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Research Article

Spatial patterns of fishing fleets on the Southeastern Brazilian Bight

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ABSTRACT. This study aimed to determine the different usage strategies of the marine environment by fishing fleets landing in São Paulo based on an analysis of the spatial distribution patterns indicated in 337,482 trips between 2010 and 2013. The sea region off the Brazilian coast between 23º00'S and 28º00'S (Southeastern Brazilian Bight) was divided into six depth strata. For each stratum, the number of trips, effective fishing days, catch and number of jobs were estimated. The stratum from 0 to 20 m depth had the highest frequency of trips and importance for the low-mobility fleets from which 33% of the total catch landed in the state was extracted. The higher mobility fleets were more represented starting at depths of 20 m. The stratum from 20-50 m had the largest catches, 52% of the total landings. The activity of the São Paulo fishing fleets, with low or high fishing power, was concentrated on the inner shelf. The region of the outer shelf and the continental shelf break are also frequently exploited by the higher mobility fleets, where the largest catches of demersal fish occur. The demersal and pelagic environments beyond the continental shelf break are rarely exploited and require the use of specific fishing gear.

Keywords: spatial distribution, fishing fleet, fishing effort, socio-economics.

Patrones espaciales de las flotas pesqueras en Southeastern Brazilian Bight

RESUMEN. El objetivo de este estudio es determinar las diferentes estrategias de uso de las áreas marinas por flotas pesqueras que llegan a São Paulo, basándose en un análisis de los patrones de distribución espacial de la actividad de 337.482 viajes realizados entre 2010 y 2013. La región de la costa brasileña entre 23º00'S y 28º00'S (Southeastern Brazilian Bight) fue dividida en seis estratos de profundidad. Para cada estrato se calculó la cantidad de viajes, días efectivos de pesca, captura y número de empleos, considerando a su vez tomando el arte o equipo de pesca y la municipalidad donde se desembarcaba la pesca. El estrato 0-20 m tuvo mayor frecuencia de viajes e importancia para aquellas flotas de movilidad baja, donde se extrae el 33% de la pesca que se desembarca en el Estado. A partir de 20 m de profundidad, las flotas de mayor movilidad estuvieron más representadas. En el estrato 20-50 m se obtuvo la mayor captura de peces (52%). La actividad de las diferentes flotas pesqueras de São Paulo, con alto o bajo poder de pesca, concentró sus operaciones en la plataforma continental interior. La región de la plataforma continental exterior y el borde continental también son frecuentemente explotados por flotas de alta movilidad, donde ocurre la mayor captura de peces demersales. Los ambientes demersales y pelágicos, que están más allá de la plataforma continental, rara vez son explotados y requieren el uso de artes y aparejos de pesca específicos.

Palabras clave: distribución espacial, flota pesquera, esfuerzo de pesca, socio-economía.

INTRODUCTION

The use of the marine environment for fishing occurred slowly until the beginning of the 20th century. Although occurring preferentially in coastal regions, the exploitation of fishing resources in oceanic areas has been practiced since the 15th and 16th centuries (Boyer, 1967 *apud* Diegues, 1983). In the mid-twentieth century, after World War II, fishing incorporated technological innovations allowing longer and safer trips increasing the fishing power of fleets, which was characterized as the most important period for the marine environment occupation. Mechanization of vessels along the southeastern and southern coasts of Brazil began in the 1940s (Valentini *et al*., 1991; Valentini & Cardoso, 1991; Valentini & Pezzuto, 2006)

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with the adaptation of purse seine for catching sardines and trawl for shrimps. In the 1970s and 1980s, supported by fiscal incentive policies, modernization and expansion of the fleets occurred with the increase in the size and autonomy of the fleets resulting in greater mobility and catching power of the vessels and in the occupation of the continental shelf. Consequently, historic peak catches were recorded for pink shrimp (*Farfantepenaeus paulenis* and *F. brasiliensis*) in 1972 (16,028 ton), Brazilian sardine (*Sardinella brasiliensis*) in 1973 (228,000 ton) and seabob shrimp (*Xyphopenaeus kroyeri*) in 1981 (14,870 ton) (D'Incao, 1991; Valentini & Cardoso, 1991; Dias-Neto, 2010). These peak catches were followed by a sharp decline in catches and abundance of these traditional resources in their distribution areas leading to diversification of catches and by an expansion of the fishing zones (Haimovici *et al*., 2006; Valentini & Pezzuto, 2006).

A new crisis scenario was established in the sector at the beginning of 2000, when the Brazilian government adopted a new incentive program, which focused on leasing foreign vessels for fishing in the outer shelf regions, slope and ocean for the purpose of prospecting new fishing resources and incorporating catching techniques into the national fleet (Perez *et al*., 2003). The negative results included a renewed increase in the fishing effort, further compromising the sustainability of the demersal fishing resources from the inner continental shelf, which was already exploited by the national fleet (Perez *et al*., 2003; Haimovici *et al*., 2006).

The marine fishing activity of the São Paulo State has been the subject of several studies (Valentini & Cardoso, 1991; Ávila-da-Silva *et al*., 2001; Graça-Lopes *et al*., 2002a, Perez *et al*., 2002b; Mendonça & Miranda, 2008). The determination of spatial patterns of fishing exploitation was addressed in the studies conducted by Carneiro *et al.* (2000), Kolling *et al.* (2008), Mourato *et al.* (2011), Carneiro *et al.*(2013) and Kolling & Ávila-da-Silva (2014). However, unified assessments of marine space occupation for both artisanal and industrial fleets are not available yet.

Knowledge of the spatial distribution of fishing fleets is of major importance for the management of fisheries (Hilborn, 1985; Salas & Gaertner, 2004; Branch *et al*., 2006) because it allows to evaluate the patterns of fishery exploitation and possible conflicts in the use of living resources and marine space. In São Paulo this knowledge has special relevance since the State has Brazil's largest marine protected area for sustainable use (São Paulo, 2008).

In this context, the present study aimed to organize available data from different fishing fleets of São Paulo State in order to determine their distribution along the Southeastern Brazilian Bight (SBB) (Butler, 1970; Castro *et al.*, 2006) as well as the usage and the economic importance of different depth strata. For that purpose, the main species captured per strata, the fishing gears used, the effort applied and the number of jobs created were determined.

MATERIALS AND METHODS

The present study included fishing trips made from January 2010 to December 2013 with landings in the state of São Paulo, Brazil. Fishing trips covered a large area off the southern Brazilian coast between Cabo de Santa Marta Grande (28°36′S) and Cabo Frio (23°S), with depths down to 4,000 m (Fig. 1). The study area corresponds to the Southeastern Brazilian Bight. It has a concave coastline covering approximately 1,100 km with a gently sloping topography. The continental shelf break is between 120 and 180 m isobaths and reaches 230 km wide in the central portion. In its northern and southern boundaries, it becomes narrower with only 50 to 70 km long (Butler, 1970; Castro *et al*., 2006). The SBB is situated in the South Brazil Shelf Large Marine Ecosystem (Watson *et al.*, 2003), which, in terms of biogeography, corresponds to the transition area between the Caribbean and Argentinian provinces (Briggs & Bowen, 2012).

For the analysis, the marine space was divided into six depth strata: 0 to 20 m (1); 20 to 50 m (2); 50 to 100 m (3); 100 to 250 m (4); 250 to 500 m (5) and 500 to 4,000 m (6). These strata were defined based on some of the current legislation that defines rules for marine activities, including fisheries. The ecological-economic marine zoning from São Paulo State (São Paulo, 1998) defines isobath of 23.6 m as the limit of the coastal zone. Marine protected areas (São Paulo, 2008) off São Paulo coast, where the sustainable use of resources is allowed, reach the isobath of 50 m in some regions (Carneiro *et al*., 2013). The fishing license regulation in Brazil (MPA/MMA, 2011) defines the isobaths of 100, 250 and 500 m as the limits of operation for several important fleets or fishing gears. Stratum 1 and 2 correspond approximately to the area of the inner continental shelf, 3 is the middle shelf, and 4 is the external shelf and the break zone. Stratum 5 is located in the area above the upper slope, and 6 is above the lower slope (Figueiredo Jr. & Madureira, 2004; Castro *et al.*, 2006).

