepède, 1801) is a large inshore sciaenid of commercial and social importance found along the entire Brazilian coast. In spite of this, there is few information on the species, both in terms of biological aspects and fishery yields, particularly off southeastern Brazil. Within this context, this study aimed to an evaluation of Acoupa weakfish fishery production off São Paulo coast (23°22'–25°18'S) based on publicly available statistical data collected between 1998 and 2016. Acoupa weakfish fishery in this State takes place on both industrial and artisanal scales, and employs at least 22 different fishing gears. The pair-trawling fishery was the most important Acoupa weakfish producer during the period surveyed, with a sharp decline in the catches from 2007 onward due to the establishment of Marine Protected Areas off São Paulo coast, which banned trawling in depths shallower than 26 meters. Acoupa weakfish yields were relatively low in São Paulo when compared with other demersal fishes exploited, despite the high retail prices commanded by the species in regional markets and restaurants.

Key words: demersal resources; LPUE; fishery; fishing gears; fishing yields; Sciaenidae.

A EXPLORAÇÃO PESQUEIRA DA PESCADA-AMARELA NA COSTA DE SÃO PAULO, SUDESTE DO BRASIL

RESUMO

A pescada-amarela *Cynoscion acoupa* (Lacepède, 1801) é um cianídeo demersal costeiro de grande porte que apresenta importância social e econômica ao longo de toda a costa brasileira. Entretanto, há pouca informação sobre a espécie em termos biológicos e pesqueiros, principalmente no sudeste do Brasil. Dentro desse contexto, o presente estudo procurou avaliar a produção pesqueira da espécie na costa de São Paulo (23°22'–25°18'S) a partir de dados estatísticos de domínio público coletados entre 1998 e 2016. A pescaria da pescada-amarela no estado ocorre em escala industrial e artesanal, e emprega pelo menos 22 tipos de artes de pesca. O arrasto de parelhas foi o mais importante produtor durante o período estudado, apresentando um declínio abrupto nos desembarques a partir de 2007, devido a implementação de Áreas Marinhas Protegidas na costa paulista, que baniu a pesca de arrasto em profundidades menores que 26 metros. Os desembarques de pescada-amarela são relativamente baixos em comparação a outros peixes demersais capturados apesar dos altos preços de varejo cobrados para a espécie nos mercados e restaurantes regionais.

Palavras-chave: recursos demersais; LPUE; pescaria; artes de pesca; produção pesqueira; Sciaenidae.

INTRODUCTION

The Acoupa weakfish *Cynoscion acoupa* (Lacepède, 1801) comprises an important fishery resource in South America, particularly off the Brazilian coast (Almeida, 2016). This large inshore sciaenid (reaching 175 cm and up to 14 kg) has a wide latitudinal distribution on the western Atlantic, ranging from Panamá (14°N) to northern Argentina (40°S), inhabiting soft bottoms between 1–35 m deep (Barletta et al., 2003; Almeida, 2016; Matos and Lucena, 2006). The species is valued mostly by its swim bladder (which is exported dried to Asiatic markets), being also regarded as an important food fish (Mourão et al., 2009).

Along the Brazilian coast, the Acoupa weakfish is exploited mostly by artisanal fisheries, particularly off the Northern States (from Amapá to Maranhão, 4°N–3°S) (Matos and Lucena, 2006). This region yields >80% of the national production, with the species being caught chiefly by gillnets (Frédou and Asano Filho, 2006; Matos and Lucena, 2006; Almeida et al., 2011). Despite its socio-economic importance, the Acoupa weakfish fisheries production is poorly recorded in Brazil. This is expected due the diverse ichthyofauna exploited by commercial fisheries in the country, where detailed landing statistics are focused on very abundant or high-valued fishery resources (Freire and Pauly, 2015).

Presently, there are no fishery regulations controlling the exploitation of Acoupa weakfish in Brazil. This is of concern because large bodied sciaenids are particularly vulnerable to overexploitation (e.g. *Bahaba taipingensis*, Sadovy and Cheung, 2003; *Totoaba macdonaldi*, Lercari and Chávez, 2007; Valenzuela-Quiñonez et al., 2015; *Argyrosomus coronus*, Potts et al., 2010; *A. japonicus*, Ferguson et al., 2014; *Pogonias cromis*, Chao et al., 2015). Actually, the Acoupa weakfish is currently considered Near Threatened (NT) off Brazilian North coast, according to the IUCN criteria (Chao et al., 2015).

Acoupa weakfish fisheries off southeastern Brazil have never been surveyed in detail, despite its relative socio-economic importance. The species, notwithstanding its low production, command high retail prices in regional markets and restaurants (R.S. Martins, personal observation). Thus, given the lack of published information on Acoupa weakfish fishing off southeastern Brazil, it is clear that a timely analysis of available fisheries data is a prerequisite for a precautionary management approach for this likely vulnerable species.

Bearing in mind the above, this study aimed for a characterization and analysis of Acoupa weakfish fishing from fisheries statistical data collected in São Paulo, as a step toward a better knowledge of this poorly studied fishery resource off southeastern Brazil.

MATERIAL AND METHODS

Acoupa weakfish time series catches were obtained from publicly available statistical data collected between 1998 and 2016. Data were gathered on a census basis at every artisanal and industrial landing site along São Paulo coast (23°22′–25°18′S; Figure 1) by local observers. Collected data were compiled by the São Paulo Fisheries Institute, where the information was crosschecked and included into an online database (ProPesq® Fishery Statistical System, Ávila-da-Silva et al., 1999). This time interval was chosen because 1998 was the first year of the time series data available at ProPesq® and 2016 was the most recent and complete dataset complied.

The database has production and grouping variables. The former includes: kg landed, number of landings, number of productive units (fishing vessels) and revenue. The latter comprises the vernacular name of the fishing resource, taxonomic group (finfish, elasmobranchs, crustaceans and molluscs), fishing gear type, landing town, month and year.

Fishing gear types used in Acoupa weakfish fishing were surveyed according to the information available in the database and their distribution plotted geographically to identify patterns and incidence of use of each fishing gear along the coast. Because the disproportional differences in the catches yielded by distinct fishing gears (ranging from few kilograms to 100s tonnes), results were sorted by catch magnitude (in weight) accumulated between 1998 and 2016, for clarity. These were: large caches (< 750 tonnes), moderate catches (< 2 tonnes) and low catches (< 0.07 tonnes).

