Multi-fleet comparison of fisheries socioeconomic performance indicators: a case study in Southeastern Brazil.

Abstract

Keywords: Ecosystem Approach to Fisheries, economic performance indicators, fishery management, industrial fisheries, fishing fleets, costs of fishing, ecosystem-based fishery management

A comparative multi-fleet rationale of socioeconomic indicators is described aiming a potential incorporation into fishery management advice at an ecosystem scale. A set of performance indicators, based on a survey of different industrial fishing fleets in São Paulo (SE Brazil) which investigated investment, fixed, effort, labour and sailing-related costs and profits, allowed for inter-fleet comparison. Costs varied between fleets with fuel being the main cost. In general, indicators of profitability and economic efficiency reveal best economic performance per fishing trip for bottom longliners and both surface and bottom-gillnet fleets mainly due to their relatively low percentage of variable cost. Purse-seiners and shrimp-trawlers, targeting mainly overexploited species, showed the worst performance of both profitability and economic efficiency mainly related to their high variable costs and relatively low catches. However, in terms of jobs generated, purse-seiners had the greatest value and the sea-bob-shrimp fleet showed the lowest crew size per vessel but generated the second highest total number of direct jobs. The inter-fleet cost and socioeconomic performance analyses reveal that additional attention should be given to the poor profitability of fleets, rent drain, fishing impacts, and open-access related issues, while social indicators might be also considered. Results may calibrate predictions related to management trade-offs between ecological, economic, and social benefits in the context of an ecosystem approach to fisheries.

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Introduction

The knowledge of real-world conditions regarding the different fishing fleets in a system may affect the management trade-offs between ecological, social and economic objectives. Therefore, comparative economic performance indicators are expected to be crucial to the success of an ecosystem approach to fisheries (EAF) [1,2]. These indicators can be useful for monitoring and assessing a particular sector's performance and the wider effects of fishing [3,4,5,6]. In addition, research on the performance of industrial fisheries around the world has drawn attention to the issues of rent dissipation, overcapacity, and the need to reduce fleets to sustainable levels [7,8,9,10,11]. However, the lack of comparative multi-fleet basic economic analysis appears to be a significant gap in both fishery management advice and current EAF research [2].

In Brazil, analyses of the dynamics and economics of fishing fleets, together with the collection of ecological data on fish stocks, has been attempted over past decades [12,13,14,15,16,17]. However, detailed cost analysis of distinct fishing fleets remains rare, limited, hard to conduct, and particularly unavailable for multi-fleet comparisons. Possible reasons for these obstacles include the lack of policies requiring fisheries to provide or analyze this kind of information (i.e., bookkeeping). Furthermore, there seems to be no reciprocal trust between the fishing industry and government institutions [18,19,20].

A fisheries ecosystem's multi-fleet economic performance comparison can be particularly useful to address policy issues such as the definition of an optimal size and composition of fishing fleets or the allocation of fuel subsidies. Thus, this paper shows a comparative cost analysis of the different fleets of the multi-gear industrial fisheries of the South Brazil Bight area.

Case Study

Fishing fleets, locally classified as "industrial", that landed in the Santos region (Fig. 1) during the period 2007-2009 were considered for the analyses. The fishing area is part of the Santos Basin (between 23º-28ºS and 42º-48ºW) which sustains important fishing grounds for the Brazilian sardine, penaeid shrimps and demersal fish. In 2007, fishing landings in the whole South Brazil Bight (SBB) were about 130,000 t per year which can be considered indeed a poor production comparing with past decades [21].

The state of São Paulo, as part of the SBB, which was formerly one of the top marine fishing states of Brazil, is now the 7th out of 26. Industrialization of the fisheries in São Paulo began in the 1950s and grew quickly with the financial subsidies in the late 1960s [22,23]. Landing peaked in 1984 followed by a strong decrease until 1999, stabilizing around 20-30 thousand tons per year. The main reason for the poor current performance was the decline of the Brazilian sardine (*Sardinella brasiliensis),* the most important local fishery resource. In 2006, its landings rose about 33 thousand tons and produced an income of 80 million Brazilian Real (R$) [21].