Fishing data were obtained from the Marine and Estuarine Fishing Activity Monitoring Program, performed by the Fisheries Institute of the State of São Paulo (Ávila-da-Silva *et al*., 2007). This program adopts the census method (FAO, 1999) to obtain fishing information through the application of structured inter-

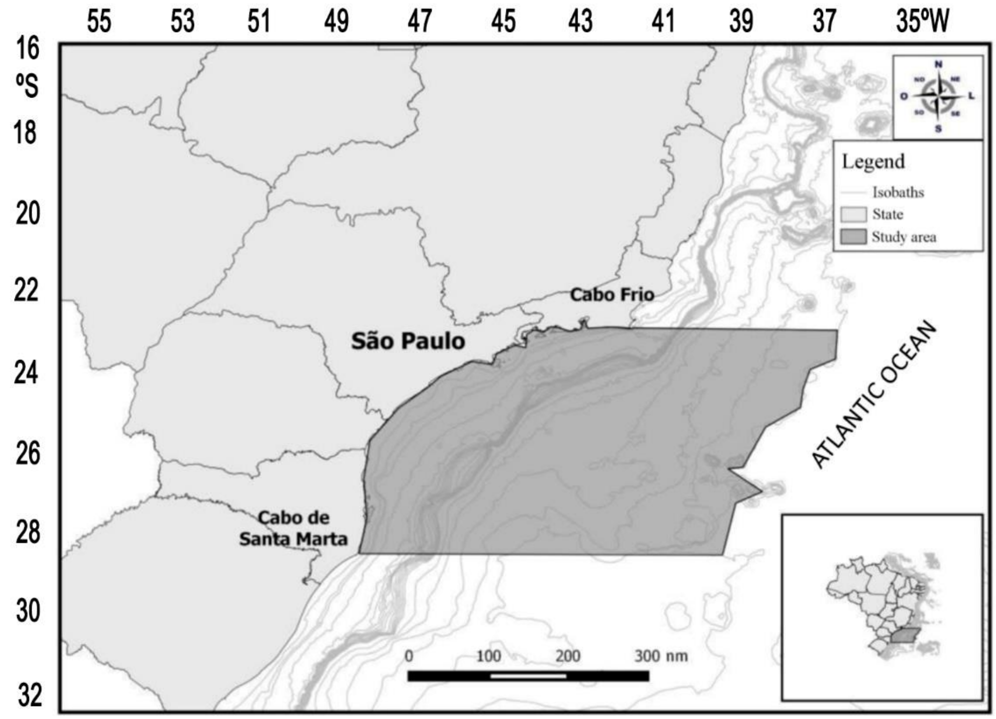

Figure 1. Study area between latitudes 23°00'S and 28°36′S in areas down to 4,000 m depth of state of São Paulo.

views (Bunce *et al*., 2000), answered voluntarily by fishers and vessel operators at the moment of catch landing. For each trip, information on species/category caught (kg), landing site, fishing area and depth, type of fishing gear and fishing effort expressed in effective fishing days were recorded. The number of crewmembers has been set based on additional interviews and field observations according to the fishing gears used and the characteristics of the landing sites.

These data have been processed, organized and made available through the ProPesqWEB database (Ávila-da-Silva *et al*., 1999; Instituto de Pesca, 2016).

For each bathymetric stratum (1-6), the number of productive units, the number fishing trips, fishing effort, total catch, catch per species/category and the frequency of use by fishing gear were calculated. The number of fishing jobs, including the number of crewmembers per stratum, was also estimated from the number of productive units. A productive unit can be a fisherman, if he works onshore; a vessel; or even a set of vessels, if operating together a single fishing gear.

The number of trips per bathymetric stratum was calculated through simple counting. In the case of a trip covering more than one bathymetric stratum, this was accounted for both bathymetric stratum visited. The same procedure was adopted for the calculation of the number of productive units per stratum.

For each bathymetric stratum, the number of effective fishing days, the catch per fish category and the total catch were calculated as follows:

$$DS_t = \frac{ND_t}{NS_t} \qquad FD_s = \sum_{\substack{t=1\\ t\in s}}^{TT} DS_t$$

$$CS_{t,f} = \frac{C_{t,f}}{NS_t} \qquad FC_{s,f} = \sum_{\substack{t=1\\ t\in s}}^{TT} \sum_{\substack{f=1\\ f\in s}}^{TF} CS_{t,f}$$

$$TC_s = \sum_{s=1}^{TS} \sum_{\substack{f=1\\ f\in s}}^{TF} FC_{s,f}$$

where DS is the number of effective fishing days per bathymetric stratum on the trip t; ND is the number of effective fishing days on the trip t; NS is the number of bathymetric strata with fishing operations on the trip t; FD is the total number of effective fishing days in the bathymetric stratum s; TT is the total number of trips; CS is the catch (kg) of the fish category f on trip t per bathymetric stratum; C is the catch (kg) of the fish category f on trip t; FC is the catch of the fish category f in stratum s; TF is the number of categories of fish caught; TC is the total fish catch in the bathymetric stratum; and TS is the total number of strata.

The number of crewmembers per productive unit was estimated considering information about the physical and operational characteristics of the fleets and fishing gear used per municipality. When a productive unit operated in more than one stratum, the jobs created were distributed according to the relative frequency of its trips per stratum. The quantity of jobs attributed to each sector was given by the median of the total annual values of the estimated jobs.

The analysis of the magnitude of the data in the period (2010-2013) was performed using the coefficient of variation (CV). The fitting of linear models and the analysis of variance (ANOVA) were applied to evaluate the variation trend with time per stratum and its significance (Zar, 2009). The statistical analyses were performed using the R software (R Core Team, 2015).

RESULTS

Table 1 shows the numbers of productive units, trips, effective fishing days, catch (ton) and jobs/year per depth stratum. This table also shows the CV values and the *P*-values of linear models fitted (Fig. 2) to the data. The monitoring of 337,482 fishing trips between 2010 and 2013 was conducted by 6,282 productive units of which, 93% fished between 0 and 20 m depth (stratum 1) at least once. This stratum was exploited in 96.2% of trips and accounted for 84% of the effective fishing days. The number of productive units decreased as the distance from the coast increased. The depth range 20-50 m (stratum 2) received 26% of the productive units, 6.2% of the monitored trips and 11.3% of the effective fishing days. Only 5.8% of the productive units exploited 50-100 m (stratum 3), representing less than 1% of the monitored trips and 3.6% of total effective fishing days. The 250-500 m depth range (stratum 5) had the lowest number of fishing days whereas 500-4,000 m (stratum 6) presented the lowest number of productive units.

The variation in the number of jobs per bathymetric stratum followed a similar trend to the number of production units, with a large concentration in areas down to 20 m depth. This stratum concentrated 78% of 9,802 jobs. Stratum 2 accounted for 16.1% of the jobs, and 3 for 4.1%. Other strata accounted for less than 2% of the jobs (Table 1).

Following a different pattern, the bathymetric range 20-50 m was the most important in terms of biomass extraction, with 52.3% of the total catches. From stratum 1 and 4, 31.1% and 11.2% of the catches were obtained, respectively. Beyond 100 m, only 3.4% of the total was extracted (Table 1).

The fishing activity, as a whole, did not show important temporal variations in the period analyzed. The number of productive units was the variable that showed the highest fluctuation. Also, in strata 1 and 2 significant decreasing trends were observed ($r^2 = 0.915$; $P = 0.029$ and $r^2 = 0.852$; $P = 0.05$, respectively). Although considered significant, p values remained above 0.01, indicating that the magnitude of this variation was not too accentuated. A high annual variation with no significant trends was observed in the number of vessels in all other strata.