Relative abundance was estimated as the nominal landing-per-unit-effort (LPUE), calculated as the ratio between the catches (in tonnes) and the generic fishing effort (number of fishing trips, which for practical purposes were assumed to be the same number of recorded landings), and expressed as tonnes fishing trip^{-1}. Despite the inherent biases of this method (Maunder et al., 2006; King, 2009), this approach was chosen due the lack of refined effort data for each fishing gear employed for catching Acoupa weakfish.

Acoupa weakfish production and LPUE was analysed taking in account temporal and spatial scales, including year, season and sub-regional divisions, i.e. north coast (23°22′–23°45′S), central coast (23°45′–24°14′S) and south coast (24°14′–25°18′S) (Figure 1). The latter followed the official geopolitical division adopted by the State government for the local littoral zone.

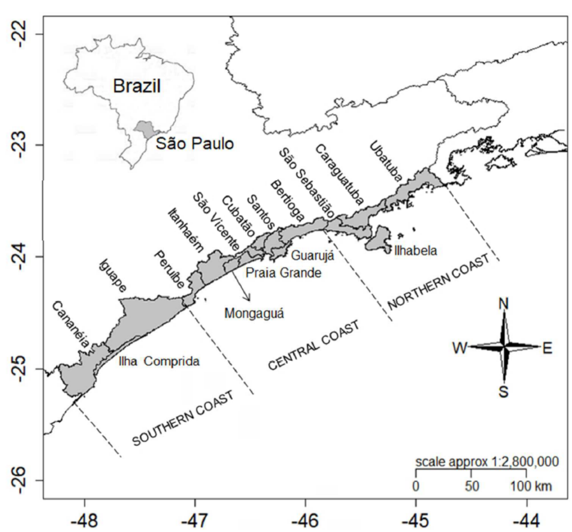

Figure 1. Study area, showing the 16 coastal towns off São Paulo coast and the three sub-regional divisions.

RESULTS

Overall, the Acoupa weakfish was a minor component of São Paulo State marine fisheries, comprising just 0.24% (~ 1,196 tonnes) of the total landed (all species pooled). Estimate Acoupa weakfish total revenue reached some US$ 2 million (inflation-corrected), corresponding to 0.5% of the total ex-vessel revenue of all catches landed in São Paulo between 1998 and 2016 (~ US$ 423 million).

At least 22 different fishing gears were employed for Acoupa weakfish fishing off São Paulo coast, including one "undetermined" category. This "undetermined" category reflect the lack of data on the fishing gear employed instead of an uncategorized fishing gear. Likewise, there was an elusive "extractivism" category with no specified fishing gear and insignificant landings (data not show), and therefore "extractivism" was not accounted herein (Table 1).

Table 1. Fishing gears employed at catching Acoupa weakfish (*Cynoscion acoupa*) off São Paulo coast between 1998 and 2016, sorted by landing frequency. Total catches and the number of landing towns for each fishing gear are also showed.

Fishing gear	Landings (n)	Catches (t)	Landing towns (n)
Bottom gillnet	16,033	268.8	15
Miscellaneous gillnet	2,485	64.1	16
Fish pen	1,437	11.4	3
Double-rig trawl	1,185	36.3	13
Multi-gear	1,000	13.5	16
Undetermined	582	29.6	6
Surface gillnet	529	4.7	13
Pair trawl	356	747.4	3
Otter trawl	254	1.1	6
Beach seining	140	1.5	6
Pound net	128	1.0	2
Purse seine	35	14.9	3
Fishing rod	34	0.4	2
Hand line	27	0.3	4
Bottom longline	9	0.05	1
"Gerival"*	9	0.2	2
Squid jigs	9	0.7	2
Cast net	6	0.03	2
Speargun	5	0.06	2
Surface gillnet (drifting)	4	0.05	1
Miscellaneous longline	5	0.1	1
Miscellaneous lines	2	0.02	1

*kind of drifting artisanal trawl

Bottom gillnet was the commonest fishing gear used, including some 16,033 landings, being present in 15 out 16 towns along the coast. "Miscellaneous gillnet" (i.e. gillnet type not specified) was the second fishing gear most used, with 2,485 landings, present in all 16 towns along the coast. Fish pens were the third most employed fishing gear, totalling 1,437 landings, being present in just three towns on the south coast (Table 1).

Double-rig trawl was also frequent (1,185 landings during the study period), being present in 13 out 16 towns. It is worth to note that the pair trawl, with 356 recorded landings in just three out 16 towns along the coast, was the most important fishing gear used for Acoupa weakfish fishing off São Paulo coast (see below). The least frequently confidentially identified fishing gear employed was the drifting surface gillnet, with four landings recorded in just one town (Table 1).

The spatial distribution of fishing gears employed in Acoupa weakfish fishing in São Paulo is depicted in Figures 2, 3 and 4. Amongst the most productive fishing gears, gillnets and double-rig trawl were present in most towns, with the latter found more often on the north coast (from São Sebastião to Ubatuba). Pair trawl and purse-seine were employed at Santos/Guarujá and Ubatuba and Santos/Guarujá and São Sebastião, respectively (Figure 2).

Out of the seven fishing gears that yielded moderate amounts of Acoupa weakfish, the surface gillnet and the unspecific "multi-gears" were present all over the coast. Pound nets were restricted to three towns on the north coast, being more frequent in São Sebastião (Figure 3). The category of "undetermined" fishing gears were present at central and south coasts, more commonly in the latter region. Fish pens, "Gerival" and fishing rods were restricted to the southernmost towns (Iguape and Cananéia, respectively) (Figure 3).

