Fisheries Research 210 (2019) 162–174

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Cost structure and financial performance of marine commercial fisheries in the South Brazil Bight

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ARTICLE INFO

Handled by Prof. George A. Rose

Keywords:
Economic indicators
Fishing cost
Profitability
Multi-fleet approach
Generalized additive model

ABSTRACT

In Brazil, economic data on fisheries are generally scarce, and difficult to interpret with respect to costs and fishery viability, thus making it difficult to practice consistent policy and industrial decision-making. Financial performance was assessed, as were the key factors affecting the fishing costs and profitability of the major fisheries fleets that operated in three Southeast and South regions. Through an unprecedented set of field survey data from 160 fishing vessels obtained during 2013–2014, we provide a cost-benefit comparison between different fleets and landing sites. Three generalized additive models (GAMLSS) were explored to identify major factors affecting gross profit. Fuel consumption, vessel repairs, revenue, and volume of catch were the most statistically significant factors explaining gross profit margin. For trawlers and purse-seiners, technical features such as vessel size and the number of fishing trips explained profitability, respectively, while the landing costs were significant to both types of fleet. Gross profits for trawlers also depend on ice cost and fleet type. Large pelagic fisheries showed the highest gross profit, while shrimp-trawlers, bottom-gillnetters and a purse-seining fleet showed the lowest profit, close to unviability. Indirectly, population size of target species may be influencing profitability. Labor wages increase when the financial performance of fleets improve; however, reduced yields and high operational cost levels may decrease the salaries. Specific policy advice and management strategies aiming to protect both financial performance and natural resources are highlighted, including the importance of cost-benefit analysis to help businessmen and vessel owners to identify factors that influence fleet profitability, thereby facilitating the creation of measures for increased efficiency. The approach presented may contribute to standardizing economic knowledge construction in data-poor fisheries, such as S/SE Brazil's and in other jurisdictions of Brazil or elsewhere.

1. Introduction

Fishing in marine waters supports social and cultural well-being and provides sources of food and nutrition; moreover, it remains important for providing employment and economic benefits for those engaged in this activity (FAO, 2016). However, the benefits that fishery resources can provide will depend largely on how well they are rebuilt and managed (Sumaila et al., 2012).

The management of fisheries in order to enhance their sustainability has primarily focused on the environmental aspect, i.e., conservation of the seafood stocks, and technological issues (Lucena and O'Brien, 2005). Nonetheless, fishing behavior is largely driven by economic incentives (Pascoe et al., 1996), and in recent decades, the social and economic aspects have been considered equally essential (Munro and Sumaila, 2015; Anderson et al., 2015). Furthermore, socio-economic indicators of fisheries are important measures used to predict, explain, monitor and evaluate the consequences and impact of the fishing management decisions (Branch et al., 2006; Daurès et al., 2013), such as input control (number and size of vessels, gear and mesh size, and temporal closures) and output controls (size limits of the species and catch quotas).

In addition, economic data, such as fishing costs and gross revenue, play an important role in understanding the economic viability of the fisheries (Lam et al., 2011) and serve as useful information for subsidizing vessels, investors and fishing incentive programs in decision-making. Thus, financial profitability could indicate the degree of hardship faced by vessel operators; this is important for assessing the livelihoods of fishermen, which is the most appropriate measure for

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https://doi.org/10.1016/j.fishres.2018.10.017
Received 5 March 2018; Received in revised form 12 October 2018; Accepted 16 October 2018
0165-7836/

indicating the sustainability of the sector in the short term (Borrello et al., 2013).

The critical deterioration of the economic health of the world's fisheries may be connected to poor governance and is both a cause and a result of the biological overexploitation. Thus, the knowledge of the economics of fisheries is fundamental to build the economic sustainability indispensable to conserving and rebuilding fish stocks and supports a consistent policy debate on fishery reform (Arnason et al., 2009).

However, just as the information on fishing costs and profitability are scarce and incomplete in most countries (Arnason et al., 2009; LAM et al., 2011), in Brazil, the economic and financial performance of fisheries are still poorly documented; there is an insignificant effort by government agencies to obtain the economic data of fleets (Gasalla et al., 2010), and the fishers and vessel owners are reluctant to provide complete information, especially for income, subsidies and taxes. Therefore, this lack of data may be contributing to the inexistence of economic studies with multi-fleet purposes. Despite these challenges, Brazilian academic research papers have been reporting economic data for inland fisheries (Almeida et al., 2001; Glaser and Diele, 2004; Cardoso and Freitas, 2006), marine small-scale fisheries such as for lobster and shrimp (Carvalho et al., 1996, 2000, 2003; Souza et al., 2009; Azevedo et al., 2014), bioeconomic models and for a few species (Castro et al., 2001; Lucena and O'Brien, 2005; Matsuura, 1981; PIO et al., 2016) and multi-fleet comparison (Gasalla et al., 2010).

In this context, the present study provides an analysis of the financial performance of the 13 commercial fleets operating in Southeast and South Brazil. Thus, based on cost and revenue data obtained from field interviews, the key objectives of this paper are as follows: (1) describe, calculate and compare the costs structure of the fish fleets for Southeast and South regions; (2) estimate and analyze the profitability of the studied fleets in the short-term (gross profit, gross profit margin and economic efficiency); and (3) identify the factors (technical features and economic indicators) determining fishing gross profit margins in the regions.

2. Methods

2.1. Data collection

The aim of the survey was to collect information on the fishing behavior of the fleet, as well as financial information (such as costs and earnings) for the 2013–2014 financial year. A survey was conducted among the primary landing points in three regions of Southeast and South of Brazil, namely, Santos/Guarujá (SG), Itajaí/Navegantes (IN) and Angra dos Reis (AR) (Fig. 1). Key-informant, semi-structured personal interviews with vessel captains and owners were used to gather data related to the technical and fishing effort details, costs and production data of the most recent fishing trips (Fig. 2) by a vessel. The vessels were aggregated by type and region (total of three home ports, SG, IN and AR), totaling 13 different commercial fleet categories: bottom-gillnetters (SG and IN), surface-tuna-longliners (IN), octopus-pots (SG), pair-bottom-trawlers (SG), pink-shrimp-trawlers (SG and IN), pole and line (IN), purse-seiners (SG, IN, AR), sea-bob-shrimp-trawlers (SG), and dolphinfish-longliners (IN). This approach was needed because there are not economic data available from the region and local governments do not collect financial details from those fleets. The interviews were performed at principal industries and public landing terminals due to the significant numbers of vessels that landed at these sites that are currently considered representative of the regional fisheries. Data were collected from a random sample of 161 fishing vessels and 215 interviews. The survey covered more than 30% of total active vessels that land about 75% of total regional catch. Total vessels in operation, the number of vessels sampled and the number of interviews per region and per fleet, are shown in Table 1. The number of potentially active vessels was obtained from the PMAP (2013); SisRGP, 2018; TAMAR Project database (2013), and SINDIPI database (2013). The data were collected across multiple months and all interviews were used. In some cases, vessel was surveyed more than once to better reflect seasonal variations.

Vessel maintenance and repair were considered to be a variable cost within this study because a fixed percentage of the revenue is taken from each fishing trip for vessel repair and this cost can be modified depending upon the catch produced per trip. Therefore, according to those interviewed, this amount is used to cover costs such as small repairs to the boat, equipment and fishing apparatus, as well as the costs involved in larger maintenance work (the boat itself and fishing equipment).

2.2. Data analysis

To describe and evaluate the financial performance of the fleets, a set of indicators was calculated. Key financial indicators are the level of capital cost, revenue, operational costs, labor costs, fixed costs, gross profit, gross profit margin and economic efficiency. Medians with minimum and maximum values were used to describe the financial indicators per fishing trip, month and year of three regions. The median value takes into consideration the number of observations within each fleet.

The capital cost, also denoted as capital investment (CI), of the fishing vessels was estimated, including the initial cost of acquiring a fishing vessel and all the equipment necessary to perform the activities. To establish the CI, we asked each owner or captain the value of their vessel, gear and equipment under the assumption that they had to sell it in its current condition at that time.

Revenue (R) is the total catch value and was calculated from the catch per species, in kilograms, multiplied by the respective ex-vessel price. The information on the quantity captured and the price refers to the last trip, and were collected across months.