The decrease in the number of productive units in stratum 1 and 2 did not correspond to a reduction in effective fishing days and catch. In stratum 5, 12 to 18 different productive units operated annually. Even though there was a significant decrease in the effort applied to this stratum, the catches and the number of jobs remained relatively stable (Table 1, Fig. 2).

Stratum 1 received the largest number of effective fishing days in all municipalities (Table 2), even those with fleets of higher mobility. The fleets from the municipalities of Bertioga, Cubatão, São Vicente, Praia Grande, Mongaguá, Itanhaém, Peruíbe, Iguape, Ilha Comprida and Cananéia directed more than 90% of their effective fishing days for this stratum (Table 2). The fleets from Ubatuba, São Sebastião, Ilhabela and Santos/Guarujá dedicated 55 to 85% of their effective fishing days to stratum A and between 15 and 40% to stratum 2. The areas deeper than 50 m were effectively occupied by vessels with landings in Ubatuba and especially in Santos/Guarujá.

Stratum 1 was the most used by gillnetters, double-rig trawlers, otter trawlers and estuarine longliners. This stratum was also exploited with weir, hand trawl, set net, dip net, artisanal beam trawl, trap, pole-and-line, cast net, and harpoon/gaff and received 85 to 100% of their effective fishing days. Multigear trips, lines, hand jigging and bottom longlines were used in stratum 1 with 55 to 70% of their estimated effective fishing days. Stratum 2 was mostly used by double-rig trawlers, pair trawlers, bottom longliners and purse seiners. Pot fishing and coastal pelagic longline fleets preferred stratum 3 whereas oceanic pelagic longline fleet operated mainly in stratum 6 (Table 3).

The ten fish categories most landed represented 70.5% of the total weight. *S. brasiliensis*, *X. kroyeri* and *M. furnieri* comprised more than 50% of the landings in the period. In stratum 1, about 95% of all *X. kroyeri*, 74% of *Macrodon atricauda* and 100% of *Anchoviella lepidentostole* were captured. Approximately 85.0% of *S. brasiliensis*, 68% of *M. furnieri*, 75% of *Cynoscion jamaicensis* and 68% of *Menticirrhus* spp. came from stratum 2. In stratum 3, 68% of the *Octopus vulgaris*

Table 1. Distribution of the number of productive units, trips, effective fishing days, estimated catches and jobs per depth stratum. The coefficients of variation (CV) of the annual values and their trend line (*P*-value). The underlined values correspond to $P \leq 0.05$). Depth strata: 1) 0-20 m, 2) 20-50 m, 3) 50-100 m, 4) 100-250 m, 5) 250-500 m, 6) 500-4,000 m. *One productive unit or one trip can cover one or more depth strata.

Strata	Productive units*			Trips*			Effective fishing days			Catch (ton)			Jobs/year		
	Total	CV	*P*	Total	CV	*P*	Total	CV	*P*	Total	CV	*P*	Average	CV	*P*
1	5,85	15	<u>0.028</u>	324,69	6	0.116	426,44	5	0.492	33,32	12	0.624	7,642	17	0.052
2	1,65	9	<u>0.050</u>	20,977	7	0.288	57,439	11	0.627	52,73	38	0.153	1,581	10	0.290
3	369	10	0.367	2,19	12	0.374	18,87	12	0.811	11,33	18	0.299	402	3	0.341
4	108	51	0.134	412	50	0.125	3,483	45	0.078	2,787	21	0.061	76	54	0.196
5	37	21	0.141	86	31	<u>0.023</u>	602	18	<u>0.012</u>	254	29	0.722	50	14	0.965
6	34	41	0.576	106	43	0.655	840	46	0.804	371	47	0.501	51	42	0.848
Total	6,28	14	<u>0.038</u>	337,48	6	0.140	507,67	6	0.437	100,8	18	0.096	9,804	13	0.099

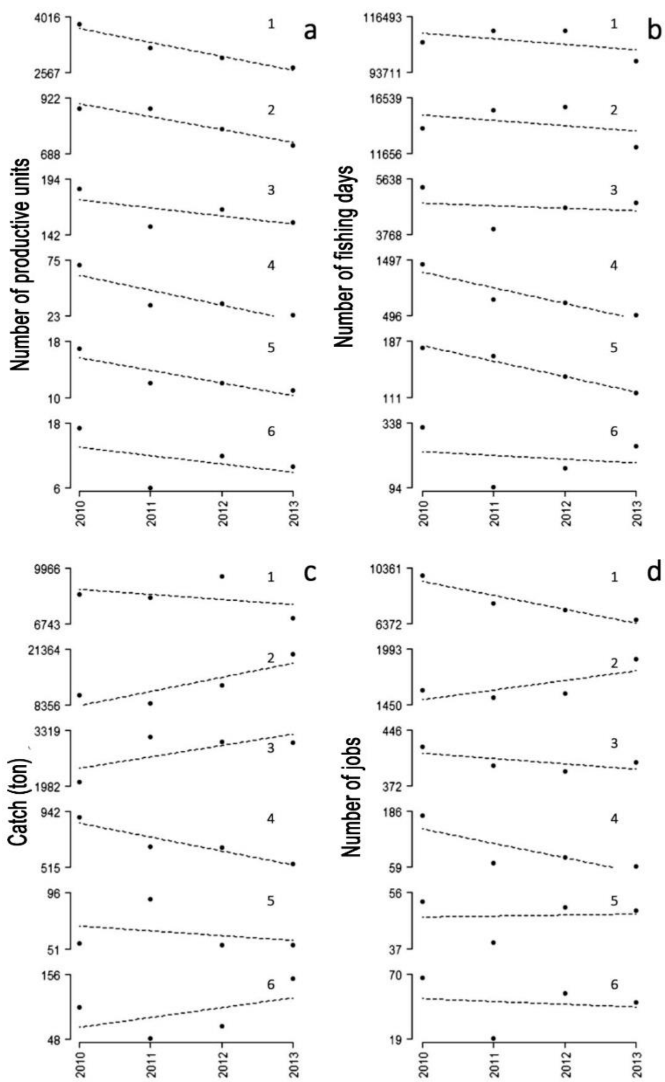

Figure 2. a) Number of productive units, b) effective fishing days, c) catch, and d) jobs/year per depth stratum between 2010 and 2013. The dotted line represents the simple linear fit model. Depth strata: 1) 0-20 m, 2) 20-50 m, 3) 50-100 m, 4) 100-250 m, 5) 250-500 m, 6) 500-4,000 m.

Table 2. Effective fishing days (EFD) per municipality and their percentage distribution per depth stratum: 1) 0-20 m, 2) 20-50 m, 3) 50-100 m, 4) 100-250 m, 5) 250-500 m, 6) 500-4,000 m. The underlined values refer to the stratum where each municipality applied greater effort in effective fishing days.

Municipality	EFD	Deph stratum					
		1	2	3	4	5	6
Cananéia	145,676	95.4	4.0	0.5	0.1	0.0	0.0
Iguape	90,345	100.0					
Santos/Guarujá	86,23	56.8	21.2	17.7	2.9	0.5	0.9
Ubatuba	55,398	56.6	36.6	4.9	1.6	0.2	0.1
São Sebastião	32,16	82.5	17.3	0.1	0.1		
Ilhabela	23,898	72.6	27.1	0.4			
Caraguatatuba	16,955	96.8	3.1	0.1			
IlhaComprida	10,604	100.0					
Peruíbe	9,433	99.9	0.1				
Praia Grande	8,356	99.4	0.6				
Cubatão	8,038	100.0					
Bertioga	6,685	93.9	5.8	0.3			
Mongaguá	5,793	99.6	0.4				
São Vicente	4,357	99.6	0.4				
Itanhaém	3,743	100.0					

Table 3. Effective fishing days (EFD) by fishing gear and their percentage distribution per depth stratum: 1) 0-20 m, 2) 20-50 m, 3) 50-100 m, 4) 100-250 m, 5) 250-500 m, 6) 500-4,000 m.