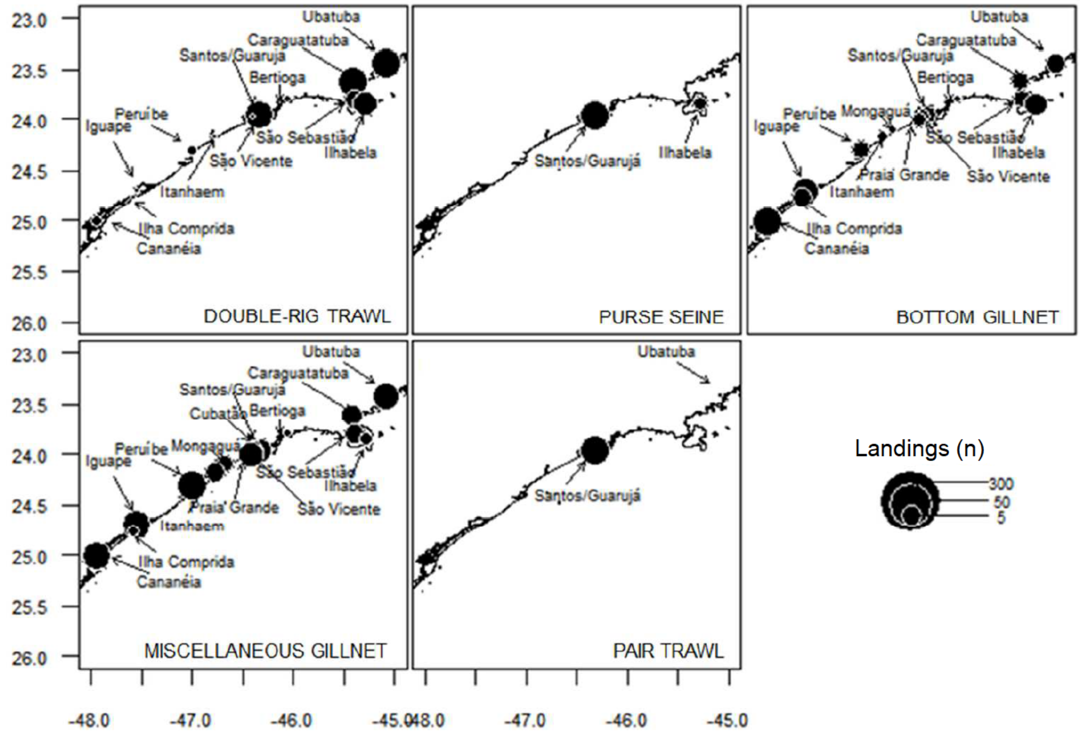

Figure 2. Spatial distribution of fishing gears that yielded large amounts (annual catches < 750 tonnes) of Acoupa weakfish off São Paulo coast between 1998 and 2016. Data were log-transformed for better visualization.

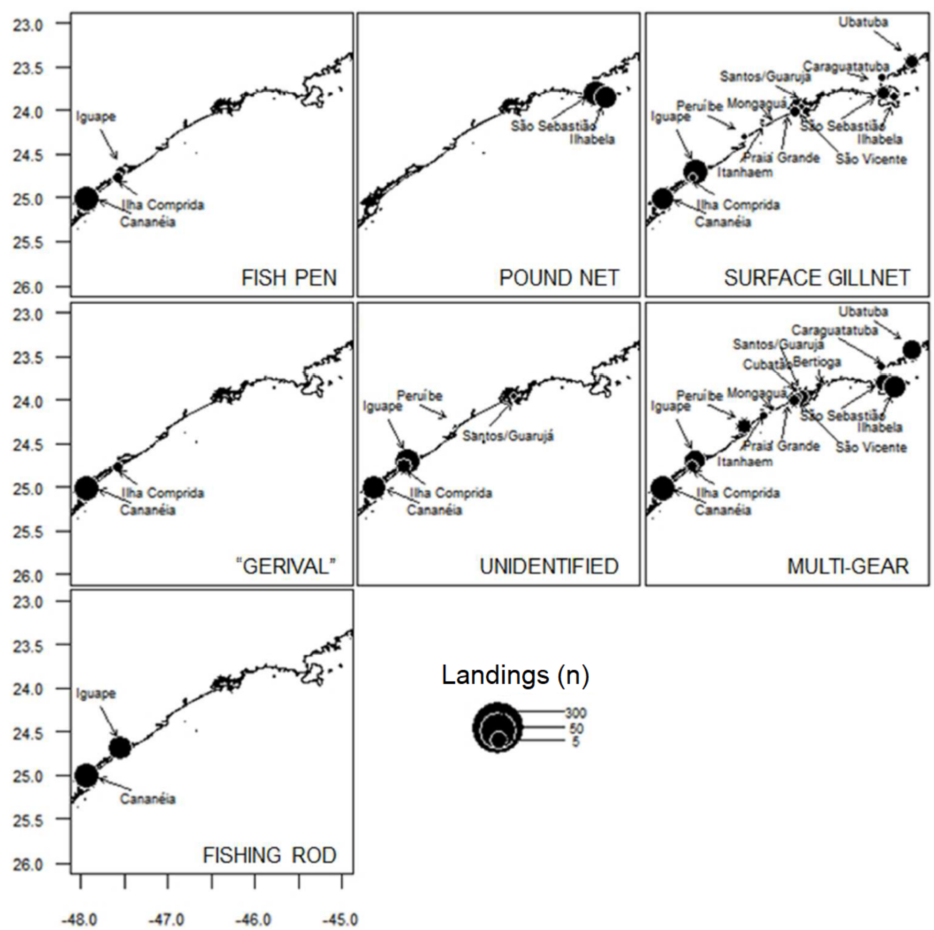

Figure 3. Spatial distribution of fishing gears that yielded moderate amounts (annual catches < 2 tonnes) of Acoupa weakfish off São Paulo coast between 1998 and 2016. Data were log-transformed for better visualization.

Among the most important fishing gears that yielded low catches, “miscellaneous lines” were restricted to the northern coast, whereas drifting surface gillnet was recorded only on the southern coast. The remaining low production fishing gears were more or less scattered along the coast, except for squid jigs, that occurred only on the northern coast (Figure 4).

For practical purposes, we considered “main fisheries” those where (a) the Acoupa weakfish was caught on a regular basis (both seasonally and interannually), (b) with fishing gears confidentially identified (this excluded the categories “miscellaneous”, “undetermined” and “multi-gears”), and (c) had total landings exceeding 10 tonnes between 1998 and 2016. Following these criteria, only four fisheries were accounted: the artisanal scale bottom gillnetting and fish pens and the industrial scale pair and double-rig trawling.