Operational costs (OC) include variable costs such as fuel, lubricating oil, ice, food, bait, repairs to the vessel and gear maintenance (between 5–25% of the revenue, depending on the vessel), as well as landings costs. Costs per month were based on the costs per trip multiplied by the number of trips per month. Annual data were calculated by multiplying the monthly values by the number of months that the fleet operated, and these data can be different for each fleet (i.e., some target species are managed through the application of closed fishing seasons). To calculate the cost of fuel per trip, the average market price of the diesel oil value was used and multiplied by the amount of fuel (in liters) on the trip per vessel. The site of the National Agency of Petroleum, Natural Gas and Biofuels - ANP was consulted to establish the market price of diesel oil. Landing cost corresponded to the fees paid by the vessel when the catches are landed and is influenced by the total volume of the landing. This rate may vary depending on the landing point and may be null in some cases.

Labor costs (LC) include all payments to crew, and involves the payment of shares that are calculated on the overall value of production per fishing trip. Thus,

$$LC = (R - OC) / 2. \quad (1)$$

This is because for all regional fleets there is a cultural split tradition of allocating 50% of the net revenue to the owner, the other half going to the crew which is divided among the fishers depending on their on-board functions (Diegues, 1983; Dias-Neto, 2010).

Fixed costs (FC) included monthly and annual expenses for fees (social security contribution), vessel tracking service, insurance (vessel and crew), forwarding agents, and accountants.

Total costs (TC) were calculated using the sum of operational costs and fixed costs.

$$\text{Total costs (TC)} = OC + LC + FC \quad (2)$$

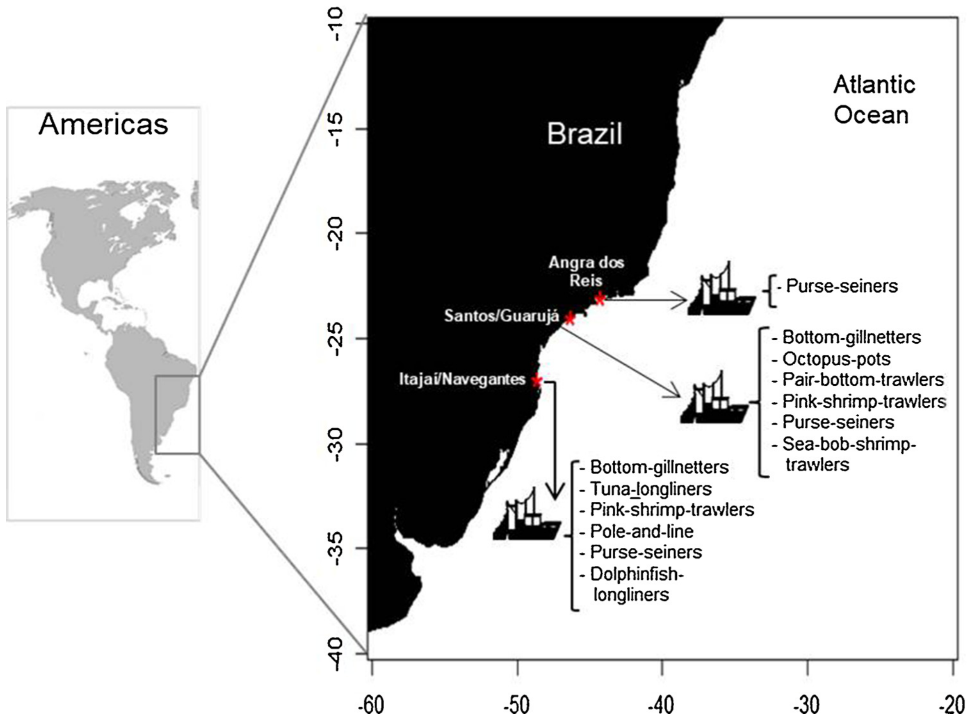

Fig. 1. Commercial fleets analyzed in the fishing ports of Angra dos Reis (AR), Santos/Guarujá (SG) and Itajaí/Navegantes (IN) on the coast of the South Brazil Bight (SBB), in South America.

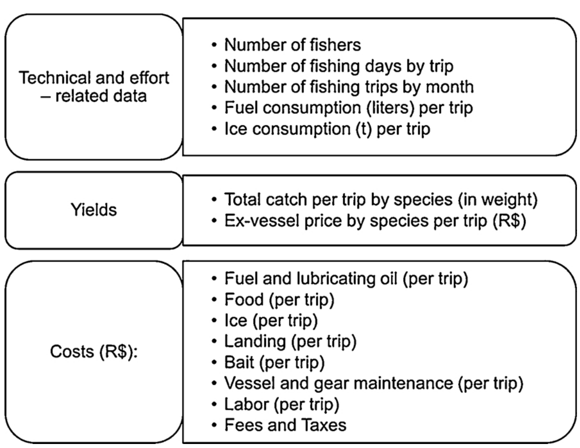

Fig. 2. Attributes included in questionnaires for data-gathering interviews.

Gross profit (before interest and taxes) is simply calculated as:

$$\text{Gross profit (GP)} = \text{R-TC} \quad (3)$$

Economic efficiency (EE) was estimated by dividing the R (annual value) by the TC (annual value).

$$\text{EE} = \text{R/TC} \quad (4)$$

Gross profit margin (GPM%) represents what is left to the vessel owner as compensation for the capital as a percentage of sales, *i.e.*, the revenue.

$$\text{GPM (\%)} = (\text{GP/R}) \times 100 \quad (5)$$

Depreciation and the opportunity cost of labor and capital were not included in the analyses because this study was not designed to be a full economic analysis of the profitability of the fleets but instead as a financial indication of benefit and cost of current operations fishing activity to those involved in the sector. Financial performance is the measure of most interest to fishers, as it represents how much income they are left with at the end of the year (Pascoe et al., 1996; Gunnlaugsson and Saevaldsson, 2016).

Note that all costs and values are in Brazilian currency (Real, R$; conversion rate of US$ 1.00 = R$ 2.23 on May 30, 2014).

To compare data relating to the gross profits and costs of fleets, we prioritize the use of monthly and annual values because the number of trips per month was considered in the calculation, and thus, we can better represent the costs and profits from the fishing operations. A better measure of the financial performance of the fleets was the “Gross profit margin (%)” and “Gross profit”, and these indicators were used to compare the profitability of the fleets, as they show how large a proportion of revenue was left after tall costs have been accounted.

Both gross profit margin and monthly costs related to the fishing operation (bait, food, fuel, ice, landing, others cost, and vessel maintenance) per fleet were tested for normality using a Shapiro–Wilk test. Because data were found to violate the criteria for normality, the non-parametric Kruskal–Wallis test (Zar, 1996) was applied to test the significant differences between the profitability of the fleets and between the costs related to the fishing operation (excluding the fixed costs) per fleet groups. The null hypothesis is that the medians of the groups are equal. When the Kruskal-Wallis test revealed significant differences among groups (different costs or fleet’s profits), *a posteriori* pairwise for multiple comparisons were conducted. All statistical tests were considered at a 0.05 level of significance, and were implemented using the function kruskalmc() (package pgirmess) in R (R Development Core Team, 2013). This function implements Dunn’s *post hoc* rank sum comparison using *z* test statistics as directed by Siegel and Castellan (1988). Pairwise comparisons allow determining which groups are different - those pairs of groups that show observed differences higher than a critical value are considered statistically different.

2.3. Generalized additive models

Generalized additive models for location, scale and shape (GAMLSS) were used to investigate the main factors that interact with profitability of the commercial fleets. The purpose is to adjust any type of regression

Table 1
Major characteristics of the nine studied fishing fleets based in the ports of Angra dos Reis (AR), Santos/Guarujá (SG) and Itajaí/Navegantes (IN), in the South Brazil Bight. Means are shown per fishing trip.

