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Decision-making processes by small-scale fishermen on the southeast coast of Brazil

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Abstract Brazilian shrimp trawlers and gillnetters were compared regarding their decisions concerning effort, processing of fish, time spent fishing and how they are affected by environmental, cultural and economic factors. Landings were recorded over 13 months ($n = 424$) and comprised mainly sea bob shrimp -*Xyphopenaeus kroyeri* (Heller) (95% of the trawler catch) and weakfish, *Cynoscion jamaicensis* (Vaillant & Bocourt) (30% of the gillnet catch). Catch per Unit of Effort varied across months, and the number of fishing trips per day was explained by wave height for both fisheries (trawlers: $r^2 = 0.4$; gillnetters: $r^2 = 0.18$). Trawlers spent more time fishing in the winter ($H = 11.6$; $P < 0.05$) and gillnetters in the summer ($F = 4.1$; $P < 0.001$), a decision that depended on the monetary profit they estimated beforehand or on the loss they had during the closed season. Cultural and economic variables (qualitatively addressed), such as how tedious they considered processing the catch or how much money they needed to make, affected their choice of processing it or not. Trawlers were subjected to taking risky actions, fishing on days when the return is highly variable ($r_{kg} = 0.72$; $P < 0.001$; $r_{\$} = 0.65$; $P < 0.001$). Understanding such processes underpinning fishermen's actions is essential for management.

KEYWORDS: artisanal fisheries, fishing strategies, human ecology, open access, trawlers.

Introduction

Artisanal fisheries are an increasingly important basis of livelihood in many developing nations (UNEP 2004). Although working at lower scales of operation, fishing close to the coast and employing a family-based economy (Colloca *et al*. 2003), artisanal fisheries account for over 45% of the world fish catch (UNEP 2004). In countries such as Brazil, artisanal fisheries can account for as much as 60% of the fish production (Diegues 2006). They also make available a greater fish diversity to the final consumer than industrial fisheries worldwide. Although artisanal fisheries are less intense than their industrial counterparts, fishing intensity does not always correspond to fishing sustainability. Thus, looking for trends/patterns among individual cases is necessary to evaluate fishery sustainability, without assuming it happens beforehand. For example, artisanal fisheries tend to focus on piscivorous and top predator species, affecting fish diversity (de Boer *et al*. 2001) and, in some cases, can use destructive methods, such as dynamite and poisons (Jiddawi & Öhman 2002).

In Brazil, artisanal fisheries research is still developing, largely because of the continental scale of operations and inaccessibility of many areas. Existing information is often spatially localised and based on short-term studies (Silvano & Begossi 2001; Lopes *et al*. 2009). In view of their importance to the country's economy and livelihoods of at least 250 000 fishermen (Diegues 2006), such fisheries need urgent management. However, like other tropical regions, Brazilian artisanal fisheries use a multitude of methods and catch a wide array of species (Bayley 1988). This

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diversity makes the use of conventional management measures (e.g. quotas) inappropriate. Another common problem in most tropical areas is the lack of personnel and funding, which results in limited information. In such situations, Johannes (1998) recommended the data-less approach, where fisheries should be managed with whatever information is available, including knowledge obtained from other similar systems and fishermen's local knowledge.

When using the data-less management approach, the decision-making process behind fisherman behaviour becomes a critical factor. Understanding how decisions are made related to what and how to fish, and when and why to fish allows understanding of fishermen's behaviour, which is fundamental to designing management plans and achieve long-term sustainability (Opaluch & Bockstael 1984). Moreover, evaluating local decision-making is likely to improve understanding of conservation issues of small-scale fisheries. Cultural, economic or ecological factors can drive fishermen to behave in particular ways that are not necessarily in accordance with conservation goals (Salas & Gaertner 2004).