Bottom gillnetting was the most important artisanal Acoupa weakfish fishery, yielding some 269 tonnes (0.02% of total catches, 22th in frequency). The highest and lowest contribution of Acoupa weakfish to bottom gillnetting catches took place in 1998 (16%) and 2001 (0.4%). Acoupa weakfish accounted for 0.5% of fish pens catches (11th in frequency), with an estimated production of 11.4 tonnes (Table 1).

Pair trawling produced 747 tonnes of Acoupa weakfish between 1998 and 2016 (Table 1), being the largest contributor to Acoupa weakfish catches off São Paulo coast, accounting for 62.5% of total catches (all fisheries pooled). The species comprised 0.84% of pair trawling catches, being the 13th in frequency. Double-rig trawling produced some 36.3 tonnes of Acoupa weakfish during the study period (0.05% of all catches pooled), with the species appearing at the 46th position in frequency (Table 1).

Overall, the bulk of Acoupa weakfish catches was landed in the central coast, and most of which was caught by pair-trawlers. This scenario changes substantially if pair trawling is not accounted, indicating that the southern coast had the largest amount landed (mostly by bottom gillnets). Acoupa weakfish catches on the north coast was much lower when compared to the central and south coasts, and again, bottom gillnetting was the largest contributor (Table 2).

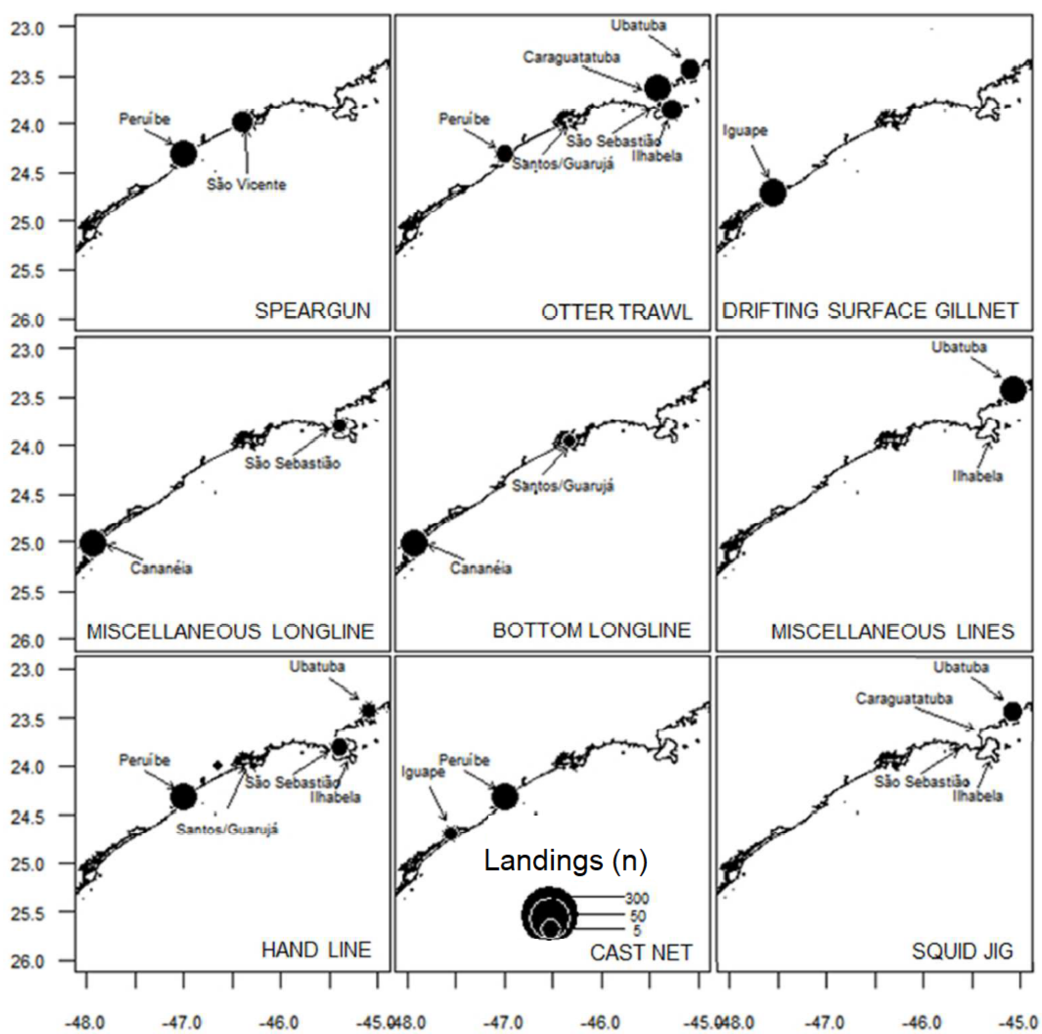

Figure 4. Spatial distribution of fishing gears that yielded low amounts (annual catches < 0.07 tonnes) of Acoupa weakfish off São Paulo coast between 1998 and 2016. Data were log-transformed for better visualization.

Table 2. Regional patterns of Acoupa weakfish production (tonnes) and average LPUE (±SD, tonnes fishing trip^{-1}; given within brackets) off São Paulo coast between 1998 and 2016.

Sector	Pair trawl	Double-rig trawl	Bottom gillnet	Fish pen	Main fisheries pooled	Remaining fisheries minus pair trawl	Remaining fisheries minus main fisheries	Total
Northern	0.4	9.5 (2.5±0.06)	53.5 (5.6±0.06)	--	63.4 (8.5±0.50)	81.7 (14.1±0.04)	18.7 (6.0±0.03)	82.1 (14.5±0.04)
Central	747.0 (161.1±1.62)	26.6 (11.9±0.70)	17.4 (8.3±0.21)	--	790.9 (108.3±1.13)	115.0 (72.8±0.80)	71.1 (52.6±1.04)	862.0 (233.9±1.10)
Southern	--	0.2 (0.2±0.03)	197.9 (8.7±0.02)	11.4 (2.15±0.01)	209.5 (11.1±0.02)	252.5 (24.7±0.02)	43.0 (13.6±0.02)	252.5 (24.7±0.02)
Total	747.4 (161.5±1.62)	36.3 (14.6±0.33)	268.8 (22.6±0.10)	11.4 (2.15±0.01)	1,063.8 (200.9±0.56)	449.2 (111.6±0.32)	401.5 (94.8±0.34)	1,196.6 (273.1±0.50)

The lowest and largest Acoupa weakfish production were 13 tonnes in 2007 and 224 tonnes in 2005, averaging 62 (± 60 SD) tonnes during the period surveyed. Earlier catches dropped sharply between 1998 and 1999 (a decrease of 84%) and then increased dramatically between 2002 and 2007, remaining bellow ~ 53 tonnes yr^{-1} thereafter (Figure 5).