Fleet	Gear	Target-species	Main bycatch	Vessels length of sampled (m)			Crew number (mean)			Fishing days (mean)			Number of active vessels (2012-2013)			Sample size (vessels)			Total number of interviews (survey)		
				AR	IN	SG	AR	IN	SG	AR	IN	SG	AR	IN	SG	AR	IN	SG	AR	IN	SG
Bottom gillnetters	Bottom-gillnet	*Micropogonias furnieri, Umbrina canosai, Cynoscion* spp.	*Urophycis* spp., *Carcharhinus* spp., *Pomatomus saltatrix*		18-24	8-19		7	6		26.6	12.8		53	51		11	12		11	26
Tuna- longliners	Surface longlines	*Xiphias gladius,Thunnus* spp., *Prionace glauca*	*Auxis thazard, Isurus spp.*, and another 20 species.		17-23			9			18.3			21			6			6	
Octopus-pots	Pots and traps	*Octopus vulgaris*	Slipper lobsters			14-22			6			12.6			18			13			17
Pair-bottom-trawlers	Bottom pair trawls	*Micropogonias furnieri, Umbrina canosai, Cynoscion* spp.	Over 77 species from 25 families.			18-30			9			12.9			9			7			16
Pink-shrimp-trawlers	Double otters trawls	*Farfantepenaeus* spp.	More than 165 fish species,35 crustaceans, and 25 mollusks.		15-23	16-26		4	5		23.4	18.5		86	52		12	19		12	34
Pole and line	Hooked line attached to a pole	*Katsuwonus pelamis*	*Thunnus* spp., Pelagic sharks		18-28			25			16.3			24			5			5	
Purse-seiners	Purse-seiners	*Sardinella brasiliensis*	*Chloroscombrus chrysurus,Trachurus lathami, Mugil* spp.	14-28	23-33	19-27	17	18	16	1.2	3.1	3	30	31	12	15	16	10	15	17	14
Sea-bob-shrimp-trawlers	Double otters trawls[a]	*Xiphopenaeus kroyeri*	80 fish species, more than 20 crustaceans, and mollusk species.			6-15			3			11.4			70			27			34
Dolphinfish-longliners (from Itaipava)	Surface longlines	*Coryphaena hippurus*	*Thunnus* spp., Pelagic sharks		13-20			6			11.5			91			8			8	

[a] sol-a-sol (dawn to dusk) vessels excluded.

Table 2
Performance indicators estimated per fishing trip, month and year (in Brazilian Reais, R$) for the purse-seiners of Angra dos Reis (EE: Economic efficiency).

Purse-seiners	Median	Minimum	Maximum
Capital investment (in 1000)	2,550	800	4,500
Per fishing trip:			
Catch (t)	35	14	80
Revenue	42,500	14,000	80,000
Operational Cost	13,843	7,146	23,635
Labor Cost	15,227	757.24	30,262
Gross profit	30,455	1,514	60,524
Monthly:			
Trips per month	12	5	18
Revenue	604,800	70,000	1,040,000
Operational Cost	180,663	50,549	322,340
Labor Cost	193,332	4,732	393,408
Fixed Cost	6,345	2,204	12,304
Gross profit	181,028	−1,665	387,062
Gross profit margin (%)	48.49	−17.60	49.19
Annual:			
Revenue	4,233,600	490,000	7,280,000
Operational Cost	1,264,641	353,844	2,256,385
Labor Cost	1,353,328	33,129	2,753,858
Fixed Cost	76,154	26,458	147,658
Gross profit	1,205,670	−43,665	2,677,703
EE (R$)	1.42	0.96	1.60

model for various types of distributions (e.g., Binomial, Exponential, Gamma, Gumbel, etc) which includes highly skew and kurtotic discrete and continuous (Rigby and Stasinopoulos, 2005).

GAMLSS were implemented using the function gamlss() (package gamlss) in R (R Development Core Team, 2013), by modeling all the parameters of the distribution as functions of the explanatory variables, ended with a cubic spline smoothing function (cs) (Stasinopoulos and Rigby, 2007).

Thus, three models were analyzed separately. The first one considered data of all fleets and was used to determine the level of significance of the response economic variable (gross profit margin) with the factors of operational costs (fuel, lubricant, ice, food, vessel maintenance [Vm], landing and other costs), fixed costs (social security [Ss], vessel tracking service [Vts] and accountants), and technical/operational characteristics of the vessels (fleet segment [fleet], vessel size [Vs], number of trips per month [Tm] and region of landing [port]) following the equation:

gamlss(gross profit margin ~ (fleet) + cs(Vs) + cs(Tm) + cs(fuel) + cs(lubricant) + cs(ice) + cs(food) + cs(Vm) + cs(landing) + cs (others) + cs (Ss) + cs(Vts) + cs (accountants), family = GU)

The second and third models were focused on purse-seiners and trawlers (shrimp-trawlers and pair-bottom-trawlers), respectively, and the level of significance of the response economic variable (gross profit) with the factors of operational costs, and technical/operational characteristics of the vessels was determined, following the equation:

.gamlss(gross profit ~ (fleet) + cs(Vs) + cs(Tm) + cs(fuel) + cs(lubricant) + cs(ice) + cs(food) + cs(Vm) + cs(landing) + cs(others), family = NO)

A Gumbel probability distribution was selected for the examination of the response variable for gross profit margin and a normal probability distribution for gross profit.

The variance inflator factor (VIF) was used to test collinearity between variables in the GAMLSS (Montgomery and Peck, 1992). Values greater than 3 printed by the function $VIF^{1/(2\times df)}$, where *df* is the degrees of freedom, indicated collinearity; thus, these variables were excluded from the analysis following the recommendation made by Zuur et al. (2010).

The best fitted models were selected based on the Akaike

Table 3
Performance indicators per fishing trip, as monthly and annual values, in R$ by fleets of Santos/Guarujá (Min.: minimum; Max.: maximum; GPM (%): Gross profit margin (%); EE: Economic efficiency).

	Bottom-gillnetters			Octopus-pots			Pair-bottom-trawlers			Pink-shrimp-trawlers			Purse-seiners			Sea-bob-shrimp-trawlers		
	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.
Capital investment (in 1000)	210	100	350	800	400	1000	1,133	1,000	1,500	650	150	2,000	1,958	458	3,000	221	50	600
Per fishing trip:																		
Catch (t)	4	1	62	2	0.6	5	25	20	55	5	0.8	25	20	5	45	1	0.5	6
Total Revenue	18,090	800	280,747	37,800	9,600	74,150	149,320	93,818	283,193	50,947	11,500	222,930	24,094	12,000	58,500	11,000	1,300	45,600
Operational Cost	9,757	2,422	55,978	20,751	10,434	55,300	69,160	48,172	95,726	37,297	10,402	121,671	11,246	5,987	20,487	6,333	968	27,519
Labor Cost	2,608	−2,979	15,118	8,355	−417	21,066	36,924	19,069	93,733	7,673	−5,018	70,735	2,987	231	21,113	2,205	−1,182	11,568
Profit	2,608	−2,979	15,118	8,355	−417	21,066	36,924	19,069	93,733	7,673	−5,018	70,735	2,987	231	21,113	2,205	−1,182	11,568
Monthly:																		
Trips per month	2.5	1	3	2	1	2	2	1.5	2	1.5	1	2.5	6.1	5.0	8.0	2.0	1.0	5.0
Total Revenue	33,274	10,776	101,776	70,560	19,200	148,300	259,702	187,637	566,387	77,126	13,679	334,395	130,000	60,500	292,500	26,022	5,200	56,550
Operational Cost	20,740	11,563	45,426	36,068	20,868	110,600	135,004	81,511	191,453	59,883	10,402	168,806	81,362	45,677	134,458	16,031	3,872	42,412
Labor Cost	3,971	−2,979	37,796	16,710	−834	42,132	62,578	38,139	187,467	9,613	−9,568	106,103	23,896	1,393	105,568	4,816	−3,264	15,128
Fixed Cost	2,380	1,164	4,129	3,338	3,338	3,338	4,061	4,061	5,500	3,274	2,007	7,232	6,345	6,345	6,345	1,716	902	3,602
Gross Profit	1,591	−5,746	35,416	13,372	−4,172	38,794	57,078	34,077	181,967	6,395	−13,700	102,828	17,550	−4,951	99,223	2,206	−4,167	13,412
GPM (%)	5.69	−33.6	34.8	17.9	−21.7	26.2	24.7	16.6	32.1	14.0	−17.6	32.0	17.0	1.5	36.1	12.7	−43.9	30.2
Annual:																		
Total Revenue	399,289	129,314	1,221,323	846,720	230,400	1,779,600	3,116,424	2,251,649	6,796,650	694,134	123,111	3,009,555	910,000	423,500	2,047,500	23,4201	46,800	508,953
Operational Cost	248,883	138,760	545,115	432,823	250,422	1,327,200	1,620,056	978,133	2,297,439	538,951	93,626	1,519,254	569,535	319,744	941,211	16,031	3,872	42,412
Labor Cost	47,663	−35,753	453,558	200,520	−10,011	505,591	750,941	457,673	2,249,605	86,519	−86,116	954,931	23,896	1,393	105,568	43,351	−29,384	136,156
Fixed Cost	28,575	13,978	49,558	40,065	40,065	40,065	48,749	48,749	66,010	39,295	24,084	86,784	76,154	76,154	76,154	15,445	8,120	32,420
Gross Profit	19,087	−68,973	424,982	160,455	−50,075	465,526	684,930	408,923	2,183,595	47,908	−135,700	915,636	91,118	−66,397	662,827	19,856	−37,505	120,711
EE (R$)	1.06	0.69	1.53	1.22	0.79	1.35	1.33	1.20	1.47	1.07	0.66	1.44	1.11	0.91	1.48	1.15	0.56	1.43