Currently, there is special interest in evaluating and classifying different fisheries management and especially finding specific patterns shared by different management regimes. The majority of studies have focused on local management systems aiming to prevent overexploitation (Siry 2006; White *et al.* 2006). Some studies have also approached the practical actions that underpin such management practices. Such studies concern fishermen's behaviour, fishing effort, gear and techniques employed (Eales & Wilen 1986; Béné & Tewfik 2001; Guest 2003). The importance of understanding such processes in fisheries, regardless of the approach used, can no longer be ignored (Opaluch & Bockstael 1984). The emerging and complex relationship between catch (fish abundance) and effort (function of fishermen's behaviour) is what controls the catch per unit of effort (CPUE) (Voges *et al.* 2005). Designing management initiatives without considering fishermen's individuality and personal goals that determine their behaviour means ignoring the most complex aspect of a chain that determines the degree of exploitation of a resource. Without such knowledge, management will almost inevitably fail (Salas & Gaertner 2004).

Here, the variables that govern fishing effort and fishermen's behaviour are investigated based on the decision-making processes in two distinct fisheries in a southeast Brazilian coast scenario, i.e. a shrimp trawl fishery and a gillnet fishery. The main question was what environmental and economic factors affect the fishermen's decision-making process, especially concerning fishing strategies, such as when, how and how long to fish. Cultural and social factors were only qualitatively addressed. It is suggested that explanations of behaviour change within a temporal scale in which environmental conditions (represented by different seasons) are considered (Béné 1996). Surveys using this approach can enhance knowledge regarding sustainability of small-scale fisheries, regardless if such fisheries are already managed or still under an open-access situation and are relevant to ground any kind of management measure or changes to existing ones.

Materials and methods

Study site and an overview of the local fishing features

The study was carried out in Perequê village, which has approximately 8000 people (Fig. 1). Migrants attracted by profits from the shrimp fishery have resulted in intense, unplanned demographic growth and development of slums lacking sewage treatment inside the mangrove. Up to 200 boats are regularly anchored on the beach. Most of what is known about the fisheries is based on verbal stories collected during the fieldwork and interviews from 2004 (Lopes *et al.* 2009). Before 1980, descendants of Indians and Portuguese (caiçaras) who used to make a living out off small-scale fishing and cassava flour commerce dominated the population. Around this time, shrimp trawlers from southern regions started to appear bringing their methods and equipment to catch shrimp, which was seen to be highly productive in the region, and subsequently attracted an increasing number of people.

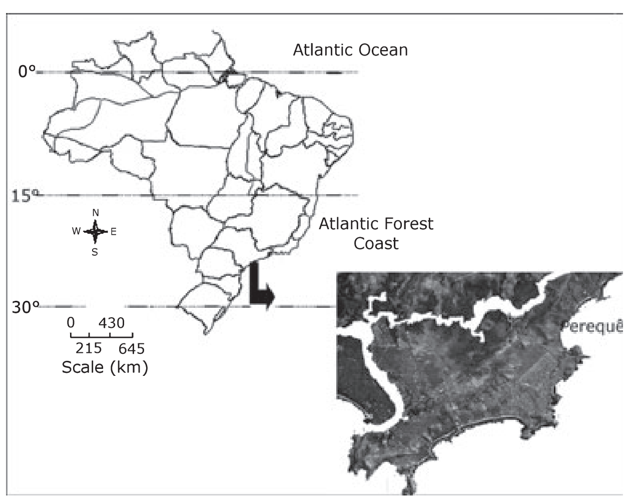


Figure 1. Map of Guarujá (23°59′S/46°15′W), São Paulo State, Brazil, indicating Perequê beach.

Local fisheries are family based; older sons usually fish together with their fathers, while wives and daughters sell the fish or clean and process the shrimp. Most fishermen prefer to sell the shrimp at a lower price directly to shrimp processing plants. Fishermen who have a successful day may share the information about good locations with their relatives and friends, using cheap talks (a communication tool that usually carries no cost, i.e. fisherman will not lose anything by doing it). The concept is widely used in game theory (Robson 1990). As most of the fishermen in the village use trawlers (76.5%), the local economy is based on shrimp processing plants, which are responsible for the commercialisation of 86% of the shrimp catch. The dependence on processing plants to reach markets generates a degree of loyalty for the fishermen.