For the purpose of this study, local fleets were classified as being 'Bottom-gillnetters', 'Bottom-longliners'; 'Surface-longliners', 'Octopus-pots', 'Pair-bottom trawlers', 'Pink-shrimp trawlers', 'Purse-seiners', 'Sea-bob-shrimp trawlers' and 'Surface-gillnetters'[2].

Methods

Data collection

A survey was conducted during 2007-2009 among the main landing points in the Santos/Guarujá zone (Fig. 1). Information was collected directly and via semi-structured personal interviews with key informants sampled from vessel owners, captains, skippers and fishery leaders. Data on yields (total catch, ex-vessel price of total catch per trip (R$)), financial details (fuel cost, vessel and gear costs, food cost, capital investment, ice cost, landing cost and bait cost) and fishing effort (duration of fishing trips, navigation time until the fishing zone, crew size, fuel and ice consumption) were obtained from questionnaires [2].

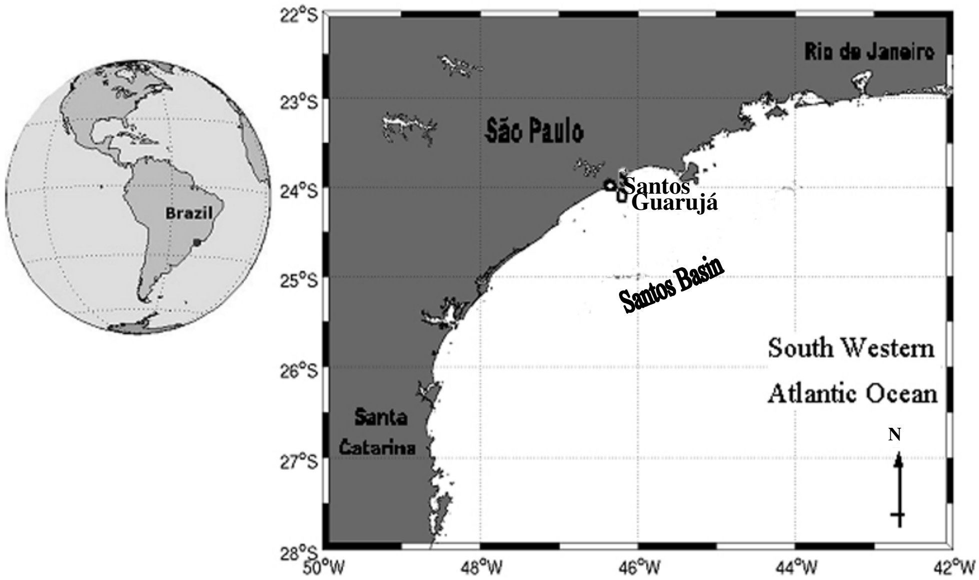

Figure 1. Location of the fishery ports (Santos and Guarujá) in the state of São Paulo, Southeastern Brazil.

Performance indicators and data analyses

The composition of fixed and variable costs is illustrated in Figure 2. Average values were used to describe the main characteristics and cost structure of each fleet, as well as net incomes per fishing trip and monthly revenues. In order to describe the main operational and technological characteristics, several socioeconomic performance indicators were calculated (Table I).

The relative importance of each type of cost within a fleet, as well as an inter-fleet comparison, was calculated from total values. Depreciation was assumed equal to zero, as suggested by Castro et al. [18,19], since most of the actual capital lifespan is due and assumed to be sunk. However, in order to consider a situation where new vessels would be built, the return foregone on other uses of that capital were taken into account as opportunity costs (i.e., interest rate, 14%).

A Kruskal–Wallis test (non-parametric, p-value < 0.05) was employed to test for significant differences between fleets with respect to the number of crew members, the time of navigation required to reach the fishing spot, the number of trip days and the price of the total catch, since there was no guarantee that the data would be normally distributed.

Table I: Indicators used to describe the main operational and technological characteristics performance of different fishing fleets.