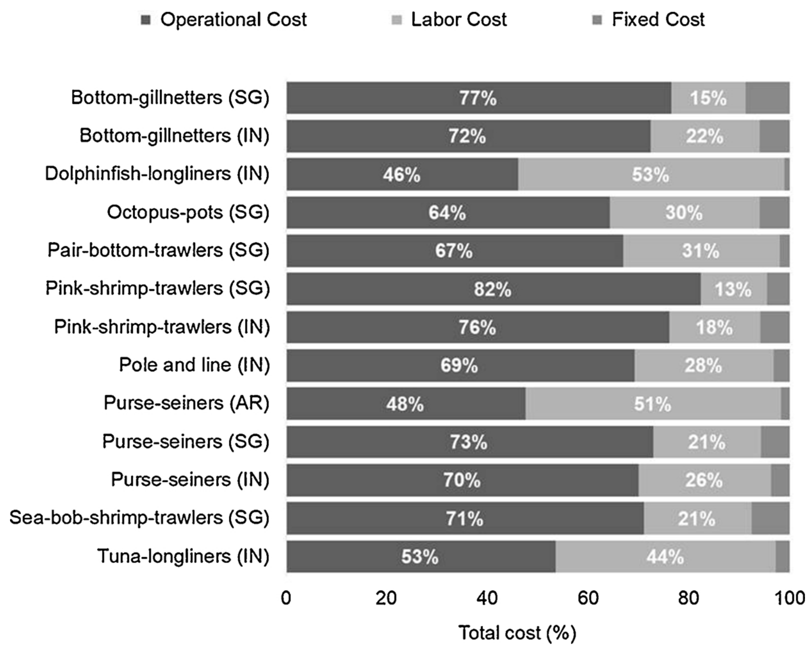

Fig. 3. Inter-fleet comparison of the relative importance of costs, as estimated by month.

Information Criterion (AIC) (at the running of the stepAIC function). AIC can be justified as Bayesian using a "savvy" prior on models that is a function of sample size and the number of model parameters (Burnham and Anderson, 2018). AIC= GD +(ρ× df)), the lower the value, the more parsimonious the model, with better fit, were AIC is special case of GAIC(p), in that the adopted penalty is p = 2, GD is Global Deviance of one fixed penalty p for each degree of freedom (*df*).

The significance of each term was accordingly to the AIC, likelihood-ratio test (LRT) and probability of the Chi-squared test criteria (PrChi) obtained (Stasinopoulos and Rigby, 2007).

3. Results

3.1. Fleet characteristics

Table 1 shows the main features of each fleet, such as fishing gear, target species, technical and operational characteristics, number of active vessels per region, as well as the number of vessels sampled and the total number of interviews per fleet and region. The shrimp-trawler, bottom-gillnetter and purse-seiner fleets are the largest in terms of the number of active vessels. Sea-bob-shrimp-trawlers have smaller boats. The size and type of gear usually determined the crew size, the pole-and-line fleet had the largest crew since more hands are required to operate that gear, followed by the purse-seiner.

3.2. Costs structure

The costs varied quite a lot across the fleets (Tables 2 and 3 and 4), though the operating cost represented the largest charge for all fleets, except dolphinfish-longliners (IN), purse-seiners (AR), and tuna-longliners (IN) where the labor cost was higher or has the same relative importance than operational cost (Fig. 3). Labor cost was collinear with revenue, gross profit and catch (t) (Fig. 4), and varied widely accordingly for each fleet segment. This variation was also influenced by value (ex-vessel price) and volume of the catch and the total operational costs, consequently because the labor salary is calculated by subtracting the operational cost (fuel, ice, repairs, etc.) from the revenue and the crew receive 50% of the net value of landings. Fuel was the main operational cost for all the fleets, except for pair-bottom-trawlers (SG) and purse-seiners of AR region, where vessel maintenance is the principal operational cost (Fig. 5). Fuel cost may account for approximately 54% of the operating costs for shrimp-trawlers, and between 42% and 48% for purse-seiners of IN and SG regions, respectively (Tables 3 and 4). However, fuel cost was only significantly (Kruskal–Wallis test) higher than the other operating costs ($p < 0.05$) for purse-seiners (SG). For all other fleets, fuel and vessel maintenance costs have the same importance, except for purse-seiners (IN), where fuel and landing were the main costs, and fuel and ice for purse-seiners (AR) (Table A1).

3.3. Profitability

Revenues are determined by the interaction between the catch (t) and ex-vessel prices of species (Tables 2, 3 and 4). Tuna longliners (IN), pink-shrimp-trawlers (SG and IN) and octopus-pots (SG) caught the highest target-stocks ex-vessel prices/kg, at R$ 12/kg, R$ 10/kg and R$ 19/kg, respectively (Tables 3 and 4). In the case of the purse-seiners, the ex-vessel price of sardines and the fish catch per trip varied between the regions of AR (35 t and R$ 1.21/kg), IN (26 t and R$ 1.61/kg) and SG (20 t and R$ 1.20/kg) (Tables 2, 3 and 4).

The results show that, on average, the gross profit was positive for all fleets. However, when we analyzed each trip separately, of the 214 fishing trips, 9.8% had negative returns. Fishing trips with negative returns were greater for the Santos/Guarujá region and for trips carried out by shrimp-trawlers, mainly the sea-bob-shrimp-trawlers, where 18% of fishing trips have had negative returns (Tables 3 and 4).

The profitability indicators (gross profit, gross profit margin, and EE) are shown in Tables 2, 3 and 4. Significant differences were detected in the annual gross profit margin inter-fleet ($\chi^2 = 61.727$, df = 12, $p = < 0.001$). On average, the fleet that had the greatest gross profit margin was the dolphinfish-longliners (IN; 33.15%) followed by the tuna-longliners (IN; 27.38%), purse-seiners (AR; 25.89%) and pair-bottom-trawlers (SG; 24.9%) (Fig. 6). The purse-seiners (SG; 7.98%), shrimp-trawlers (SG; 3.6% and IN; 7.8%) and bottom-gillnetters (SG; 7.66%) had the lowest gross profit margins among all analyzed fleets.

In terms of economic efficiency (EE), for every R$ 1 invested, dolphinfish- longliners (IN) had an income of R$ 1.55, followed by tuna-longliners (IN; R$ 1.43) and purse-seiners (AR; R$ 1.42), as the fleets that were more economically efficient among those analyzed. Shrimp-trawlers (from IN and SG), purse-seiners (SG) and bottom gillnetters (SG) showed the lowest incomes between R$ 1.06 and R$ 1.15 (Tables