Shrimp processing plants are usually owned by companies outside the community and can vary in their size or capacity to process shrimp and fish (from 200 kg to several tonnes of shrimp per day). The plants operate at a regional scale, selling their products to grocery stores state wide or to the São Paulo State Distribution Company (CEAGESP), which will sell them to other intermediate distributors. Thus, the original shrimp processing plant becomes the first of several middlemen between the fishermen and the final consumer.

A fishing day usually starts between 05.00 and 06.00 am for shrimp trawlers (hereafter just trawlers) and they return between 15.00 and 17.00 pm to sell the shrimp. Subsequently, fishermen usually return to their boats to make any necessary repairs. Trawlers work from Monday to Friday, if the sea is calm. Some fishermen rent their boats on the weekends to recreational fishermen, working as captains. Fishermen that use gillnets (hereafter gillnetters) fish close to the beach, setting their nets early in the morning between 07.00 and 10.00 am and setting other nets in the afternoon if there is a prospect of good fishing. During the day, they fix the nets and boats or operate small fish stores. Like trawlers, gillnetters can work at weekends for recreational fishermen, although they usually fish in a regular way on Saturdays, resting on Sundays.

Fieldwork

Socioeconomic data: 51 (of 200) fishermen were interviewed. These were chosen from subjects willing to take part in the study, those older than 20, and with a minimum 10 years of experience (Lopes *et al.* 2009). Thereafter, 32 fishermen who wanted to participate (25 trawlers and seven gillnetters) and 15 helpers had their fish landings measured for 5 days each month over a 13-month period. Shrimp landings were not sampled between March and May (closed season).

Shrimp was weighed in the shrimp processing plants, while researchers weighed the fish. After each fish landing, fishermen were interviewed with respect to the fishing location, type and size of net, fishing time, catch (kg), sale price and expenses. Finally, 21 trawling trips scattered throughout the year were followed using a participant observational method. On each trip, the number of trawls, the total time spent trawling, the crew size and the total amount caught were registered.

Statistical analyses

Monthly and seasonal variations in CPUE (gillnet or trawler) were compared using a Kruskal–Wallis test or ANOVA. Variance in gillnetter's fishing time was normally distributed, allowing the use of one-way ANOVA to compare differences among average seasonal or monthly changes in gillnet CPUE. For trawlers, temporal data were non-normal and therefore compared with a Kruskal–Wallis test.

CPUE was defined differently for each fishery. The CPUE series with a normal distribution among a set of correlated series was chosen to minimise variance and best represent the entire population (Petrere 1978). Correlations among the following paired $CPUE_{gillnet}$ series were tested for normality: (1) catch (kg) vs net size $(m)^{-1}$; (2) catch (kg) vs time fishing^{-1} and (3) catch (kg) vs (net size vs time fishing)$^{-1}$. The $CPUE_{gillnet}$ series that had the highest degree of normal distribution (#1) was chosen as the most representative for the effect of season on fishing effort/behaviour. The following paired correlations were tested for the trawlers: (1) catch (kg) vs trawl area size $(m^2)^{-1}$ × number of consecutive trawlings^{-1}; (2) catch (kg) vs number of consecutive trawlings^{-1}, (3) (catch (kg)/crew number) vs time fishing^{-1}; (4) catch (kg) vs crew number^{-1}, (5) catch (kg) vs time fishing^{-1}. The chosen CPUE series was number 2, as the one that best suited the normality criteria.

To understand the environmental effects (available at: http://www.cptec.inpe.br) on the number of daily fishing trips (T), two multiple linear regressions were carried out for both trawl and gillnet fisheries using a stepwise (backward) method to identify significant environmental variables. The initial model was defined as

$$T = u + WH + WS + MT + IT + AH + MP,$$

where u represents the intercept, WH wave height (m); WS wind speed (m s^{-1}); MT maximum temperature

(°C); *IT* minimum temperature (°C); *AH* humidity and *MP* moon phase.

To calculate profit per trip per fisherman, the following equation was used:

$$\pi = \sum G_i ti - C_t$$

where G_i refers to the money made from the capture of each species per trip (*ti*) and C_t is the sum of total expenses (costs).