Performance indicator	Equation and Description
Average direct jobs (J) in each fleet f	J_f = number of vessels x crew size (CS_f) (Eq. 1) Where f represents each one of the fishing fleets
Relative importance of total jobs (% J_f)	$\%J_f = \left(\frac{J_f}{\sum_f J}\right)\times 100$ (Eq. 2)
Catching efficiency (CE)	$CE = \frac{Catch_f\,(t)}{CS_f \times \text{days per fishing trip}}$ (Eq. 3)
Total Cost (TC) per fishing trip	TC = Fixed Cost (FC) + Variable Cost (VC) (Eq. 4)
Average capital investment (CI)	CI = cost of acquiring a fishing vessel and all the equipment necessary to carry out the activity
Economic efficiency (EE) per fishing trip	$EE = \frac{GI \times (1+i)}{TC \times (1+i)}$ (Eq. 5) **GI** is the Gross Income and i is the annual interest rate.
Net present value (NPV)	$NPV = \sum_{t=0}^{T} \frac{GI_t - TC_t}{(1+i)^t}$ (Eq. 6) Indicator of investment or project viability. If NPV > 0, the investment would add value, but when NPV < 0 the investment would subtract value and the project should be rejected. TC_t is the total cost of the project at time t, and the opportunity cost of capital is represented by the interest rate (i = 0,1). We considered a 4-year exploitation scenario with the investment in vessel plus gears integrally applied in year zero.
Relative importance of TC (%TC)	$\%TC = \left(\frac{TC_f}{\sum_f TC}\right)\times 100$ (Eq. 7)

Energy cost ratio per fishing trip	$$\% \text{ Energy cost} = \left(\frac{\text{Fuel}_f}{TC_f} \right) \times 100 \qquad \text{(Eq. 8)}$$ Fuel_f = Fuel cost per fleet.
Relative importance of CI (%CI)	$$\% \text{ CI} = \left(\frac{\text{CI}_f}{\sum_f \text{CI}} \right) \times 100 \qquad \text{(Eq. 9)}$$

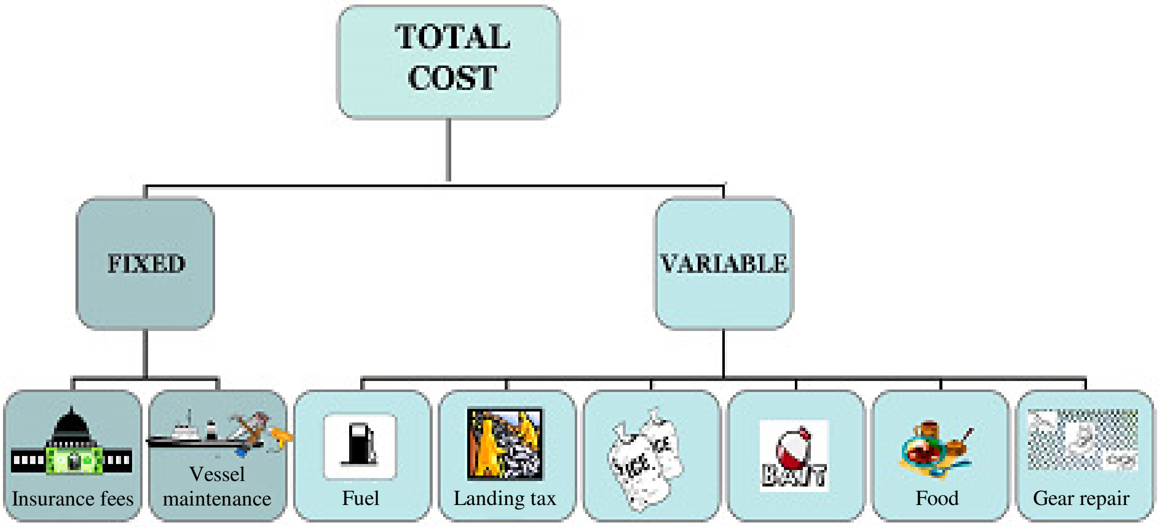

Figure 2. Composition of fixed and variable costs. Fixed costs included repairs, social insurance and fees (i.e., unions). Variable costs included fuel, ice, food, bait, gear and others such as sodium sulfite used for on-board conservation.