Interannual trends of Acoupa weakfish yields and LPUE for the main fisheries are depicted in Figures 6 and 7. Bottom gillnetting catches had a crescent tendency between 1998 and 2016. It is remarkable that catches had a strong increment form 2007 onward, peaking in 2012 and decreasing thereafter (Figure 6). A smaller peak can be discerned in 2004, with more or less stable production in the following three years (Figure 6).

The mean bottom gillnet LPUE was highest in 1998 (0.14 tonnes fishing trip^{-1}), decreasing sharply in the following four years and oscillating between 0.01 and 0.05 tonnes fishing trip^{-1} from 2006 onwards. The effort increased steadily from 1998–2007, with a strong increase thereafter, peaking in 2012, declining abruptly in the following three years and remaining constant in the last couple of years of the time series (Figure 7).

Fish pens also had two peaks of production (2003 and 2015), and a steep increase between 2009 and 2016 (Figure 6). The average LPUE had two distinct peaks (2002: 0.016 tonnes fishing trip^{-1} and 2009: 0.011 tonnes fishing trip^{-1}), displaying a steady but smooth increase tendency over the whole time series (Figure 7). Overall, the fishing effort increased steeply over the whole time series, with the effort in 2015 nearly 20 times higher than that of 1998. However, effort remained relatively low between 2004 and 2009 (< 50 fishing trips year^{-1}) (Figure 7).

Pair trawling yields were above 99 tonnes in 1998, remained under 10 tonnes between 1999 and 2001 and had an abrupt increase between 2002 and 2006, with a peak of ~ 200 tonnes in 2005. Catches decreased dramatically from 2007 onward, never exceeding 30 tonnes until the end of the time series (Figure 6). There were no Acoupa weakfish catches in 2010 (Figure 6).

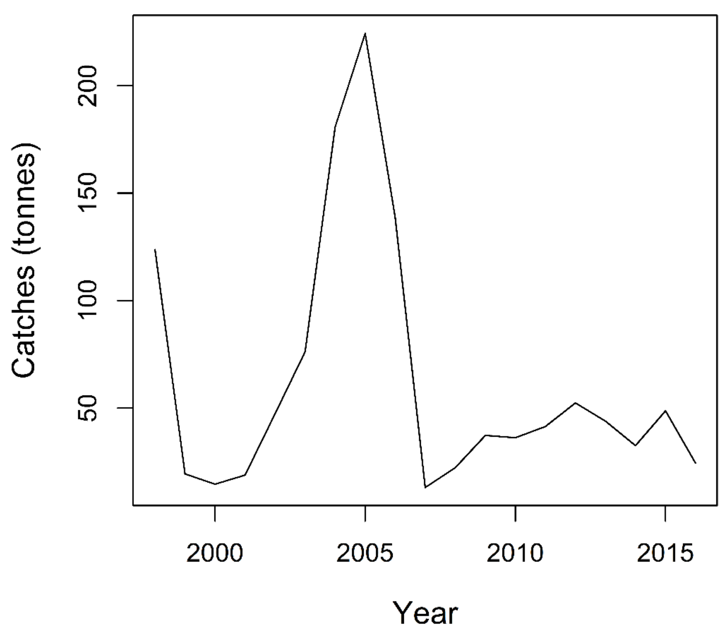

Figure 5. Time series of Acoupa weakfish catches off São Paulo coast between 1998 and 2016.

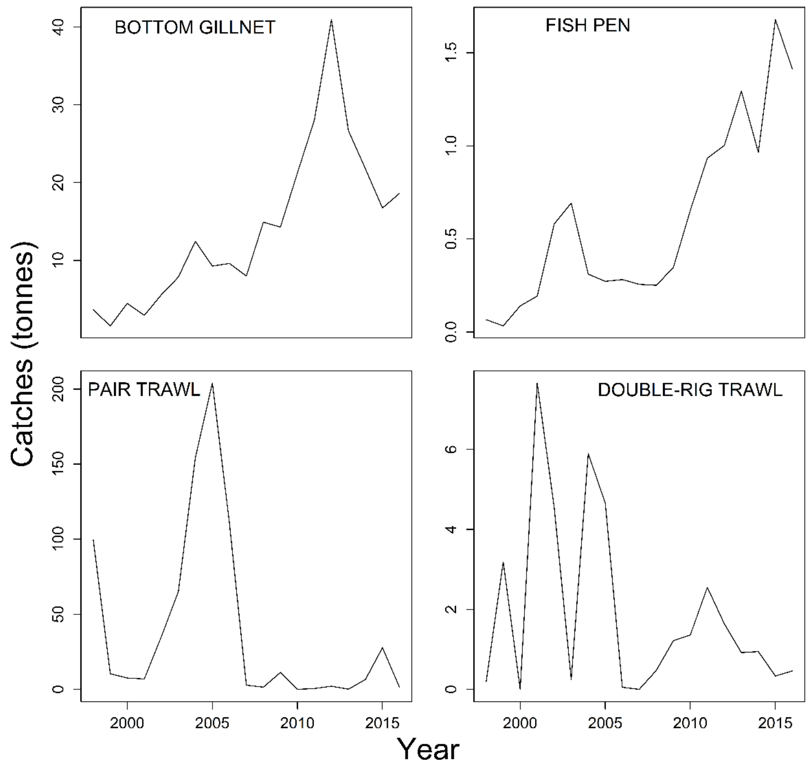

Figure 6. Annual recorded production of Acoupa weakfish caught by the main fisheries off São Paulo coast between 1998 and 2016. Note the different *y*-axis.