A Spearman correlation was used to measure how the amount paid to the fishermen per kilogram of catch varied according to the supply. Only sea sob shrimp, *Xyphopenaeus kroyeri* (Heller), and weakfish, *Cynoscion jamaicensis* (Vaillant & Bocourt), the most important commercial product for each fishery type, were used. The effect of fishing time on returns (catch or revenue) was evaluated by a second Spearman correlation, which was used to test whether the number of trips increased when the variance in the return (financial or kg) increased (separately for the variance of the day and of the previous day). Normality was tested through a Shapiro–Wilk test.

Results

The fisheries

Landings from 325 shrimp and 93 gillnet fisheries were sampled. *Xyphopenaeus kroyeri* comprised 95% of the trawlers' catch, although part of what is sold as *X. kroyeri* included at least five other shrimp species in smaller amounts (trawlers' total catch = 33 709 kg). *Cynoscion jamaicensis* was the dominant species caught by the gillnet fishery (30% of total), with the remaining catch comprising of 12 other fishes, each representing <5% of the total gillnet catch of 1800 kg.

Only 1% of the shrimp catch was used for family consumption and about 3% (of a total of 220 events) was given to relatives as a donation and to people in the community in exchange for local assistance with transport of shrimp and supplies. Bycatch was mostly small fishes, such as juvenile rays and juvenile representatives of the family Sciaenidae, and is given as payment for assistance by local non-fishers. Gillnetters consumed 8% of the total catch and donations were limited ($n = 55$ donations) to relatives, friends and especially to the fisherman's helper. For the gillnet fishery, donation refers to a mix of small, low-value fishes (68%), usually the same species caught as bycatch by the trawlers, and commonly referred to as ''mix''. Bycatch varied between the two fisheries, as trawlers caught 969.9 kg over 10 months (average of 3.7 kg trip^{-1}, $n = 325$ trips), while gillnetters caught 144 kg over 13 months (average of 7 kg trip^{-1}, $n = 93$ trips).

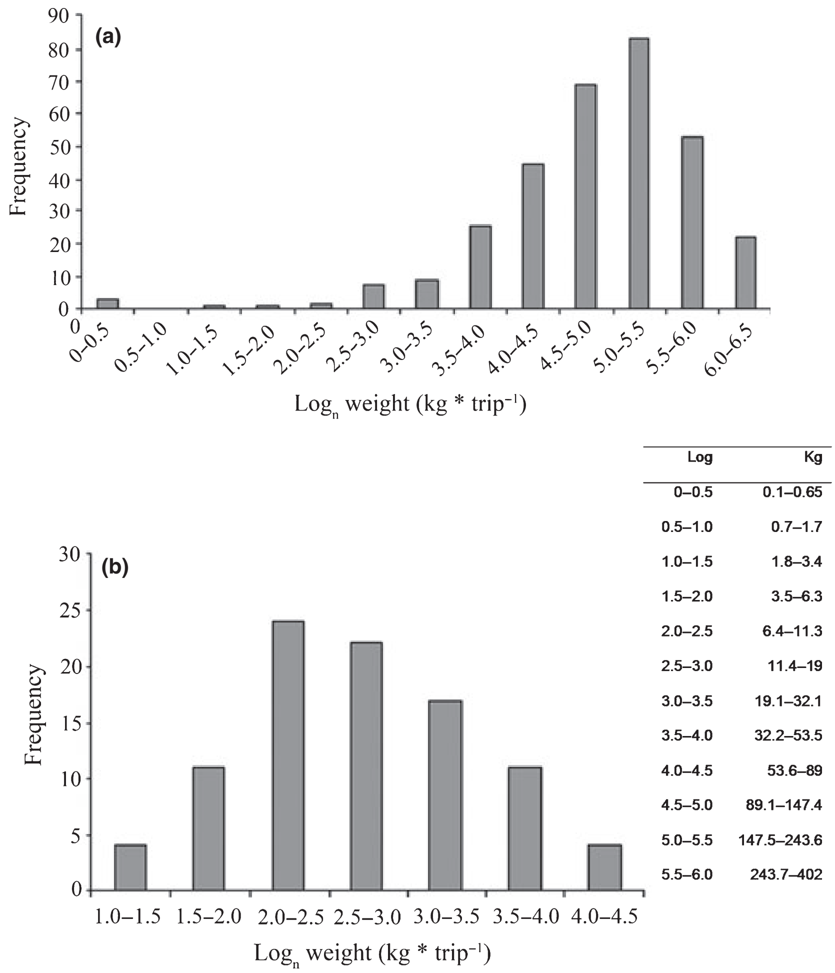
On average, trawlers caught 103.2 kg shrimp trip^{-1} ($\pm$75.3 kg), with a low coefficient of variation (CV = 0.73), while gillnetters had a lower average return (19.3 kg fish $\pm$16.0 trip^{-1}; CV = 0.83). No difference was observed between the CV, showing that the variability in the return was the same between the two groups ($Z = 1.11$; $P > 0.05$). Fishing trips with no return were rare ($n = 3$, <1% of the trips) and occurred only during trawl trips. They were usually because of cancellation of the trip before trawling due to equipment damage or bad weather. Frequency distribution of the catch was distinct for each fishery, with trawlers skewed toward higher returns (kg), while gillnetter frequency distribution of fish catches (kg) followed a normal distribution (Fig. 2a,b; Shapiro–Wilk test, $P = 0.41$).