Results

An estimate of the total number of fishing trips and the time required to navigate to the fishing zone per trip for each fleet is shown in Figure 3. The fleets that exploited a range of different species (such as longliners, bottom-gillnetters, pair-bottom trawlers and pink-shrimp trawlers) were significantly different from other fleets in both the duration of fishing trips (spending 3-16 days at sea) and the navigation time to the fishing spot ($p < 0.0001$ and $p < 0.0002$, respectively).

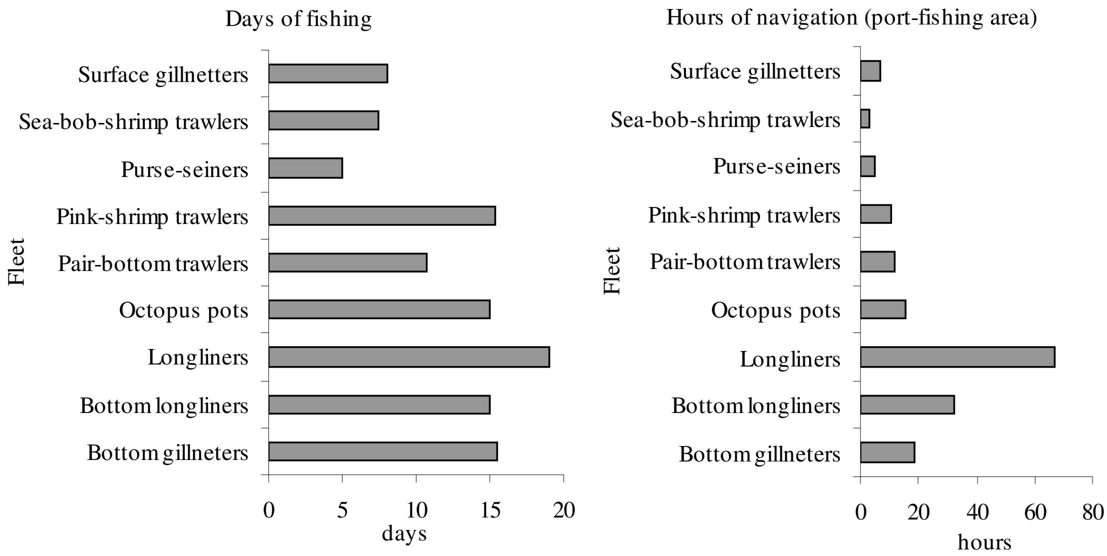

Figure 3. Days of fishing and navigation time to the fishing zone (hours) of the different fishing fleets estimated as the mean per fishing trip.

Table II shows the average crew size of each fleet, from which the number of jobs per fleet can be estimated. Significant inter-fleet differences ($p<0.001$) were found, and these differences appear to be related to the type of gear used. Table II compares the percentage of direct jobs per fleet and the corresponding number of vessels providing an indicator of social benefits. 'Purse-seiners' demonstrated the greatest number of total direct jobs (15 men/vessel; 49% of the total). Although the 'sea-bob-shrimp' fleet had the lowest crew size per vessel (2.5 men), it generated the second greatest total number of direct jobs (23%) due to the large number of boats.

Table II: Mean of crew members, number of vessels, direct jobs and estimated percentage of direct jobs per fishing fleet of the Santos region in 2007.

Fleet	Vessels (n)	CS_f	% J_f	CE	EE	%TC	%CI	% Energy cost	NPV
Bottom gillnetters	2	7.0	0.4	0.04	2.0	7.0	8.4	34	133,067
Bottom longliners	24	6.5	4.3	0.04	2.5	6.5	4.9	53	549,137
Longliners	10	8.0	2.2	0.09	1.3	28.0	10.8	39	358,851
Octopus pots	20	6.0	3.3	0.05	1.6	9.0	16.8	54	358,605
Pair-bottom trawlers	15	8.6	3.5	0.26	1.6	15.3	13.2	42	668,864
Pink-shrimp trawlers	89	5.1	12.4	0.09	1.2	13.5	10.8	54	-131,756
Purse-seiners	120	15.0	49.3	0.55	1.2	16.3	28.1	51	-3,613,163
Sea-bob-shrimp trawlers	339	2.5	23.2	0.12	1.2	2.3	2.2	58	735,285
Surface gillnetters	10	5.0	1.4	0.10	2.2	3.0	4.8	48	321,052

Technological or catching efficiency (CE) estimates per fishing trip for each fleet, ranging from 0.04 to 0.55 (Table II). The purse-seiner fleet was the most technically efficient (0.55), followed by the pair-bottom trawler fleet (0.26).