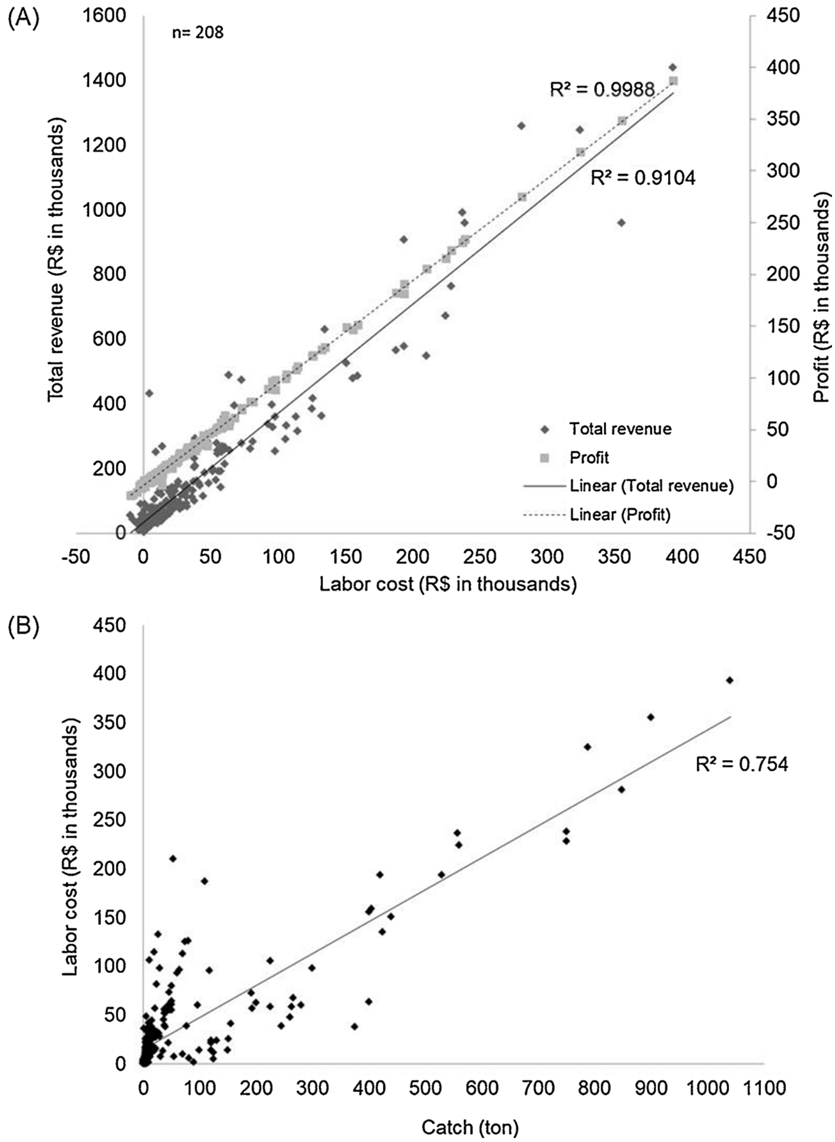

Fig. 4. Monthly indicators for all sampled fleets. Labor cost as a function of (A) total revenue and profit and (B) catch (ton).

2, 3 and 4).

3.4. Generalized additive models

All GAMLSS models showed a good fit to the data and the residuals appear random, although the normal Q-Q plot shows possible single outliers in the upper tail and lower tail. (Figs. A1, A2 and A3)

For *all fleets model,* the variance inflator factor (VIF) indicated co-linearity between the gross profit margin and labor cost, catch (t), and revenue, and thus, these variables were excluded from the analysis. The final *all fleets model* is shown in Table 5, and gross profit margins were explained by vessel maintenance cost, fleet type, fuel cost and ice cost. Gross profit margin showed a negative relationship with fuel cost and a positive relationship with vessel maintenance cost (Table 5). The fleet type effect shows that the dolphinfish-longliners (IN), purse-seiners (AR), and pole-and-line (IN) had the significantly highest gross profit margins, and octopus-pots had the lowest ($p < 0.05$) (Table 5).

The *purse-seiners model*, the variance inflator factor (VIF) considered the indicated co-linearity between gross profit and labor cost, vessel maintenance, catch (t) and revenue, so these variables were excluded from the analysis. Landing cost, number of trips per month, oil and food costs were the most likely variables in the model (LRT and Chi-squared test) (Table 6). A significant positive relationship was observed between the gross profit and number of trips above 10 per month (Fig. 7A). Gross profit decreased with a landing cost of approximately R$ 20,000 and R$ 40,000, and there is slight increase up to above this value (Fig. 7B).

The *trawlers model* (shrimp-trawlers and pair-bottom-trawlers), the variance inflator factor (VIF) indicated co-linearity between gross profit and labor cost, vessel maintenance, fuel cost, other costs, catch (t) and revenue, and thus, these variables were excluded from the analysis. Landing and ice costs, fleet type, and vessel size were the most likely variables in the model (LRT and Chi-squared test) (Table 6). A positive correlation was found between gross profit and landing cost, with an increasing trend (Fig. 8A). The effect of vessel length on gross profit increased for vessels up to 18 m (Fig. 8B). The gross profit was positively correlated to the pair-bottom-trawlers and pink-shrimp-trawlers (IN), while it was negatively correlated in the other two fleets (Fig. 8C).

Each panel of the GAMLSS plot in Figs. 7 and 8 is on the same y-axis scale, allowing for the identification of the relative contribution of each covariate and factor in explaining model variability.

4. Discussion

Economic data collection is a continuous challenge for fisheries

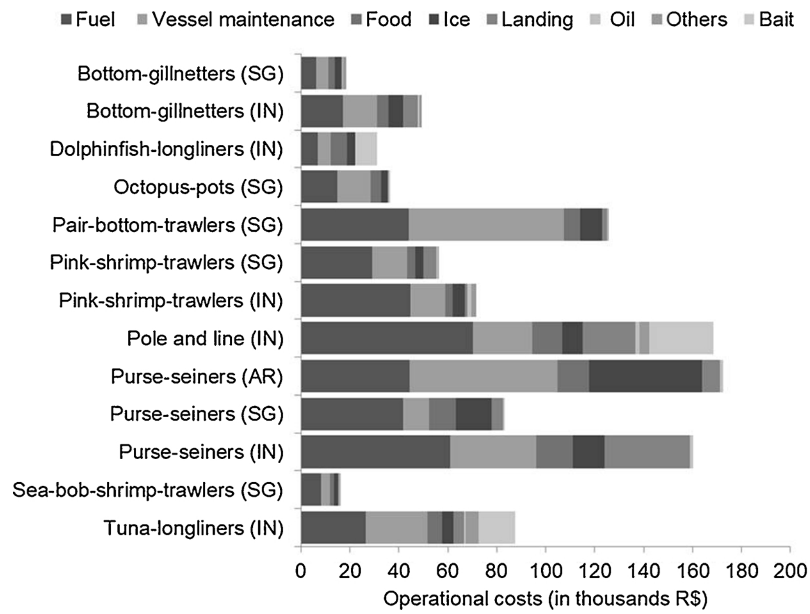

Fig. 5. Operational costs (median) within each fishing fleet as estimated per month and per region, Angra dos Reis (AR) Santos/Guarujá (SG) and Itajaí/Navegantes (IN).

research in Brazil. Therefore, undoubtedly, the results presented in this paper will be of great contribution to understanding the economic circumstances still unpublished for most of the national commercial fleets.

4.1. Structure of fishing costs

Fuel and vessel maintenance costs were the primary operational costs for all fleets, The differences in the level and structure of fishing costs observed between the fleets can be related to their dynamics of the fishing operation. For instance, in general, 'passive' fishing methods (e.g., gillnets, pots, and longlines) tend to be less energy demanding (fuel consumption) than 'active' ones (e.g., trawls and seines) (Tyedmers et al., 2005; Schau et al., 2009). When comparing the studied fleets that operate passively with active fisheries such as trawlers and purse-seiners, it is evident that gillnetter, dolphinfish longliner and octopus-pot vessels consume less fuel, and therefore, this factor can contribute to lower operating costs. However, pole-and-line, which also operates passively, presented high fuel costs, probably because they operate beyond the continental shelf (offshore). Thus, the range of the distances from fishing grounds to harbors and the fishing effort might primarily affect operational costs (Port et al., 2016).

In the studied fisheries, labor cost was correlated with revenue and catch. Indeed, according to interviews, vessel captains do not end the fishing trip until they are able to catch enough to pay the expenses and the labor. This fact opens an important question about the remuneration systems being based on productivity, consequently providing incentives for the captains to increase production in order to maximize their personal income (Vestergaard, 2010). However, labor wages can be varied if there are significant changes in the fishing conditions due to management measures, uncertain catches due to overfished fish stocks and increases in fishing effort (Guillen et al., 2017). The labor costs were either the most important cost component or had the same importance of operational costs in the dolphinfish-longliners, tuna-longliners and purse-seiners (AR) fisheries, as was the case in small-scale fisheries in France, Germany and Norway (Tietze and Lasch, 2005). For the other ten fleets studied, labor cost played a less important role than operational cost, as also was the case in the other fleets elsewhere such as in Argentine trawlers, Peruvian purse-seiners and French, German and Norwegian offshore and deep-sea fisheries (Tietze and Lasch, 2005).

4.2. Explaining the fishing profitability

Profitability was positive for all the fleets in 2013–2014. However, the costs per trip turned out to be higher than the total revenue per trip for some vessels, mainly for shrimp-trawlers. Negative returns had already been evidenced for the pair-bottom-trawlers (Castro et al., 2001b), purse-seiners and pink-shrimp-trawlers (Gasalla et al., 2010) off southeastern Brazil. Vessel maintenance cost, fuel cost and fleet type played a key role in explaining fishing profitability.