Effort and catch per unit effort

Significant variation was found in trawl CPUE between month, especially as a result of lower values in July 2005 (Kruskal–Wallis, $H = 34.5$; $P < 0.0001$). By contrast, there was no seasonal variation in trawl CPUE for the fishing periods of spring, summer and winter ($H = 4.14$; $P > 0.05$), although warmer months (November to February) had higher values. Monthly differences in CPUE were also found in the gillnet fishery ($H = 22.79$; $P < 0.01$) but no seasonal differences in CPUE were identified ($H = 1.1$; $P > 0.5$) (Fig. 3a,b).

Time dedicated to fishing varied during the year, with trawlers spending more time during the winter than in the summer ($H = 11.6$; $P < 0.05$), while gillnetters spent more time fishing in the summer than in spring (one-way ANOVA $F = 4.1$; $P < 0.001$; no clear differences were observed among other seasons) (Table 1). For trawlers, there was no significant correlation between the time spent fishing and catch in kilogram (Spearman $r = 0.11$; $P = 0.31$) or profit (Spearman $r = 0.16$; $P = 0.12$). By contrast, gillnetters' fishing time was positively correlated with catch (Spearman $r = 0.99$; $P < 0.001$) and profit (Spearman $r = 0.76$; $P < 0.001$).

Environmental factors were strongly correlated with fishing activity. After testing for collinearity of environmental variables, the final model indicated that the intercept and wave height (*WH*) alone explained 40% of the variation in the number of trawling trips per day ($T = 15.59–3.2WH$, $r^2 = 0.4$, $P < 0.001$, d.f. = 37;



Log	Kg
0–0.5	0.1–0.65
0.5–1.0	0.7–1.7
1.0–1.5	1.8–3.4
1.5–2.0	3.5–6.3
2.0–2.5	6.4–11.3
2.5–3.0	11.4–19
3.0–3.5	19.1–32.1
3.5–4.0	32.2–53.5
4.0–4.5	53.6–89
4.5–5.0	89.1–147.4
5.0–5.5	147.5–243.6
5.5–6.0	243.7–402

Figure 2. Frequency distribution of (a) shrimp (n = 325) and (b) fish caught (n = 93) in the sampled fish landings over 13 months between 2004 and 2005 in Perequê, Guarujá.

n = 325). In the gillnet fisheries, wave height was again the most relevant factor in the complete model in addition to maximum temperature. However, once collinearity was removed, the model explained only 18% of the variability in the number of fishing trips per day, and this value was mainly given by the intercept ($T = 1.86–0.62WH$, $r^2 = 0.18$, $P < 0.01$, d.f. = 47; n = 93).