Fishing gear	EDF	Depth stratum					
		1	2	3	4	5	6
Gillnet	209,724	89.7	9.2	1.0	0.0		
Double-rig trawl for *X. kroyeri*	88,075	93.7	6.1	0.2	0.0		
Weir	40,888	100.0					
Extractivism	38,698	100.0					
Double-rig trawl for *Farfantepenaeus* spp.	28,866	2.7	56.5	33.1	7.6	0.1	
Hand trawling	13,083	100.0					
Multigear trip	13,071	69.9	24.5	3.7	1.6	0.2	
Floating trap	12,172	96.8	3.2				
Dip net	8,416	100.0					
Pot fishing for *O. vulgaris*	7,495	0.9	22.8	73.4	2.9		
Otter trawl	7,404	93.7	6.3				
Lines	7,014	67.2	28.0	1.4	2.8	0.2	0.4
Artisanal beam trawl	6,377	100.0					
Pair trawl	5,489	16.7	79.9	3.4			
Hand-jigging	4,132	69.3	30.7				
Estuarine longline	4,063	100.0					
Bottom longline	3,282	57.6	27.3	4.4	9.3	1.4	
Trap	2,409	88.0	11.7	0.3			
Purse seine	2,397	28.1	62.7	9.2			
Oceanic longline	1,398	0.1	1.1	6.7	11.7	29.0	51.5
Pole and line	911	100.0					
Coastal surface longline	879	13.4	20.5	31.2	14.1	10.8	10.2
Cast net	837	100.0					
Harpoon/gaff	591	87.3	12.7				

Table 4. Catch (ton) of the main *taxa* and their percentage distribution per depth stratum: 1) 0-20 m, 2) 20-50 m, 3) 50-100 m, 4) 100-250 m, 5) 250-500 m, 6) 500-4,000 m. *Category of small and/or cheap fishes sold together.

Taxon	Total (ton)	Depth stratum					
		1	2	3	4	5	6
Sardinella brasiliensis	31,118	0.8	85.0	14.2	0.0		
Xiphopenaeus kroyeri	10,564	94.9	5.0	0.1			
Micropogonias furnieri	9,832	20.4	67.9	11.6	0.1		
Cynoscion jamaicensis	4,149	21.0	75.4	2.7	0.8		
Macrodon ancylodon	3,668	73.6	26.3	0.1	0.0		
Anchoviella lepidentostole	3,022	100.0					
Menticirrhus spp.	2,533	37.8	57.8	4.3	0.1		
Octopus vulgaris	2,360	0.7	27.9	68.3	3.1		
Scomber japonicus	2,290	0.1	83.6	16.3	0.0		
Farfantepenaeus spp.	1,528	1.8	46.5	51.3	0.4		
Mugil liza	1,482	75.2	24.3	0.5			
Selene spp.	1,410	24.8	62.7	12.5			
Ariidae	1,316	79.9	16.0	3.9	0.2		
Prionotus punctatus	1,220	9.9	56.8	27.4	5.9		
Trichiurus lepturus	1,121	51.1	44.7	3.7	0.6	0.0	0.0
Oligoplites spp.	874	60.8	36.7	2.5			
Crassostrea brasiliana	830	100.0					
Urophycis spp.	797	0.6	7.1	22.6	69.0	0.7	
Doryteuthis spp.	787	21.7	65.1	12.3	0.9		
Caranx crysos	731	67.4	31.2	1.4			
Mugil curema	677	99.6	0.4	0.0			
Opisthonema oglinum	673	92.7	7.3				
Selachii (sharks)	606	29.7	36.7	16.4	4.1	2.8	10.4
Paralichthyidae	604	5.5	18.2	18.8	57.4	0.1	
Merluccius hubbsi	480	0.2	3.8	16.5	79.3	0.2	
Xiphias gladius	332	0.3	0.4	0.5	2.2	42.6	54.0
Genypterus brasiliensis	297	0.1	2.1	21.6	76.0	0.2	
Metanephrops rubellus	240	0.2	1.9	22.2	75.0	0.7	
Lophius gastrophysus	220	0.1	4.0	17.6	78.1	0.2	
Arhynchobatidae	214	0.3	17.5	35.9	46.3	0.1	
Coryphaena hippurus	175	2.1	11.6	31.1	41.3	6.2	7.8
Isurus oxyrinchus	106	0.4	17.5	40.2	12.4	9.6	20.0
Lopholatilus villarii	55	2.7	1.0	5.3	63.6	27.4	
Prionace glauca	50	0.4	1.1	5.7	12.3	29.4	51.0
Fish mixture*	3,833	39.2	49.1	9.9	1.8	0.0	0.0
Other species	10,598	49.0	38.5	7.9	3.6	0.3	0.6
Total	100,792	33.1	52.3	11.2	2.8	0.3	0.4

and 51% of the *Farfantepenaeus* spp. landed were captured (Table 4).

The largest amount of demersal fish such as *Urophycis mystacea*, *Merluccius hubbsi*, *Genypterus brasiliensis*, *Lophius gastrophysus* and *Lopholatilus villarii* and the deep-sea lobster *Metanephrops rubellus* were captured in areas with local depths from 100 to 250 m. The pelagic environment of this stratum was the main area for catching *Coryphaena hippurus*. *L. villarii* was the demersal species that reached deeper (250-500 m) with relatively high abundances. From stratum 5 to deeper areas, the main catches were from pelagic fishes as *Xiphias gladius*, *Prionace glauca* and *Isurus oxyrinchus* (Table 4).

DISCUSSION

Between 2010 and 2013, no important variation was observed in the fishing patterns analyzed but rather in the catches landed in the state of São Paulo, which varied from 21,000 to 31,000 ton. This variation was mostly related to fluctuations in *S. brasiliensis* landings, the main species caught, whose annual variation reached to 370% between 2011 and 2013. Landings of *X. kroyeri*, the second main species, presented losses around 48% from 2012 to 2013 (Ávila-da-Silva *et al.*, 2011, 2012, 2013, 2014). Both species have a short lifespan.

According to Matsuura (1998), annual variation in the abundance of *S. brasiliensis* is common in SBB because of their recruitment cycles linked to upwelling process. Fluctuations in population size of *X. kroyeri* are related to variations in water temperature and fluvial outflow that affect recruitment (Kolling, 2011; Kolling & Ávila-da-Silva, 2014).

The results showed a strong bathymetric stratification in the fishing activity performed by the fleets of São Paulo in SBB. The largest concentration of productive units, fishing effort and jobs occurred down to the 20 m depth (stratum 1), whereas the greatest extraction of biomass occurred between 20 and 50 m (stratum 2). Although these two contiguous bathymetric strata compose the inner continental shelf, the differences in catch composition, fishing gears used and production scale indicated that they must be considered as different units for fishing and territorial management purposes. From the 24 types of fishing gears listed, eight were used exclusively at depths down to 20 m and other 10 in this stratum had the highest frequency of use.

The bathymetric distribution of fishing effort has shown that artisanal fishery with low mobility is very relevant in the state of São Paulo, especially for its role in areas shallower than 20 m. In addition, artisanal fishing sector stands out for being the main employer in at least 11 of the 15 coastal municipalities. The fleets of São Sebastião and Ilhabela, although typically artisanal, can fish at greater depths along the coast portion named as "Island and Channel of São Sebastião on the north coast of São Paulo" (Ab'Saber, 2000). This area is characterized by the advancement of the coastline towards the sea and by the presence of a high continental island that provides great depths in the channel portion.