The gross profit margin for fishing fleets presented here varied widely, and as a ratio of more than 10 percent can be considered as good (Tietze and Lasch, 2005), large pelagic fisheries, pair-bottom-trawlers and purse-seiners (AR) may be considered highly profitable. This finding may be mainly due to these fleets presenting higher revenue, with a balance between the volume of sales and the value of the product (higher fishing efficiency). For example, purse-seiners (AR) presented the lowest ex-vessel price/kg (R$ 1.06) but had the second highest catch per trip (39,730 kg) when compared to the other fleets studied. On the other hand, the shrimp-trawlers, purse-seiners (SG) and bottom-gillnetters (SG) had the lowest profitability, with gross profit margins between 3.6% and 9.2%, possibly very close to the negative gross profit, mainly if there was a decrease in the fish sales price and increase in operational costs. The EE obtained indicated a return of 7 to 12 cents on the Brazilian Real for shrimp fishing vessels, which is low compared to the R$ 2.93 (US$ 1.18) from marine shrimp aquaculture (Rego et al., 2017).

Paradoxically, shrimp-trawlers, purse-seiners and bottom-gillnetters, that have many active vessels in the studied area (Table 1), may be targetting fully fished or overfished species. Although there are not updated stock assessments for target species such as pink-shrimp, Brazilian sardines, and demersal fishes, Valentini and Pezzuto (2006); Pincinato and Gasalla (2010); Haimovici and Cardoso (2016) and Pio et al. (2016) have been mentioning declining yields, and fleets overlaping the same target resource (Valentini et al., 1991; Perez et al., 2001). Considering profits and catches correlate statistically in this study, thus, it should be mentioned that unmeasured biological factors such as population size and hyperstability (catch per unit effort remaining high as fish density declines) of target species may be also

Table 4
Performance indicators per fishing trip, as monthly and annual values, in R$ by fleets of Itajaí/Navegantes (Min: minimum; Max: maximum; GPM (%): Gross profit margin (%); EE: Economic efficiency).

	Bottom-gillnetters			Tuna-longliners			Pink-shrimp-trawlers			Pole and line			Purse-seiners			Dolphinfish-longliners		
	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.
Capital investment (in 1000)	7	0.6	2,000	2,333	1000	3,000	692	300	900	6,116	700	12,000	2,687	1000	14,000	365	250	800
Per fishing trip:																		
Catch (t)	20	9	45	18	13	27	6	1	20	59	30	97	26	5	70	6	4	12
Revenue	90,000	32,000	165,400	221,500	94,600	284,000	61,200	16,400	316,000	171,130	135,000	265,780	42,000	12,000	87,000	46,500	28,000	72,100
Operational Cost	53,036	34,431	63,568	65,525	50,610	121,416	42,340	17,136	108,306	107,340	54,476	137,430	19,206	9,265	61,996	12,863	9,362	38,672
Labor Cost	15,918	−5,007	54,254	75,646	20,276	105,120	11,590	−368	114,384	48,156	7,741	64,175	10,193	1,072	28,067	16,492	8,327	28,640
Profit	15,918	−5,007	54,254	75,646	20,276	105,120	11,590	−368	114,384	48,156	7,741	64,175	53,985	−3,687	215,509	16,492	8,327	28,640
Monthly:																		
Trips per month	1	1	1	1	1	2	1	1	2	2	1	2	10	3	15	2	2	5
Revenue	90,000	32,000	165,400	242,000	126,000	550,160	79,200	16,400	316,000	267,890	215,250	397,520	314,692	120,000	672,000	108,000	56,000	255,000
Operational Cost	53,036	34,431	63,568	92,382	60,000	129,680	48,771	17,137	108,306	163,876	81,714	239,036	168,118	92,645	363,380	28,757	18,724	77,344
Labor Cost	15,918	−5,007	54,254	75,646	20,276	210,240	11,591	−368	114,385	65,472	15,482	103,599	63,012	13,399	224,537	32,983	16,654	98,030
Fixed Cost	4,344	2,848	5,538	4,728	4,228	5,253	3,712	2,941	4,361	7,545	3,537	7,765	9,027	1,864	17,364	647	590	700
Gross Profit	11,739	−10,361	49,909	71,167	15,547	205,537	8,150	−4,309	110,744	59,821	7,937	96,054	63,012	13,399	224,537	32,335	15,954	97,383
GPM (%)	13.9	−32.4	30.2	29.9	12.3	37.4	10.8	−26.3	35.0	22.7	2.9	29.4	15.8	−3.1	32.8	36.2	22.7	39.3
Annual:																		
Revenue	1,080,000	384,000	1,984,800	2,904,000	1,512,000	6,601,920	712,800	147,600	2,844,000	3,214,680	2,583,000	4,770,240	2,202,846	840,000	4,704,000	540,000	280,000	1,275,000
Operational Cost	636,432	413,180	762,816	92,382	60,000	129,680	438,936	154,229	974,757	1,966,512	980,568	2,868,432	1,176,823	648,517	2,543,657	143,786	93,620	386,720
Labor Cost	191,016	−60,084	651,053	907,752	243,312	2,522,880	104,318	−3,315	1,029,461	785,658	185,784	1,243,188	441,083	93,796	1,571,757	164,915	83,272	490,150
Fixed Cost	52,433	34,578	66,658	56,738	50,988	64,538	44,540	35,286	52,326	90,541	42,438	93,179	108,326	22,370	208,370	7,910	7,230	8,600
Gross Profit	140,577	−124,634	598,619	853,888	186,573	2,466,453	63,032	−50,601	985,775	717,849	95,243	1,152,647	332,757	−112,629	1,463,430	157,010	74,672	482,240
EE (R$)	1.16	0.68	1.43	1.43	1.14	1.60	1.10	0.73	1.53	1.29	1.03	1.42	1.17	0.88	1.48	1.55	1.28	1.63

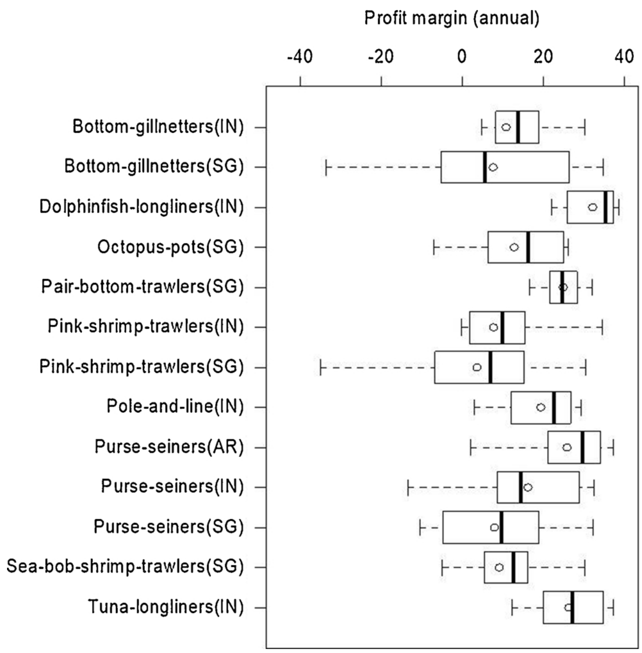

Fig. 6. Box plot of annual gross profit margin per fleet. The heavy horizontal line represents the median, the boxes represent the interquartile ranges, whiskers represent 95% confidence intervals, and the balls represent the average annual gross profit margins.

influencing profits. Thus, the bad financial performance found for some fleets highlights the need of better knowledge on population status. The cost structure presented here may also be useful for future bio-economic models that better explain the dynamics of stock abundance, cost, revenues and profitability.

In particular, the differences in profitability and EE between the analyzed purse-seiner fleets are possibly due to the number of trips per month, different landing costs, and in addition, different prices fetched for the same species (sardine) in different regions (ports). In fact, the sardine price is relatively smaller and stable in the State of São Paulo (Gasalla et al., 2010; Pincinato and Gasalla, 2010) than in the Itajaí and Navegantes regions. The key role of the landing cost in explaining the gross profit can be related to the difference between catch volume (largest catches higher revenue), where landing costs are generally considered a linear function of total revenue in bio-economic models (Prellezo et al., 2012). Whereas the key role of food cost on the profitability of purse-seiners is consistent with the high number of crew members and trips per month presented.

Conversely, the *trawlers model* also confirmed the key role of landing costs on fishing gross profit, in addition to fleet type and ice cost. In fact, this result is consistent with the differences in the relationship of catch volume between the tree trawlers fleets, where consequently, larger catches produce high profits but also a larger consumption of ice to maintain the fish and high costs of landing. On the other hand, the evidence of the effect of vessel size on profit can be especially attributed to smaller shrimp vessels, that cannot expand their catch and revenues because they are limited to waters close to shore, due to their low autonomy and restricted storage capacity.