A high positive correlation was observed between the variance in the daily catch in kilograms (Spearman correlation: $r = 0.72$; $P < 0.001$, $n = 30$) or monetary revenue ($r = 0.65$; $P < 0.001$, $n = 30$) with the number of trawlers going fishing on a given day. Additionally, the variance of the previous days return (kg or monetary revenue) was positively related to the number of trawlers next day (return in kg: $r = 0.68$; $P = 0.002$; return in R$: $r = 0.76$; $P = 0.002$, $n = 18$).[1] Finally, the number of trips on the next day was positively correlated with catch (kg or R$) in the previous day (return in kg: $r = 0.71$; $P < 0.001$, return in R$: $r = 0.81$; $P < 0.001$, $n = 18$). These analyses were not performed for gillnetters because there were insufficient data to calculate the variance for most of the days.

Income was highly variable through the year (Fig. 3c). Although shrimp trawling had higher returns relative to gillnet fishing, the latter never had losses. Despite the higher chances of a good return, trawlers incurred greater expenses, especially with respect to fuel and ice. Both types of fisheries had similar maintenance repair costs (Fig. 4a,b).

There was no correlation between the shrimp catch and the price paid per kilogram ($r_s = -0.4$; $P > 0.05$) (Fig. 5a). Different shrimp plants paid

[1]Number of cases varied because only days that had the variance of the previous day were considered.