The relative importance of average capital investment (CI %) with a breakdown of contributions from the vessel and the gear used by the nine different fishing fleets is shown in Table II. Sea-bob-shrimp trawlers have smaller boats and simpler engines resulting in a lower total average investment 2.2 % (around R$ 78,000) in contrast to the purse-seine fleet whose initial investments required around R$ 1 million.

A synthesis of relative importance of average total costs and energy cost of the different fishing fleets is also presented in Table II. The purse-seiner fleet had the highest total costs per trip, while sea-bob-shrimp trawlers had the lowest values.

Variable costs, which consist of running costs, were mainly due to fuel. The highest energy costs (fuel) corresponded to sea-bob-shrimp, pink-shrimp trawlers and octopus pots (58% and 54%, respectively) (Table II).

Assessing the economic efficiency per trip (EE), we found that purse-seiners had the lowest EE together with both shrimp trawlers fleets (Table II). Bottom-longliners and surface gillnetters appeared to be the most economically efficient fleets. Thus, for every R$1 invested, purse-seiners had an income of R$1.20 per trip, and bottom-longliners had an income of R$2.50 (Table II).

However, the assessment of the fleets sustainability based on a measure of the financial viability of capital investment (NPV) (Table II), shows that purse-seiners and pink-shrimp trawlers' projects appeared to be net losers (NPV<0), since the present value of the expenses is greater than the earnings. The highest NPV values were found for sea-bob shrimp trawlers, pair-bottom trawlers and bottom longliners.

Discussion

The examination of fishing behavior and performance in a multi-fleet context within an ecosystem provides a useful overview for ecosystem-based fisheries management. In practice, although most fisheries involve many species, management recommendations are often made on a single-species or single-fleet basis, failing to meet the operational needs that can be addressed by an ecosystem approach. In this study, the richness of both marine biological species and fishing vessels types indicates that a multi-fleet approach is more appropriate for such a purpose.

A series of deficiencies were detected among the fleets operating in the South Brazil Bight area. First, fleet size and mobility were correlated with vessel size. Smaller boats (e.g., sea-bob shrimp trawlers) tended to make a larger number of shorter trips over the course of the month, and tended to concentrate their efforts in near-shore areas because of limited fuel and ice capacity. Larger boats (e.g., longliners and purse-seiners) adopted more itinerant strategies covering a larger total area and consequently placed less emphasis on one particular fishing ground. The size and type of gear usually determined the crew size [24]. The purse-seiner fleet had the largest crew since more hands are required to operate that gear, followed by pair-bottom trawlers. However, in terms of the total number of direct jobs offered, the shrimp trawler fleets (both pink-shrimp and sea-bob shrimp) generated the second highest percentage of jobs (36%) due to the higher number of vessels. This higher level of employment associated with trawl fleets also occurs in other countries such as Indonesia and Mexico, where the shrimp fleets offer a vastly greater number of jobs on board than local larger vessels [25].

Catching efficiency parameters provide an overview of fishing performance taking account of different gear and technology [26]. Purse-seiners appear to be more technically efficient (CE=0.55) than other fleets, even with the lowest EE values. When the target species is reduced or overfished, the skippers' experience can greatly influence the catching efficiency [27]. However, when catching is analyzed together with economic efficiency, the fleets that are most efficient in catching are not necessarily the most economically efficient. This was the case for purse-seiners that fish for sardines. The *Sardinella brasiliensis* stock forms dense schools that are efficiently caught by fishers in a single operation. Nevertheless, sardine prices are relatively low and stable both monthly and annually which tend to result in low economic efficiencies (15). This is similar to purse-seining for skipjack tuna in the western and central Pacific Ocean [28].