4.3. Financial performance and sustainability concerns

In this study, we estimate the financial performance of fisheries in the Southeast and South of Brazil, and this was the first estimate for many of the fleets of the region. It should be understood that the estimate of the gross profit can be considered as the main indicator for the availability of the fisheries in the short term (Pinello, 2017). The analysis of this indicator can be the first step to understanding the current situation of the sector and can subsidize more comprehensive studies, such as studies on fisheries economic performance; moreover, this work may also be useful to alert decision-makers to the need for more effective fisheries management.

Thus, how cost and revenue can be largely attributed to effort or stock size, respectively, for the lowest profitability fleets presented here, the cost of catching would seem greater than it could be and may indicate overfishing and fleet overcapacity. However, fisheries are capable of earning substantial profits provided they are effectively managed (Arnason et al., 2009). Thus, the key role exerted by fleet category (type/region) on the profitability confirms the importance for the implementation of a fleet management system in the region and not only of fishing resources in isolation. In addition, the establishment of specific management measures by fishing category (type/region) could

Table 5
Summary of GAMLSS models fitted to the gross profit margin (month), where the explanatory variables are operational costs (fuel, lubricant, ice, food, vessel maintenance [Vm], landing, and others); fixed costs (social security [Ss], vessel tracking service, and accountants); and technical/operational characteristics of the vessels (fleet segment [fleet], vessel size [Vs], number of trips per month [Tm] and region of landing [port]) from commercial fleets of Angra dos Reis (AR), Santos/Guarujá (SG) and Itajaí/Navegantes (IN). (AIC = Akaike Information Criterion; LRT = Likelihood-ratio test; Pr(Chi) = probability of Chi squared test, and cs() = cubic spline).

Selected model: Profit margin ~ fleet + cs(trips per month) + cs(fuel costs) + cs(ice costs) + cs(vessel maintenance costs) + cs(others costs), family = GU)

Variables	Estimate	Std. Error	t value	Pr(> |t|)	AIC	LRT	Pr(Chi)
(Intercept)	15.5000	2.3200	6.687	0.00000			
Vm (df = 4)	0.0004	0.00004	8.343	0.00000	1665.1	97.921	< 2.2e-16
Fuel (df = 4)	−0.0003	0.00003	−7.682	0.00000	1605.8	38.529	2.95e-07
Ice (df = 4)	−0.0004	0.00009	−4.750	0.00000	1588.1	20.877	0.000854
Tm (df = 4)	1.1700	0.40900	2.857	0.00482	1575.5	8.252	0.142953
Others (df = 4)	−0.0002	0.00107	−0.142	0.88711	1575.3	8.096	0.151044
Fleet					1629.6	76.387	2.01e-11
Dolphinfish-longliners (IN)	17.1000	3.6900	4.635	0.000007			
Purse-seiners (AR)	23.9000	6.1300	3.903	0.000137			
Pole and line (IN)	13.2000	5.4400	2.425	0.016351			
Pink-shrimp-trawlers (SG)	4.7100	2.6100	1.804	0.073004			
Purse-seiners (SG)	7.8400	4.3800	1.792	0.074989			
Tuna-longliners (IN)	6.5900	5.6200	1.172	0.242705			
Purse-seiners (IN)	1.7200	4.8600	0.353	0.724757			
Pair-bottom-trawlers (SG)	0.3540	3.9800	0.089	0.929119			
Pink-shrimp-trawlers (IN)	0.0706	1.3800	0.051	0.959193			
Sea-bob-shrimp-trawlers (SG)	−1.6700	2.6800	−0.622	0.534508			
Octopus-pots (SG)	−7.6700	3.0700	−2.500	0.013386			

Table 6
Models for explaining monthly profit for purse-seiner and trawler fleets. Variables in final models selected by LRT and AIC are in bold.

Dependent variables	N of observations	Explonatory variables
Gross profit on purse-seiners	44	~ port + **cs (trips per month)** + cs(lubricant cost) + cs(ice cost) + cs(fuel cost) + **cs(food cost)** + **cs(landing cost)**
Gross profit on trawlers	94	~ **fleet segment** + **cs(vessel size)** + cs(trips per month) + cs(lubricating cost) + **cs(ice cost)** + cs(food cost) + **cs (landing cost)**

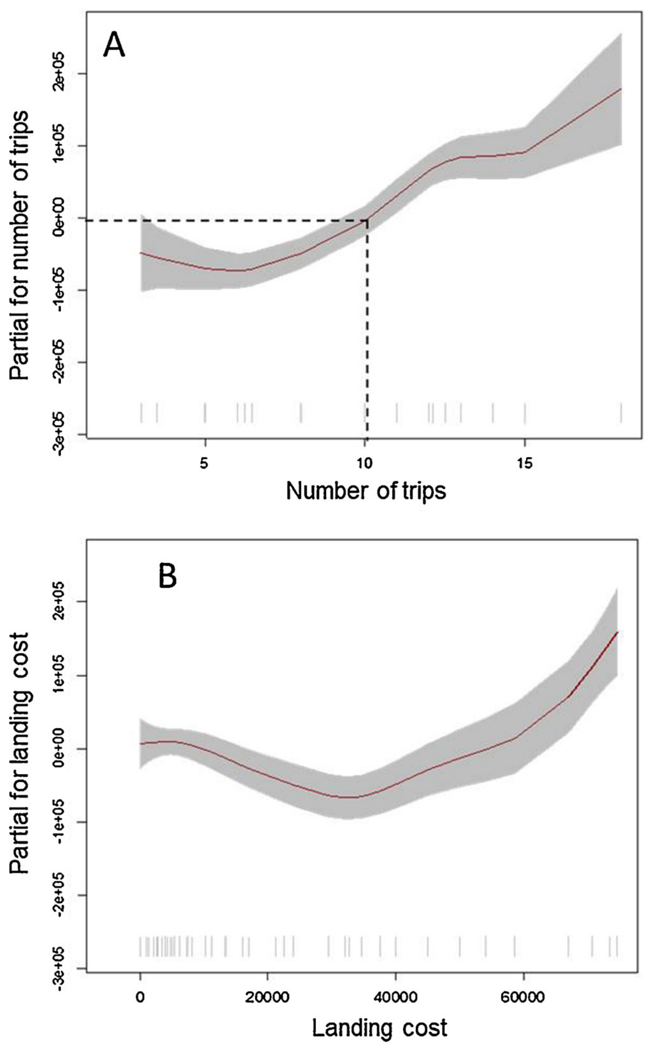

Fig. 7. Graphical summary of the GAMLSS analysis considering purse-seiner fleets. The response variable, gross profit, is shown on the y-axis as a centered smoothed function scale to ensure valid pointwise 95% confidence bands. Covariates and factors are shown on the x-axis: (A) number of trips and (B) landing cost. For covariates, solid curves are the smoothing spline fits conditioned on all other covariates and factors, and the shaded areas are bounded by pointwise 95% confidence curves around the fit in each panel.

be an alternative for the purse seine (SG) fleet that presented quite a distinct performance among the three regions studied. Therefore, for the region of study, where has already been proven through studies on the dynamics of the fleets and biological factors of the fishing stocks, the need for a reduction of fishing effort in bottom-trawling (Perez et al., 2001), purse-seine (Cergole and Rossi-Wongtschowski, 2005) and gillnetter fisheries (Mendonça and Pereira, 2014), the low profitability shown here for these fleets, are complementary from an economic point of view of previous evidence.

Conversely, fisheries management has many objectives, of which increasing economic performance is only one (Pascoe et al., 1996). Thus, the low economic performance of the fleets should not only encourage management measures, since high economic profits can stimulate the entry of new vessels into a fishery, thus intensifying pressure on stocks (Whitmarsh et al., 2000). In fact, the risk of biological overexploitation will be highest when the species is valuable, costs little to exploit, is easily caught and is both long-lived and slow-growing (Branch et al., 2006; Collette et al., 2011; Norse et al., 2012), as is the case of some species caught by the profitable large pelagic fisheries shown here. However, the management of pelagic resources within this region is non-existent, and biological and ecological information on which to base management decisions is often lacking (Abdallah and Sumaila, 2007).

To avoid the greatest fishing pressure, and consequently biological overexploitation and a less efficient fishery (both technically and economically), input controls (fishing capacity and effort controls) need to be designed in combination with output controls, directly restricting catch. If a few input aspects are regulated, fishing fleets may act to maximize their individual well-being, using unregulated dimensions for increasing the effort, leading to excessive investment in fishing technology, which may result in unpredictable and unfavorable consequences (Branch et al., 2006). For the multispecies fisheries in the United States, the indices reveal that the economic wellbeing of the fishing fleet has improved under catch share management (Walden and Kitts, 2014).