The concentration of fishing activity on the continental shelf, considered here as areas shallower than 200 m, has been reported worldwide once they provide more than 90% of the global fishing catches (Caddy *et al*., 1998; Pauly *et al*., 2002). Previous studies on the dynamics of the main industrial fishing fleets in the southeastern and southern regions of Brazil have already indicated a convergence of fishing effort on the shelf and its impact on the exploited resources (Haimovici *et al.*, 1997; Carneiro *et al.*, 2000; Rossi-Wongtschowski *et al*., 2007; Kolling *et al.*, 2008). However, as these studies did not covered the artisanal and low mobility fisheries, they did not report the intense use of the zone closest to the coast.

In turn, Andriguetto-Filho *et al.* (2009), Castello *et al.* (2009), Martins *et al.* (2009), Carneiro *et al.* (2013), Carneiro & Ávila-da-Silva (2015) and Carneiro *et al.* (2015) considered the various artisanal fisheries and discussed the sustainability this activity in different coastal areas of SBB. The studies concluded that the worst indicators of sustainability are related to the fisheries in estuarine and coastal regions because of environmental vulnerability to fishing and other human impacts and management limitations.

Jackson *et al.* (2001) stated that the extinction of ecological resources for fishery caused by overfishing precedes all other human perturbations in coastal ecosystems, including pollution, degradation of water quality and anthropogenic climate changes. The coastal region of the state of São Paulo is almost completely covered by marine protected areas of sustainable use (São Paulo, 2008), which reach the 50 m isobath in some regions. Carneiro *et al.* (2013) spatialized and analyzed the fishing activity within these protected areas. The overlap of artisanal and industrial fishing grounds with the marine protected areas provides an excellent opportunity for environmental management and, hence, to improve the sustainability of the activity.

Many of the resources exploited in this shallowest stratum, such as *A. lepidentostole*, *Crassostrea brasiliana*, *Mugil curema* and fish from the Ariidae family, have strict relations with rivers and estuarine areas (Figueiredo & Menezes, 1978; Pereira *et al*. 2001; Mendonça & Bonfante, 2011) and are exploited with artisanal fishing techniques, some of which do not require vessels. Shrimp *X. kroyeri*, which supports a traditional and relevant trawling fisheries (Kolling & Ávila-da-Silva, 2014), and the sciaenid fish *M. atricauda*, which also figures among the main resources landed in São Paulo, were mostly caught at depths down to 20 m. *X kroyeri* inhabits sandy and muddy bottoms down to 30 m depth (Iwai, 1973). *M. atricauda* occurs down to 60 m, but it is concentrated along the 20 m isobath (Carneiro & Castro, 2005). In shallower areas, *M. atricauda* is caught mainly with gillnets and in deeper waters, with pair trawl (Castro *et al.*, 2007; Tomás, 2007). These fisheries are economically important in São Paulo State (Ávila-da-Silva *et al.*, 2011, 2012, 2013, 2014; Carneiro *et al.*, 2013) and are traditionally among the top 20 landed fishing resources.

In marine areas with local depths between 20 and 50 m (stratum 2), three of the four main fishing resources of São Paulo were caught with the greater abundance: the small pelagic *S. brasiliensis*, which was the most important catch in all years analyzed (Ávila-da-Silva *et* *al*., 2011, 2012, 2013, 2014), along with the sciaenids *M. furnieri* and *C. jamaicensis*. Fishing for *S. brasiliensis*, *Scomber japonicus* and *Selene* spp. is usually done with purse seines in areas with depths down to 80 m (Gasalla *et al.*, 2007; Schwingel & Occhialini, 2007). The sciaenid fish *M. furnieri*, *C. jamaicensis* and *Menticirrhus* spp., are caught with gillnets and pair trawls. *Prionotus punctatus* and *Doryteuthis* spp. are caught primarily with double-rig trawl (Andrade *et al*., 2005; Gasalla *et al.*, 2005). *Doryteuthis* spp. are also caught in coastal waters with hand-jigging fishing gear (Postuma & Gasalla, 2010).

Stratum 2 was the second most important in allocation of jobs and effective fishing days. Purse seiners and pair trawlers operated here with high catching power vessels, which led to an increase in the yield of catches. For comparison purposes, the average catches in this stratum, roughly estimated, were 251 kg per trip or 92 kg per effective fishing days, whereas in the stratum 0-20 m, these numbers were 10.3 and 7.8 kg, respectively. Nevertheless, the estimates of productivity must be interpreted with caution given the diversity of fleets and the variation of the fishing power among them.

In the stratum from 50 to 100 m, the demersal catches of *Farfantepenaeus* spp. with double-rig trawl, *O. vulgaris* with traps and the pelagic fishing of *I. oxyrinchus* with coastal surface longline were important. The double-rig trawl fleet for *Farfantepenaeus* spp. has multi-species characteristics, catching at least 258 species (Graça-Lopes *et al.*, 2002b). Among them are *P. punctatus*, *Doryteuthis* spp., *O. vulgaris* and *Menticirrhus* spp., caught at depths from 30 to 50 m. Double-rig trawl was also the most used fishing gear to exploit demersal species beyond the depth of 100 m, an environment also exploited with bottom longline.

The number of trips, fishing effort, catches and number of jobs had a decreasing trend with increasing depths, especially after the isobath of 100 m. Deeper regions after the wide Southeastern Continental Shelf are found far off of the coast (Castro *et al.*, 2006) and medium to large vessels are required to carry out fishing operations. The effective expansion of the industrial fishing area to depths greater than 100 m occurred in Brazil only after 1998, with a federal government program for leasing foreign vessels (Perez *et al*., 2003). However, after a few years of exploitation, the stocks of some of the primary species with high economic value were already depleted (Haimovici *et al.*, 2006), and fishing activity in this region was reduced.

The pelagic environment of the oceanic areas with depths between 100 and 250 m was used frequently for the capture of *C. hippurus* with pelagic longlines. This species has seasonal occurrence, with catches concentrated in the spring and the beginning of summer. The fleet that exploits this fish, known as the "Itaipava fishing fleet", is from the state of Espírito Santo (21°S) and follows the migration of this species along the Brazilian coast to 28°S (Ávila-da-Silva & Vaz-dos-Santos, 2000; Martins *et al.*, 2005; Dallagnolo & Andrade, 2007). Although the Itaipava fleet has artisanal features, it has very high mobility.

The pelagic environment of areas beyond the 500 m isobath was used to catch *X. gladius* and sharks *P. glauca* and *I. oxyrinchus*, primarily with industrial oceanic longlines. This fishing gear was introduced at the end of the 1950s and had great importance in São Paulo until the 1990s (Zavala-Camin & Tomás, 1990; Arfelli & Amorim, 2000); however, the number of vessels that use this gear and their annual catches have decreased in recent years (Mourato *et al.*, 2011, Ávila-da-Silva *et al.*, 2014).

The demersal environment between 100 and 500 m depth was exploited with double-rig trawls and bottom longlines. In this bathymetric range, the highest concentration of effort was directed to depths down to 250 m for flat fishes (Paralichthyidae), *M. hubbsi*, *G. brasiliensis, L. gastrophysus,* skates (Elasmobranchii: Arhynchobatidae) and for the deep-sea lobster *M. rubellus*. The use of the outer shelf to a depth of 200 m for fishing was traditionally performed by vessels that use vertical longlines (Santos *et al.*, 1988; Paiva & Andrade, 1994) until the middle of the 1990s, when the bottom longline fishing method was introduced, enabling the fleet to operate to depths of 600 m (Ávila-da-Silva *et al*., 2001). As previously mentioned, at the end of the 1990s, government actions were implemented to stimulate fishing at greater depths (Perez *et al.*, 2003), and between 2006 and 2009, special licenses were issued for vessels engaged in fishing shrimp *F. paulensis* and *F. brasiliensis* for catching fish and crustaceans to the 250 m isobath during the closure season. In the 2000s, boom and bust cycles were observed in several fisheries, for example, those directed to *L. gastrophysus* (Perez *et al.*, 2002[b]), deep-sea shrimp from the Aristeidae family (Dallagnolo *et al*., 2009) and crabs *Chaceon notialis* and *C. ramosae* (Pezzuto *et al.*, 2006). The demersal area beyond the 100 m isobath was also prospected in various research cruises conducted between 1996 and 2002 for the Program for the Assessment of the Sustainable Potential of Living Resources in the Exclusive Economic Zone (REVIZEE in Portuguese) with traps, otter trawls and different types of bottom longlines (Haimovici *et al.* 2004; Bernardes *et al.*, 2005; Haimovici *et al.*, 2006; Haimovici *et al.*, 2008).