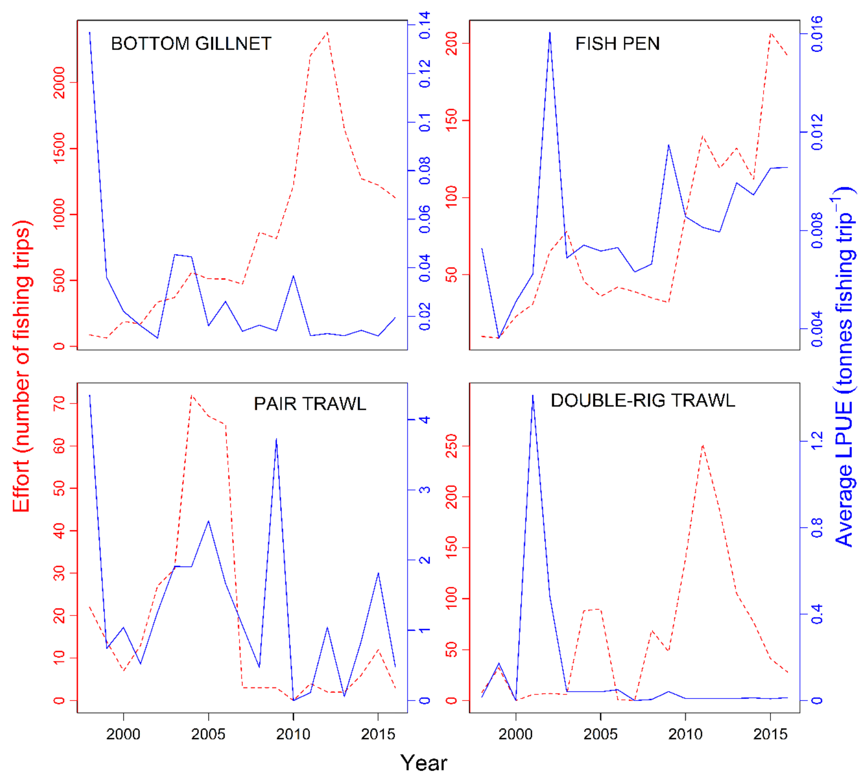

Figure 7. Annual effort (continuous line) and LPUE (broken line) of Acoupa weakfish main fisheries off São Paulo coast between 1998 and 2016. Note the different *y*-axis.

Average LPUE behaved erratically, with at least seven discernible peaks on the time series. The highest LPUE was recorded in 1998 (4.4 tonnes fishing trip^{-1}) and the lowest in 2013 (0.06 tonnes fishing trip^{-1}). Fishing effort declined in the first three years, followed by and steep increase between 2000 and 2006 and an abrupt decreased from 2007 onward (Figure 7).

The bulk of double-rig trawling production took place between 1999 and 2005 (despite a minimum observed in 2003), never exceeding 30 tonnes thereafter, with a small peak (~ 25 tonnes) in 2011 (Figure 6). No Acoupa weakfish was landed by double-rig trawlers in 2000 and 2007 (Figure 5).The LPUE had a strong peak in 2001 (1.4 tonnes fishing trip^{-1}), remaining lower than 0.04 tonnes fishing trip^{-1} thereafter (Figure 7). The effort had five peaks over the 18 years, with the highest of them recorded in 2011 (252 trips) and the lowest in 2001, with a single trip documented (Figure 7).

Bottom gillnetting catches had a marked seasonality, with highest values during austral spring-summer (September-March) and lowest captures during autumn-winter (April-August) (Figure 8). Both LPUE and effort had the same seasonal signal found for catches (Figure 8).

Fish pens catches increase from April onward, peaking in October (Figure 8). Average LPUE dropped between April and September, whereas effort had an inverse tendency, with more trips on the same period (Figure 9).

Seasonal signal of catches was less clear for pair trawling due two peaks detected in February and July. Ignoring those “noisy” peaks, catches seems to decline from January to December, with lowest catches detected in October (Figure 8). LPUE and effort follows the same tendency of catches (Figure 9).

Double-rig trawling catches had no discernible seasonal pattern, with lowest and highest catches in March and July, respectively (Figure 8). However, average LPUE and effort had an inverse signal, i.e. whenever average LPUE was high, the concomitant effort was low (and *vice versa*) (Figure 9).

An analysis of catches of all fisheries pooled and all fisheries pooled minus the main fisheries (i.e. bottom gillnetting, fish pens, pair and double-rig trawling) was very similar to the signal detected for pair-trawling, with catches decreasing from January to December, also having the same peaks months (February and July) and the lowest value in October (data not show).