On the other hand, the fleet individual results of financial analysis presented here may be useful for helping businessmen and vessel owners to identify factors that are influencing fleet profitability, which may facilitate the creation of measures for improvements in the internal processes of the fishing activity. Indeed, changes in technological and operational measures, in addition to behavioral adaptations, can result in significant improvements in profitability (Johnson, 2011; Suuronena et al., 2012) as a result of reduced costs. For example, fuel savings can be achieved by eliminating the complete lack of engine maintenance, just as with the use of autopilot (savings of 20–30%), and a reduction in fishing or cruise speed, and unnecessary vessel weight as spare parts (Abernethy et al., 2010; Johnson, 2011; Poos et al., 2013; Renck, 2014). In addition, Pio et al. (2016), estimated that a 46% reduction in fishing gear size of the South Brazil gillnet fleet can reduce the maintenance costs by at least 40%, and the expected effects may be positive with an increase in the profitability.

Finally, the results presented could also be useful to guide the government agencies that dictate the development and modernization of Brazilian fisheries fleets (e.g., PROFROTA, Law 12.712/2012) in the adoption of credit liberalization policies that prioritize the low-profit vessels in the acquisition of low-impact and cost-effective technology improvements (e.g., incentives for the purchase of engines that consume less fuel). In addition, the results warn for a possible risk in the release of the incentives for the acquisition of new vessels for the fleets that are close to the negative gross profit, where the government support for vessel construction should inevitably lead to the overcapitalization of the fisheries, with adverse consequences for stocks, profitability and fisher salaries (OECD, 2006).

5. Conclusions

For the fleets as a whole, the financial returns were positive over the reporting period, indicating that the fleets are still profitable. Nonetheless, purse-seiners (SG), shrimp-trawlers and bottom-gillnetters

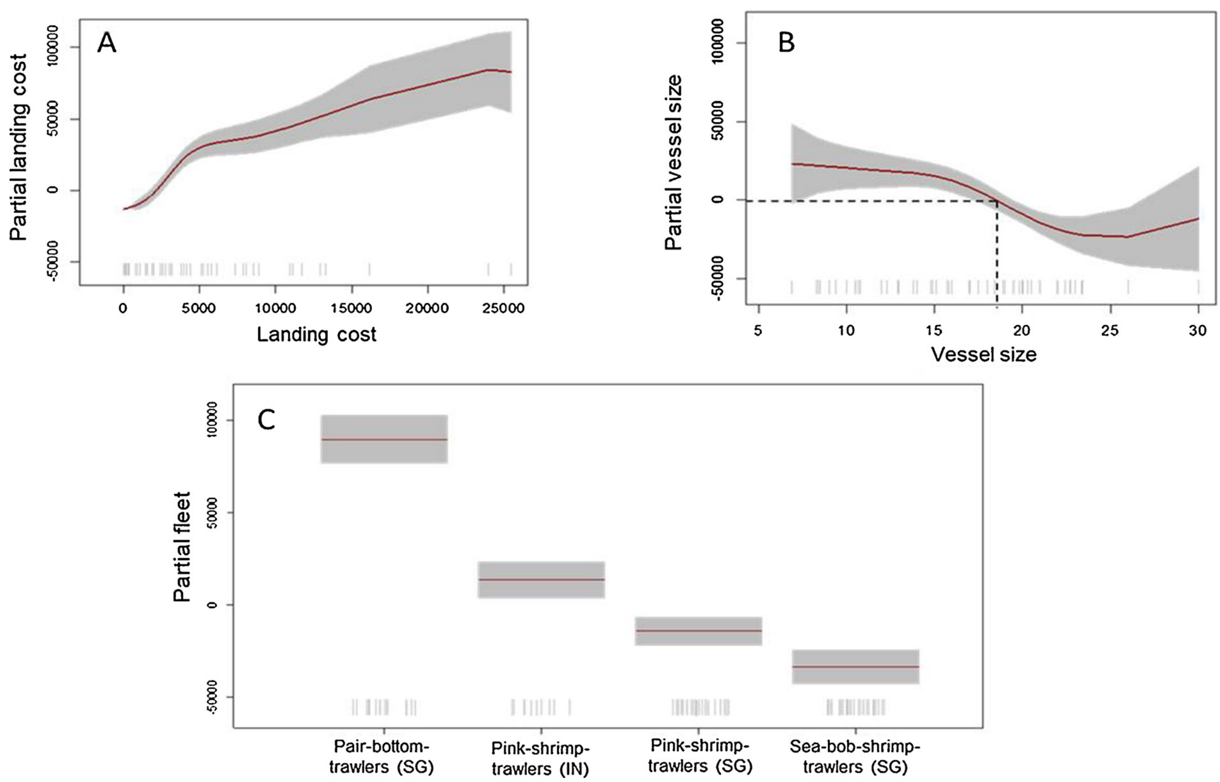

Fig. 8. Graphical summary of the GAMLSS analysis considering trawler fleets. The response variable, gross profit margin, is shown on the y-axis as a centered smoothed function scale to ensure valid pointwise 95% confidence bands. Covariates and factors are shown on the x-axis: (A) landing cost, (B) vessel size, (C) fleet type. For covariates, solid curves are the smoothing spline fits conditioned on all other covariates and factors, and the shaded areas are bounded by pointwise 95% confidence curves around the fit in each panel.

(SG) were less profitable and close to a negative gross profit, especially if there was an increase in fuel and vessel maintenance costs, which played a key role in explaining the fleet profitability and were identified as the main operating costs. Dolphinfish-longliners, tuna-longliners, purse-seiners (AR) and pair-bottom-trawlers were the most profitable fleets. Thus, gross profitability varied significantly among the fleets and was clearly related to the following main factors: fuel consumption, vessel maintenance expenses, ice cost, fish price, catch volume, and for technical features for certain fleets, such as the trawlers (from SG and IN) and purse-seiners (from AR, SG and IN).

Labor costs (or labor wages) are influenced by catch value and volume as well as the running (i.e., operational) costs of fishing, whereas wages are constrained by reduced productivity and high operational cost levels.

The findings should guide decisions and resolutions aimed to redress the economic situation of vulnerable fleets and in fishery management measures (e.g., input controls/fishing effort reduction, recovery plans for overfished stocks), especially for the bottom-gillnetters, shrimp-trawlers, and purse-seiners whose commercial fishing is operating in a scenario of overcapacity and overfished stocks. To ensure the profitability of regional fisheries, the introduction of a management system that aims at reducing overcapacity while promoting the recovery of overfished stocks seems urgent, especially for the Santos/Guarujá region, where the majority of the less profitable fleets were identified.

The findings indicate considerable variation in financial performance within and between the fleets. As such, they can be a benchmark and can highlight the need of future surveys, better knowledge on population status, may provide support to decisions by vessels owners, and can be used as a basis for management discussions. In this sense the variation in the performance of the fleets according to region is an important factor for management purposes since fleets may not be treated homogeneously but only in terms of fleet type. For practical use, the fleet categories presented here (i.e., fleet type and region) should be considered management units due to the distinct economic performance of the same fleet in the four studied regions.

Finally, while it is noted that economic data on Brazilian fisheries are scarce, this study presents a method and an approach for economic data collection and analysis that may contribute to standardizing economic knowledge construction in data-poor fisheries, such as S/SE Brazil's, in other jurisdictions of Brazil. The use of this approach proved to be appropriate to investigate different types of fleets and results in detailed information on several aspects of the cost structure and economic performance that can be benchmark indicative of how fleet economics are behaving. The findings should guide decisions and resolutions aimed to redress the economic situation of unviable and vulnerable fleets and in fishery management measures.

Acknowledgments

We thank all the fishermen, skippers and vessel owners that kindly contributed to this research. We are very grateful to Alina Pellegrinelli, Viviane M.B. Steimbach and Ritchelly S. Luz (ITI scholarships), and Celso Luiz Eleutério and Fabricio Gandini (DTI scholarships) for their help in the collection and organization of data. The authors gratefully acknowledge Luiz Rodrigo Maçaneiro and Caiame J. Nascimento of the Fundação Pró-TAMAR, Itajaí (SC) for their help in field surveys. Research was funded by the Brazilian National Research Council (CNPq) (Project No. 406614/2012-1 and 445809/2015-9). A.R.R. received financial support (PhD scholarship) from CAPES (Brazilian Agency for the Improvement of Graduate Education) and M.A.G., a productivity grant from CNPq.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.fishres.2018.10.017.

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