Bottom-gillnetters showed one of the lowest values of catching efficiency (0.04), possibly due to the duration of fishing trips (15.5 days in average). However, this fleet was the third most economically efficient (2.00), probably due to the catch of the internationally highly valued monkfish *Lophius gastrophysus,* and its associated increasing export opportunities to European and Asian markets [29].

From the economic analyses of EE per fishing trip, it can be seen that bottom-longliners, and both bottom- and surface-gillnetters, showed high profitability rates. Purse-seiners and shrimp trawlers had the worst economic indicator per fishing trip, possibly due to their high variable costs (e.g., fuel, ice, food). The values of costs found in this study by sea-bob shrimp trawlers, are in the range of those found by Souza et al. [30].

As the fishing pressure on the practically unmanaged resources becomes stronger, their production gradually declines (first in terms of valuable species, then in terms of the species that replace the original stock), and both economic overfishing and reduction of incomes occur together with biological overfishing [31]. This may be what is occurring with traditional purse-seining for sardines and trawling for shrimps in the Southeastern Brazil Bight, whose target species are considered overexploited and their NPV was found to be negative.

Shrimp trawler fleets, octopus pots, bottom longliners and purse-seiners were among the fleets with higher energy cost (%). If the amounts spent on fuel and other fishing costs have risen more than the general price level for these items, this is probably evidence that a greater effort is being applied. If there were no consequent increase in the catches, the return would fall and the fishery would not be sustainable.

Some findings will require additional attention such as the cost/benefit analysis of shrimp and purse-seiner fleets. Employment associated with these fisheries is often thought to be one of the main benefits, but low profitability may indicate a decline of the target-species. It is likely that the fleets that (1) showed better economic performance (such as bottom-longliners, bottom-gillnetters and surface gillnetters), (2) those that are important for seafood supply (pair-bottom trawlers, longliners), and (3) those that are considered socially important (trawlers and purse-seiner), can be reluctant to approve reduction measures that would be suggested based on the present results. It has been suggested that a fundamental problem of many of the world's shrimp fisheries is their lack of regulation and their open access [32]. In general, if there are no barriers to entry, fisheries typically end up at the point where the total revenue equals the total cost (profitability shrinks to zero) or beyond if subsidies are provided. The history of shrimp' fishery management shows that management interventions (e.g., catch limits, closed seasons) that do not address real participation are usually ineffective at preventing overcapacity and economic overfishing in the long term [25]. Thus, the present situation of fishery management in the Southeastern Brazil Bight area, with a particular emphasis on the pink-shrimp fishery, should be further reviewed.

The situation of purse-seiners seems to be also critical. Our findings on both poor economic efficiency and viability (NPV<0) of this fleet are expected to be particularly relevant for consideration into the policy arena, especially with regard to fleet size optimization and effort reduction needs based on biological reference points. This is one example of how this type of economic information could be used to address specific policy questions regarding the management of Brazil's fisheries and elsewhere.

The trends in the costs of each aspect of production are relevant not only for an understanding of the historical patterns in fisheries, but also to provide a basis for future projections, for example on the effect of rising fuel prices, economic trends related to particular costs of supplies or species, or other scenarios (i.e., potential climate change). In this sense, the adaptability of the different fishing fleets and markets could be better understood taking into consideration this multi-fleet cost analysis.

Suggestions that could improve the current situation of poor local profitability include the avoidance of open access regimes, the reduction of overcapacity, and an improvement of the enforcement towards fuel-subsidized vessels. Further consideration on the benefits and management trade-offs between ecological, economic and social aspects of sustainability should be taken into account.

Finally, the multi-fleet cost analyses resulted in an important spot for fishery management recommendation. Our results should be useful for considerations concerning fishing capacity, the analysis of the conflicting use by different fleets, the proposition of new input or output controls, and ecosystem approaches to fishery management. However, the inclusion of and the advice to stakeholders should be essential to the effective learning of real deficiencies and problems solution.

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