The results of these scientific expeditions and the experience of the commercial fishers showed that the limitation in the abundance of stocks combined with the lack of proper fishing management precludes the sustainable use of the valuable demersal resources of this area.

CONCLUSIONS

Different fishing fleets operating from São Paulo occupy diverse environments in SBB in a highly stratified manner, despite the great extension of the continental shelf. Fishing activity is concentrated in the inner shelf zone to a depth of 50 m (strata 1 and 2 of this study) and areas to a depth of 20 m receive a greater number of fishing days and trips. This easily accessible area supports the largest number of fishermen and some small-scale fisheries that are done with small boats or even without them, by using shore based or handheld gear. Special attention should be given to the fact that in São Paulo State, almost all of this coastal area is within conservation units. This gives perspectives for a proper management adjusted to local demands. Middle and outer continental shelf, although fully exploited, still have an important role for both biomass extraction and job creation. The history of fishery exploitation and the panorama shown in the present study indicated that the discovery of new fish stocks in continental shelf capable of changing the profile of fisheries in the region is unlikely. The best use of the living resources will be attained through fishing management strategies that specifically consider the spatial distribution of the fisheries, including the allocation of effort and jobs.

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REFERENCES

Ab'Saber, A.N. 2000. Fundamentos da geomorfologia costeira do Brasil atlântico inter e subtropical. Ver. Bras. Geomorfol., 1:27-43.

Andrade, H.A., S.H.B. Lucato, L.R. Almeida & E. Cerchiari. 2005. *Prionotus punctatus* (Bloch, 1793). In: M.C. Cergole, A.O. Ávila-da-Silva & C.L.D.B. Rossi-Wongtschowski (eds.). Análise das principais pesca-rias comerciais da região Sudeste-sul do Brasil: dinâmica populacional das espécies em explotação. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 139-150.

Andriguetto-Filho, J.M., R. Krul, S. Feitosa, 2009. Analysis of natural and social dynamics of fishery production systems in Paraná, Brazil: implications for management and sustainability. J. Appl. Ichthyol., 25: 277-286.

Arfelli, C.A. & A.F. Amorim. 2000. Analysis of the Santos (SP) longliners from Southern Brazil (1997-1999).Col. Vol. Sci. Pap. ICCAT, 51(4): 1359-1366.

Ávila-da-Silva, A.O., G.C.C. Bastos & S.L.S. Tutui. 2001. Atividade pesqueira do Estado de São Paulo: análises das capturas do biênio 1998-1999 com espinhel-de-fundo. Bol. Inst. Pesca, 27(1): 33-38.

Ávila-da-Silva, A.O., M.H. Carneiro & L. Fagundes. 1999. Gerenciador de banco de dados de controle estatístico de produção pesqueira marítima - ProPesq®. In: XI Congresso Brasileiro de Engenharia de Pesca e I Congresso Latino-Americano de Engenharia de Pesca, 1999. Anais do XI Congresso Brasileiro de Engenharia de Pesca e do I Congresso Latino-Americano de Engenharia de Pesca, Recife, pp. 824-832.

Ávila-da-Silva, A.O., M.H. Carneiro, J.T. Mendonça, G.J.M. Servo, G.C.C. Bastos & P.D.A. Batista. 2007. Produção pesqueira marinha do Estado de São Paulo no ano 2005. Série Relatórios Técnicos, São Paulo, 26: 1-44.

Ávila-da-Silva, A.O., M.H. Carneiro, J.T. Mendonça, G.C.C. Bastos, L.V. Miranda, W.R. Ribeiro & S. Santos. 2011. Informe da produção pesqueira marinha e estuarina do Estado de São Paulo: Dezembro 2010. Inf. Pesqueiro São Paulo, 5: 1-4.

Ávila-da-Silva, A.O., M.H. Carneiro, J.T. Mendonça, G.C.C. Bastos, L.V. Miranda, W.R. Ribeiro & S. Santos. 2012. Informe da produção pesqueira marinha e estuarina do Estado de São Paulo: Dezembro 2011. Inf. Pesqueiro São Paulo, 17: 1-4.

Ávila-da-Silva, A.O., M.H. Carneiro, J.T. Mendonça, G.C.C. Bastos, L.V. Miranda, W. R. Ribeiro & S. dos Santos. 2013. Informe da produção pesqueira marinha e estuarina do Estado de São Paulo: Dezembro 2012. Inf. Pesqueiro São Paulo, 29: 1-4.

Ávila-da-Silva, A.O., M.H. Carneiro, J.T. Mendonça, G.C.C. Bastos, L.V. Miranda, W. R. Ribeiro & S. dos Santos. 2014. Informe da produção pesqueira marinha e estuarina do Estado de São Paulo: Dezembro 2013. Inf. Pesqueiro São Paulo, 42: 1-4.

Ávila-da-Silva, A.O. & A.M. Vaz-dos-Santos. 2000. Análise das capturas de atuns e afins pelos métodos de vara e isca viva e corrico realizadas pelo N/P Malacostraca de 1980 a 1991. Bol. Inst. Pesca, 26(2): 211-221.

Bernardes, R.A., J.L. Figueiredo, A.R. Ricci, L.G. Fischer, C.M. Vooren, M. Haimovici & C.L.D.B. Rossi-Wongtschowski. 2005. Peixes da Zona Econômica Exclusiva da região sudeste-sul do Brasil: levantamento com armadilhas, pargueiras e rede de arrasto de fundo. EDUSP, São Paulo, pp. 297.

Branch, T.A., R. Hilborn, A.C. Haynie, G. Fay, L. Flynn, J. Griffiths, K.N. Marshall, J.K. Randall, J.M. Scheuerell, E.J. Ward & M. Young. 2006. Fleet dynamics and fishermen behavior: lessons for fisheries managers. Can. J. Fish. Aquat. Sci., 63: 1647-1668.

Briggs, J.C. & B.W. Bowen. 2012. A realignment of marine biogeographic provinces with particular reference to fish distributions. J. Biogeogr., 39: 12-30.

Bunce, L., P. Townsley, R. Pomeroy & R. Pollnac. 2000. Socioeconomic manual for coral reef management. Australian Institute of Marine Science, Townsville, 251 pp.

Butler, L.W. 1970. Shallow structure of the continental margin, southern Brazil and Uruguay. Geol. Soc. Am. Bull., 81: 1079-1096.

Caddy, J.F., F. Carocci & S. Coppola. 1998. Have peak fishery production levels been passed in continental shelf areas? Some perspectives arising from historical trends in production per shelf area. J. Northwest Atl. Fish. Sci., 23: 191-219.

Carneiro, M.H. & A.O. Ávila-da-Silva. 2015. Pesca extrativa e aquicultura marinhas nos municípios de Caraguatatuba, Ilhabela e São Sebastião, São Paulo, Brasil, 2009-2012. Inf. Pesqueiro de São Paulo, 57: 1-70.

Carneiro, M.H. & P.M.G. Castro. 2005. *Macrodon ancylodon* (Bloch & Schneider, 1801). In: M.C. Cergole, A.O. Ávila-da-Silva & C.L.D.B. Rossi-Wongtschowski (eds.) Análise das principais pescarias comerciais da região sudeste-sul do Brasil: dinâmica Populacional das espécies em explotação. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 81-93.

Carneiro, M.H., L. Fagundes, A.O. Ávila-da-Silva & M.R. Souza. 2000. Ambientes marinhos explorados pelas frotas pesqueiras de Santos e Guarujá (SP). An. do V Simpósio Bras. Ecossistemas, 109: 83-91.