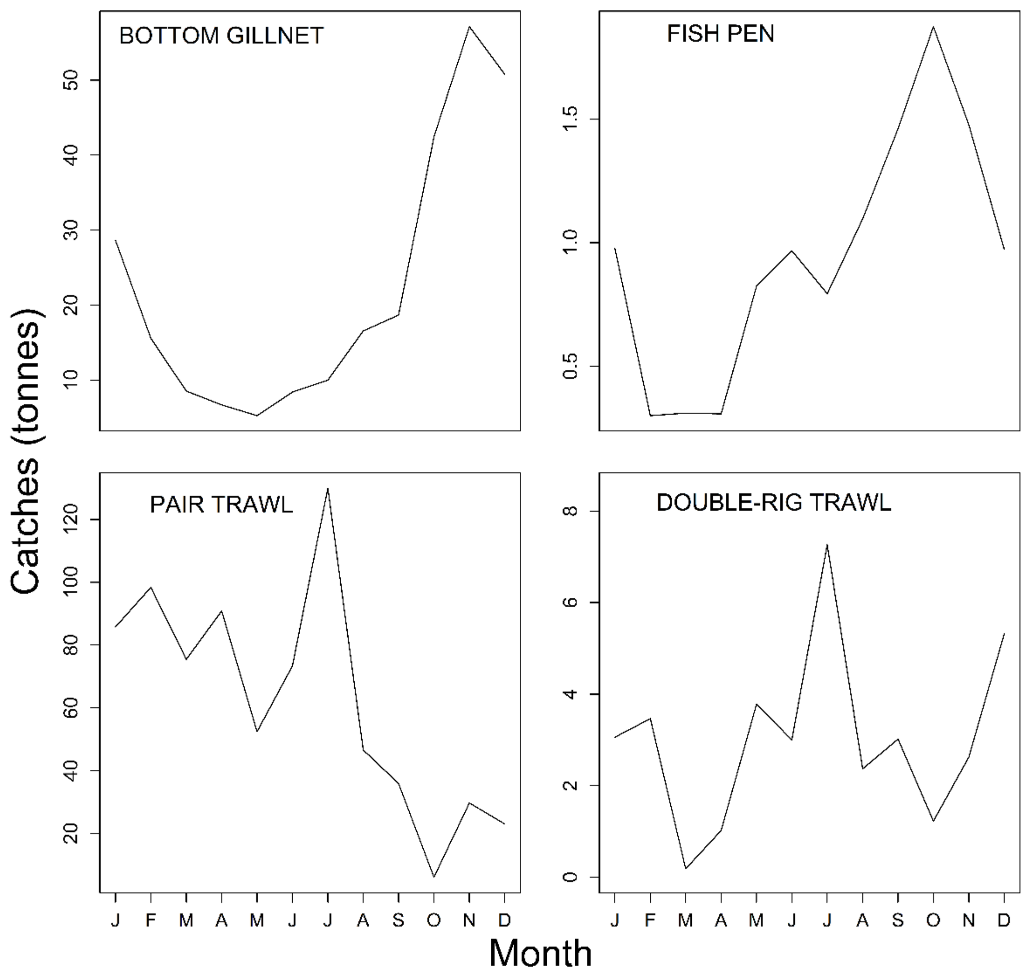

Figure 8. Seasonal production of Acoupa weakfish caught by the main fisheries off São Paulo coast between 1998 and 2016. Note the different *y*-axis.

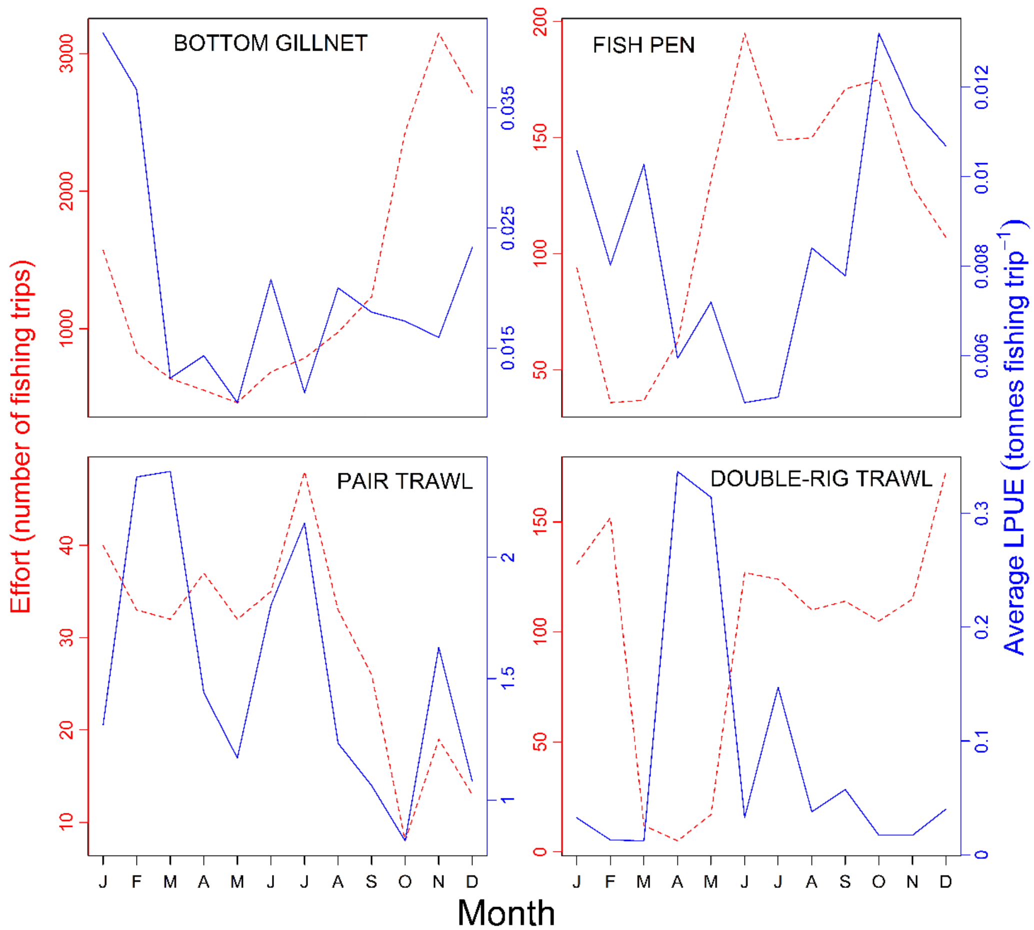

Figure 9. Seasonal effort (continuous line) and LPUE (broken line) of Acoupa weakfish main fisheries off São Paulo coast between 1998 and 2016. Note the different *y*-axis.

DISCUSSION

Despite its relative socioeconomic importance, there is limited information on Acoupa weakfish off southern Brazil. This contrast with the situation described for Brazilian North coast, where Acoupa weakfish production is much larger and the attached socio-economic importance is much greater, and therefore there is more research on the species (e.g. Matos and Lucena, 2006; Rodrigues et al., 2008; Mourão et al., 2009, Almeida et al., 2011; Barletta et al., 1998, 2003; Almeida, 2016; Ferreira et al., 2016; Vane et al., 2018). Thus, Acoupa weakfish fishery off São Paulo State may be characterized as "data-poor" (i.e. there is insufficient good quality scientific information to establish meaningful reference points for management) according to the classification of Richards and Maguire (1998).

Many fishing gears are employed for Acoupa weakfish fishing off São Paulo coast. This may be explained by the variety of different fishing practices, as most of those gears are used by artisanal fishers that operate inshore (Vasconcellos et al., 2011). Nonetheless, there is no directed fishing targeting the species, and catches are often the result of multispecific catches. Interestingly, there are exceptions to this general pattern: some artisanal gillnetters are "specialized" at catching Acoupa weakfish, i.e., they set their nets targeting primarily at the species. This is not unexpected, since the species is sold at premium retail prices in local restaurants and markets (~ US$ 7,00) kg^{-1}, R.S. Martins, personal observation, 2017).