Carneiro, M.H., J.A. Kolling, A.O. Ávila-da-Silva, J.T. Mendonça, R.C. Namora & L.V. Miranda. 2013. A pesca nas áreas de proteção ambiental marinha do estado de São Paulo, Brasil, entre agosto de 2008 e julho de 2009. Informe Pesqueiro de São Paulo. Instituto de Pesca, São Paulo, 36:1-34. [http://www.propesq.pesca.sp.gov.br/arquivos/pagina/1496738655_InfoPesqSP036_Pesca%20nas%20APAMs.pdf]. Reviewed: 18 July 2016.

Carneiro, M.H., L.V. Miranda, A.O. Ávila-da-Silva. 2015. Diagnóstico da atividade pesqueira nas praias “massaguaçú”, “cocanha” e “mococa”, Caraguatatuba, São Paulo, Brasil, 2009-2013. Inf. Pesqueiro de São Paulo, 58: 1-9.

Castello, J.P., P.S.Sunye, M. Haimovici, & D. Hellebrandt. 2009. Fisheries in southern Brazil: a comparison of their management and sustainability. J. Appl. Ichthyol., 25(3): 287-293.

Castro, B.M., J.A. Lorenzzetti, I.C.A. Silveira & L.B. Miranda. 2006. Estrutura termohalina e circulação na região entre o Cabo de São Tomé (RJ) e o Chuí (RS). In: C.L.D.B. Rossi-Wongtschowski & L.S. Madureira (orgs.). O ambiente oceanográfico da plataforma continental e do talude na região Sudeste-Sul do Brasil. São Paulo, Editora da Universidade de São Paulo, pp. 11-120.

Castro, P.M.G., M.H. Carneiro, G.J.M. Servo, C.M.D. Mucinhato & M.R. Souza. 2007. Dinâmica da frota de arrasto de parelhas do estado de São Paulo, In: C.L.D.B. Rossi-Wongtschowski, R.A. Bernardes & M.C. Cergole (eds.) Dinâmica das frotas pesqueiras comerciais da região sudeste-sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 60-103.

Dallagnolo, R. & H.A. Andrade. 2007. Observações a respeito da pescaria sazonal de dourado (*Coryphaena hippurus*) com espinhel-de-superfície no sul do Brasil. Bol. Inst. Pesca, 34(2): 331-335.

Dallagnolo, R., J.A.A. Perez & P.R. Pezzuto. 2009. O ordenamento da pescaria de camarões-de-profundidade (Decapoda: Aristeidae) no sudeste e sul do Brasil. Braz. J. Aquat. Sci. Technol. 13(2):31-43.

Dias-Neto, J. 2010. Gestão do uso dos recursos pesqueiros marinhos no Brasil. Ministério do Meio Ambiente - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Brasília, 242 pp.

Diegues, A.C.S. 1983. Pescadores, camponeses e trabalhadores do mar. Editora Ática, São Paulo, 287 pp.

D'Incao, F. 1991. Pesca e biologia de *Penaeus paulensis* nos Lagos dos Patos, RS. Atlântica, 13(1): 159-169.

Figueiredo, J.L. & N.A. Menezes. 1978. Manual de peixes marinhos do Sudeste do Brasil. II. Teleostei (1). Museu de Zoologia da Universidade de São Paulo, São Paulo, 110 pp.

Figueiredo Jr., A.G. & L.S.P. Madureira. 2004. Topografia, composição, refletividade do substrato marinho e identificação de províncias sedimentares na região sudeste-sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, 64 pp.

Food and Agriculture Organization (FAO). 1999. Guidelines for the routine collection of capture fishery data. FAO Fish. Tech. Pap., 382: 113 pp.

Gasalla, M.A., J.A.A. Pérez, C.A. Marques, A.R.G. Tomás, D.C. Aguiar & U.C. Oliveira. 2005. *Loligo sanpaulensis* (Brakoniecki, 1984). In: M.C. Cergole, A.O. Ávila-da-Silva & C.L.D.B. Rossi-Wongtschowski (eds.). Análise das principais pescarias comerciais da região Sudeste-sul do Brasil: dinâmica populacional das espécies em explotação. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 69-73.

Gasalla, M.A., G.J.M. Servo & A.R.G. Tomás. 2007. Dinâmica da frota de traineiras da região de Santos, São Paulo. In: C.L.D.B. Rossi-Wongtschowski, R.A. Bernardes, M.C. Cergole (eds.) Dinâmica das frotas pesqueiras comerciais da região sudeste-sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 199-217.

Graça-Lopes, R. da, A.R.G. Tomás, S.L.S. Tutui, E. Severino Rodrigues & A. Puzzi. 2002a. Comparação da dinâmica de desembarques de frotas camaroeiras do estado de São Paulo, Brasil. Bol. Inst. Pesca, 28(2): 163-171.

Graça-Lopes, R. da, A.R.G. Tomás, S.L.S. Tutui, E. Severino Rodrigues & A. Puzzi. 2002b. Fauna acompanhante da pesca camaroeira no litoral do estado de São Paulo, Brasil. Bol. Inst. Pesca, 28(2): 173-188.

Haimovici, M., J.P. Castello & C.M. Vooren. 1997. Fisheries. In: U. Seeliger, C. Odebretch & J.P. Castello (eds.). Subtropical convergence environments: the coastal and sea in the southwestern Atlantic. Springer-Verlag, New York, pp. 183-196.

Haimovici, M., A.O. Ávila-da-Silva & C.L.D.B. Rossi-Wongtschowki (eds.). 2004. Prospecção pesqueira de espécies demersais com espinhel-de-fundo na Zona Econômica Exclusiva da região sudeste-sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 112.

Haimovici, M., M.C. Cergole, R.P. Lessa, L.S.P. Madureira, S. Jablonski & C.L.D.B. Rossi-Wongtschowski. 2006. Panorama nacional. In: Ministério do Meio Ambiente (MMA). Programa REVIZEE avaliação do potencial sustentável de recursos vivos na Zona Econômica Exclusiva: relatório executivo. Brasília, DF, pp. 79-125.

Haimovici M., C.L.D.B. Rossi-Wongtschowski, R.A. Bernardes, L.G. Fischer, C.M. Vooren, R.A. Santos, A.R. Rodrigues & S. Santos. 2008. Prospecção pesqueira de espécies demersais com rede de arrasto-de-fundo na região sudeste-sul do Brasil Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 184.

Hilborn, R. 1985. Fleet dynamics and individual variation: why some people catch more fish than others. Can. J. Fish. Aquat. Sci., 42: 2-13.

Iwai, M. 1973. Pesca exploratória e estudo biológico sobre o camarão na costa centro/sul do Brasil com o navio oceanográfico "Prof. W. Besnard" em 1969-1971. SUDELPA/IOUSP, São Paulo, 71 pp.

Instituto de Pesca. 2016. Programa de monitoramento da atividade marinha e estuarina do Instituto de Pesca, Banco de Dados ProPesqWEB. [http:// http://www.propesq.pesca.sp.gov.br/]. Reviewed: Reviewed: 18 July 2016.

Jackson J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, R.R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science, 293: 629-638.

Kolling, J.A. 2011. Variação espacial e temporal na abundância do camarão sete-barbas, *Xiphopenaeus kroyeri* (Heller, 1862), descarregado no estado de São Paulo entre 1990-2009: identificação das influências pesqueiras e ambientais. Master thesis, Post-Graduation Program in Aquaculture and Fisheries. Instituto de Pesca, São Paulo [http://www.pesca.sp.gov.br/dissertacoes_pg.php]. Reviewed: 17 August 2015.

Kolling, J.A., P. A. Batista, A.O. Ávila-da-Silva & M.H. Carneiro. 2008. A utilização do ambiente marinho e de seus recursos vivos pela frota pesqueira paulista: o ambiente demersal. Série Relatórios Técnicos, Instituto de Pesca, São Paulo, 32: 1-62.

Kolling, J.A. & A.O. Ávila-da-Silva. 2014. Evaluation of determinants of *Xiphopenaeus kroyeri* (Heller, 1862) catch abundance along a southwest Atlantic subtropical shelf. ICES J. Mar. Sci., 71(7): 1793-1804.

Martins, A.S., G. Olavo, P.A.S. Costa. 2005. A pesca de linha de alto mar realizada por frotas sediadas no Espírito Santo, Brasil. In: P.A.S. Costa, A.S. Martins & G. Olavo (eds.). Pesca e potenciais de exploração de recursos vivos na região central da Zona Econômica Exclusiva brasileira. Museu Nacional, Rio de Janeiro, pp. 35-55.

Martins, A.S., L.B. Santos, G.T. Pizetta, C. Monjardim & J.R. Doxsey. 2009. Interdisciplinary assessment of the status quo of the marine fishery systems in the state of Espirito Santo, Brazil, using rapfish. J. Appl. Ichthyol., 25(3): 269-276.

Matsuura, Y. 1998. Brazilian sardine (*Sardinella brasiliensis*) spawning in the southeast Brazilian Bight over the period 1976-1993. Rev. Bras. Oceanogr., 46(1): 33-43.

Mendonça, J.T., T.M. Bonfante. 2011. Assessment and management of white mullet *Mugil curema* (Valencienne, 1836) (Mugilidae) fisheries of the south coast of São Paulo state, Brazil. Braz. J. Biol., 7(3): 663-672.

Mendonça, J.T. & L.V. Miranda. 2008. Estatística pesqueira do litoral sul do estado de São Paulo : subsídios para gestão compartilhada. Panam. J. Aquat. Sci., 3: 152-173.

Ministério da Pesca e Aquicultura e Ministério do Meio Ambiente (MPA/MMA). 2011. Instrução Normativa nº10, Normas gerais e a organização do sistema de permissionamento de embarcações de pesca para acesso e uso sustentável dos recursos pesqueiros. June 10, 2011.

Mourato, B.L., C.A. Arfelli, A.F. Amorim, H.G. Hazin, F.C. Carvalho & F.H. Hazin. 2011. Spatio-temporal distribution and target species in a longline fishery off the southeastern coast of Brazil. Braz. J. Oceanogr., 59(2): 185-194.

Paiva, M.P. & M.F. Andrade. 1994. Pescarias de barcos linheiros ao largo da costa sudeste do Brasil (1979-1985). Boletim Técnico do Instituto de Pesca, São Paulo, 18: 1-21.

Pauly, D., V. Christensen, S. Guénette, T. Pitcher, U.R. Sumaila, C.J. Walters, R. Watson & D. Zeller. 2002. Towards sustainability in world fisheries. Nature, 418: 689-695.

Pereira, O.M., I.C. Machado, M.B. Henriques, M.S.N. Galvão & N. Yamanaka. 2001. Avaliação do estoque da ostra *Crassostrea brasiliana* em rios e gamboas da região estuarino-lagunar de Cananéia (São Paulo, Brasil). Bol. Inst. Pesca, 27(1): 85-95.

Perez, J.A.A., R. Wahrlich, P.R. Pezzuto & F.R. de A. Lopes. 2002a. Estrutura e dinâmica da pescaria do peixe-sapo *Lophius gastrophysus* no sudeste e sul do Brasil. Bol. Inst. Pesca 28: 205-231.

Perez, J.A.A., P.R. Pezzuto, H.A. Andrade, P.R. Schwingel, M. Rodrigues-Ribeiro & R. Wahrlich. 2002b. O ordenamento de uma nova pescaria direcionada ao peixe-sapo (*Lophius gastrophysus*) no sudeste e sul do Brasil. Notas Téc. Facimar, 6: 65-83.

Perez, J.A.A., R. Wahrlich, P.R. Pezzuto, P.R. Schwingel, F.R.A. Lopes & M. Rodrigues-Ribeiro. 2003. Deep-sea fishery off southern Brazil: recent trends of the Brazilian fishing industry. J. Northwest Atl. Fish. Sci., 31:1-18.

Pezzuto, P.R., J.A.A. Perez & R. Wahrlich. 2006. O ordenamento das pescarias de caranguejos-de-profundidade (*Chaceon* spp.) (Decapoda: Geryonidae) no sul do Brasil. Bol. Inst. Pesca 32(2): 229-247.

Postuma, F.A. & M.A Gasalla. 2010. On the relationship between squid and the environment: artisanal jigging for *Loligo plei* at São Sebastião Island (24°S), southeastern Brazil. ICES J. Mar. Sci., 67(7): 1353-1362.

R Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing. [http://www.R-project.org] Reviewed: 12 June 2015.

Rossi-Wongtschowski, C.L.D.B., R.A. Bernardes & M.C. Cergole. 2007 (eds.). Dinâmica das frotas pesqueiras comerciais da região sudeste-sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, 343 pp.

Salas, S. & D. Gaertner. 2004. The behavioural dynamics of shers: management implications. Fish Fish., 5: 153-167.

Santos, R.A., R.W. Seckendorff & M.L.F.M. Amaral. 1988. Espécies mais comercializadas na região sudeste do Brasil e respectivas artes e embarcações utilizadas nas capturas. Bol. Téc. Inst. Pesca, 6: 31 pp.

São Paulo. 1998. Lei nº 10.019, Plano estadual de gerenciamento costeiro. July 03, 1998.

São Paulo. 2008. Decretos n° 53.525, 53.526 e 53.527, Áreas de proteção ambiental marinha de São Paulo. October 08, 2008.

Schwingel, P.R. & D.S. Occhialini. 2007. Descrição e dinâmica da frota de traineiras do porto de Itajaí, Santa Catarina, entre 1997 e 1999. In: C.L.D.B. Rossi-Wongtschowski, R.A. Bernardes & M.C. Cergole (eds.) Dinâmica das frotas pesqueiras comerciais da região sudeste-sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 218-247.

Tomás, A.R.G. 2007. Dinâmica da frota de emalhe do estado de São Paulo. In: C.L.D.B. Rossi-Wongtschowski, R.A. Bernardes & M.C. Cergole (eds.) Dinâmica das frotas pesqueiras comerciais da região Sudeste-Sul do Brasil. Instituto Oceanográfico, Série documentos Revizee: Score Sul, São Paulo, pp. 263-276.

Valentini, H. & R.D. Cardoso. 1991. Análise da pesca da sardinha-verdadeira, *Sardinella brasiliensis*, na costa sudeste-sul do Brasil. Atlântica, 13(1): 45-54.

Valentini, H. & P.R. Pezzuto. 2006. Análise das principais pescarias comerciais da região sudeste-sul do Brasil com base na produção controlada do período 1986-2004. Instituto Oceanográfico, Série documentos Revizee, Score Sul, São Paulo, 56 pp.

Valentini, H., F.D'Incao, L. Rodrigues, J.R. Neto & E. Rahn. 1991. Análise da pesca do camarão-rosa (*Penaeus brasiliensis* e *Penaeus paulensis*) nas regiões sudeste e sul do Brasil. Atlântica, 13(1), 143-157.

Watson R., D. Pauly, V. Christensen, R. Froese, A. Long Hurst, T. Platt, S. Sathyendranath, K. Sherman, J.

O'Reilly & P. Celone. 2003. Mapping fisheries onto marine ecosystems for regional, oceanic and global integrations. In: G. Hempel & K. Sherman (eds.). Large marine ecosystems of the world: Trends in exploitation, protection, and research: Elsevier Science, New York, 375-395.

Zar, J. H. 2009. Biostatistical analysis, Prentice Hall, New Jersey, 699 pp.

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Zavala-Camin, L.A. & A.R.G. Tomás. 1990. A pesca de atuns com espinhel no atlântico sudoeste por barcos japoneses e brasileiros (1959-1979). Bol. Inst. Pesca, 17(1): 61-75.