The geographic distribution of each fishing gear along the coast was quite heterogeneous. For example, whereas gillnets were widespread along the coast, other fishing gears, such as the industrial pair-trawl and the artisanal "Gerival", were restricted to a few towns. This is due the particularity of each fishing gear. For instance, pair-trawl vessels require a large and complex harbour infrastructure and other facilities because of the bulky catches landed. In São Paulo State, this structure is found only in Santos/Guarujá; the single landing recorded in Ubatuba — where this kind of infrastructure does not exist — was clearly an exception to this rule. On the other hand, the artisanal "Gerival" fishing gear is very characteristic to the Iguape-Cananéia estuarine system, and is not found elsewhere (Mendonça and Katsuragawa, 2001).

Among artisanal fishing gears, inshore bottom gillnets were certainly the most important for the species, being widespread along the coast. In addition to Acoupa weakfish, bottom gillnetting captures other large and medium-sized inshore demersal fish, such as a few other sciaenids (mostly white croaker, *Micropogonias furnieri*), marine catfishes (Aridae) and demersal sharks, among others. Fish pens, which also operated inshore, likewise catch Acoupa weakfish regularly, although in a much smaller magnitude when compared to gillnets.

Bottom gillnetting and fish pen catches had an evident seasonal signal, with highest captures in austral spring-summer and lowest in autumn-winter, more remarkable in the former. At least in the case of bottom gillnetting, this pattern may be linked to the mullet (*Mugil liza*) fishing season that takes place between April and July (Lemos et al., 2014), when gillnetters direct part of their effort toward this species. Alternatively, gillnetters may simply decrease their fishing effort in the cold season due rough sea conditions and/or remove some nets placed on particular fishing spots to avoid interference with seasonal mullet beach seining. On the other hand, fish pens are static traps that remain fixed year round in an estuarine area, suggesting that the catch pattern maybe related to a likely seasonal inshore migration of Acoupa weakfish in the warm season. This is supported by the large size of fish caught in fish pens in this season (J.T. Mendonça, Instituto de Pesca, personal communication, 2018).

Pair trawl was the most productive fishing gear for the species, operating at an industrial scale. Pinpointing pair trawling fishing grounds for Acoupa weakfish is difficult, because this fleet operates in a wide latitudinal range (22–29°S; Valentini and Pezzuto, 2006). However, the steep drop in Acoupa catches following the implementation of Marine Protected Areas (MPAs) — which banned trawling in in shallow waters (< 26 m deep) from 2007 onward — suggest that at least some of the main fishing grounds may be located off São Paulo coast. The same pattern was observed for many inshore species caught by pair trawling in this State (Rolim and Ávila-da-Silva, 2016). Double-rig trawl catches also had an abrupt drop following the establishment of the MPAs, and the high mobile nature of this fleet also prevents the identification of fishing grounds.

Acoupa weakfish yield decline in both pair and double-rig trawling vessels was likely related to the shallow-water, inshore habitat of the species (Almeida, 2016; Barletta et al., 2003; Matos and Lucena, 2006), which was protected by the bathymetric limit enforced by the MPAs (Rolim and Ávila-da-Silva, 2016). This is even more evident taking in consideration that the highest production on record was obtained in between 2004 and 2005 (> 65 trips year^{-1}) — thus just before the enforcement of shallow water fishing ban — when the pair-trawling fish effort was the highest within the time series. The second highest peak in pair trawling catches was observed in the first year of the time series (1998), when both yields and LPUE were very high, despite the low effort recorded (~20 trips year^{-1}). It can be hypothesized that, at least in this case, such a pattern may be the result of a concentration of hauls on dense fishing grounds for the species.

Interestingly, bottom gillnetting catches actually increased following MPAs implementation, and since 2007 this fishery alone has been responsible for the bulk of Acoupa weakfish catches off São Paulo coast. The same pattern was also observed in the fish pen fishery. This suggests that competition with the powerful trawler fishing effort was rather alleviated, allowing for higher catches. This increase seems to be the result of more nets/fish pens deployed and the associated increase in the fishing effort (i.e. more fishing trips). In fact, the frequency of gillnetting and fish pen fishing trips increased some 80% and 64.2%, respectively, following MPAs implementation, whereas pair-trawling fishing trips decreased by 88%. It may be possible that gillnetters were now able to set their nets on bottoms that were previously exploited by the trawling fishery (Rolim and Ávila-da-Silva, 2016).

Comparing the main Acoupa weakfish fisheries is difficult, because they differ substantially in fishing power, selectivity and operational characteristics. In common, these fisheries are multispecific in nature, and in none of them the Acoupa weakfish figures as an important catch component. However, because pair trawling has a very high fishing power (both in terms of efficiency at catching fish and the biomass removed), this fishery was likely the major source of fishing mortality for the species, at least until the establishment of the MPAs and the resultant ban of trawling in shallow waters.

Taking in account the inshore trawling ban established by the creation of MPAs from 2007 onward, it is likely that fishing mortality is currently at safe levels, at least in terms of biomass removed from the ecosystem, since trawling fisheries were the largest Acoupa weakfish producer within the time series. However, this situation must be treated with caution, since differential mortality imposed at different life stages and/or sexes by the variety of fishing gears employed at catching Acoupa weakfish is presently unknown.

CONCLUSION

Judging from our results, the Acoupa weakfish is exploited using a wide range of fishing gears and practices, and have been a minor fishery component off São Paulo coast over the last 18 years — except for two short pulses of relatively high catches (> 120 tonnes year^{-1}) in 1998 and 2005. The main fisheries for the species includes industrial pair and double-rig trawling, and artisanal bottom gillnetting and fish pens. Both artisanal fisheries have a clear seasonal signal, with highest catches in austral warm months (October–March) and lowest catches in cold months (April–September). Such seasonality cannot be discerned in the industrial fisheries. Pair trawling fishery — once the major Acoupa weakfish producer — declined substantially from 2007 onward due shallow water trawl fishing ban enforced by MPAs implementation, and currently bottom gillnetting have been the most important fishery for the species off São Paulo coast.

Currently, it is not possible to evaluate if the Acoupa weakfish main fisheries have been operating at a sustainable level of fishing effort, because neither there is a stock assessment available for the species, nor there are data on fishing mortality for the different fishing gears employed for catching the species. However, until a robust stock assessment be available, along with a comprehensive evaluation of fishing mortality by the different fishing gears, it is advised a precautionary approach toward the Acoupa weakfish off São Paulo coast. Given the typical vulnerability of large sciaenids to overexploitation, even moderate fishing mortality may be harmful, compromising the stability of the stock in the long term.

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