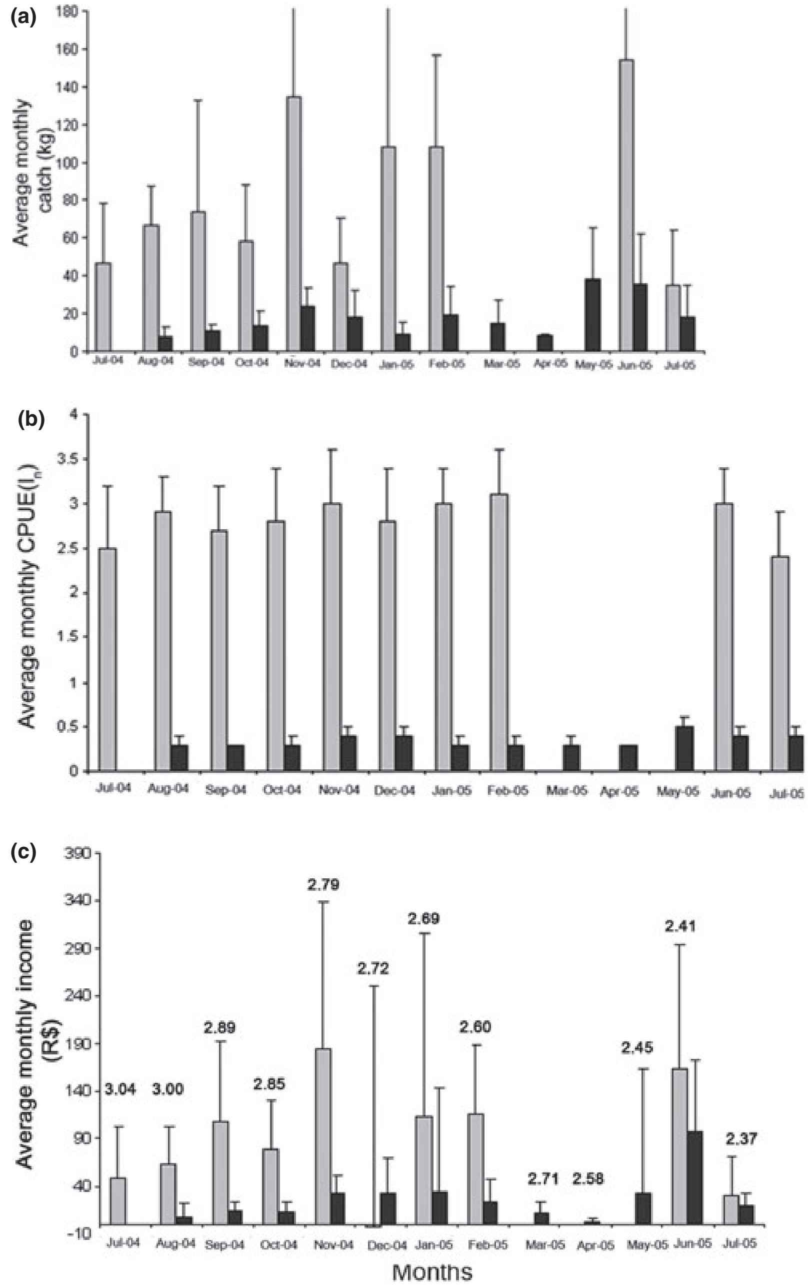


Figure 3. Monthly average (a) catch (kg), (b) CPUE ($\log_n$), and (c) average net income (R$) made per fisherman (money earned from fisheries) in each month, between 2004 and 2005. The profit of each trip was calculated as: $L = \sum C_i vi - G_t$, where C_i refers to the price paid to each species and G_t is the total expenses; the result of the equation represents the net income. Numbers above the bars in c represent the average dollar (1US$) for its respective month. Months with no bars correspond to the closed season in case of trawlers or to insufficient data in the case of gillnetters. Light grey = trawlers; dark grey = gillnetters.

similar prices (R$ 1.50–2.20 kg^{-1} in 2004) when buying shrimp from the fishermen, which did not change according to market demands (although the final consumer observed a high variation in the shrimp price through the year – R$ 7.00–18.00 in the local markets in 2004). Gillnet catches of *C. jamaicensis* rarely fluctuated and were not related to the price paid (Fig. 5b).

Trawling was slightly more productive in the winter, both in catch weight and financial return, although the differences were not significant. The only significant differences through the seasons were among travel time

Table 1. Seasonal catch (kg), fishing trip (min), fishing time (min) and fishing return (R$, kg) for gillnetters and trawlers in Perequê, Guarujá (Southeastern Brazilian coast) over 13 months in 2004 and 2005

Season	Total amount caught (kg) (AVG ± SD)	Travel time (min) (AVG ± SD)	Fishing time (min) (AVG ± SD)	Per capita return rate (kg min^{-1})	Total gross revenue (R$) (AVG ± SD)	Per capita return rate (R$ min^{-1})
Gillnet fishery						
Spring	320.9 (26.7 ± 23.0)	2875 (239.6 ± 60.6)	5635 (563.4 ± 150.3)	0.04	1901.3 (158.4 ± 167.0)	0.23
Summer	545.6 (17.6 ± 10.1)	7130 (237.7 ± 97.4)	35855 (1236.4 ± 2779.7)	0.01	1602.9 (51.7 + 31.2)	0.04
Fall	397.0 (16.5 ± 13.0)	5460 (237.4 ± 79.3)	19110 (910.0 ± 439.4)	0.02	1621.4 (67.6 ± 65.9)	0.06
Winter	528.4 (20.3 ± 20.0)	8475 (326.0 ± 168.1)	16760 (728.7 ± 337.3)	0.02	1452.00 (55.8 ± 41.1)	0.06
Shrimp fishery						
Spring	13346.4 (118.1 ± 84.7)	24885 (220.2 ± 102.1)	43655 (386.3 ± 126.4)	0.19	24142.31 (213.6 ± 169.5)	0.35
Summer	11299.79 (106.6 ± 81.7)	35038 (330.5 ± 972.2)	41065 (387.4 ± 123.0)	0.15	23822.88 (224.7 ± 152.9)	0.31
Winter	8870.32 (87.8 ± 50.3)	17344 (171.7 ± 79.6)	35758 (354.0 ± 132.0)	0.17	15877.57 (157.2 ± 89.3)	0.30

Averages (AVG) and standard deviations (± SD) per trip shown in parenthesis. No shrimp landing was sampled during the autumn, which is the shrimp closed season when trawling is not allowed.

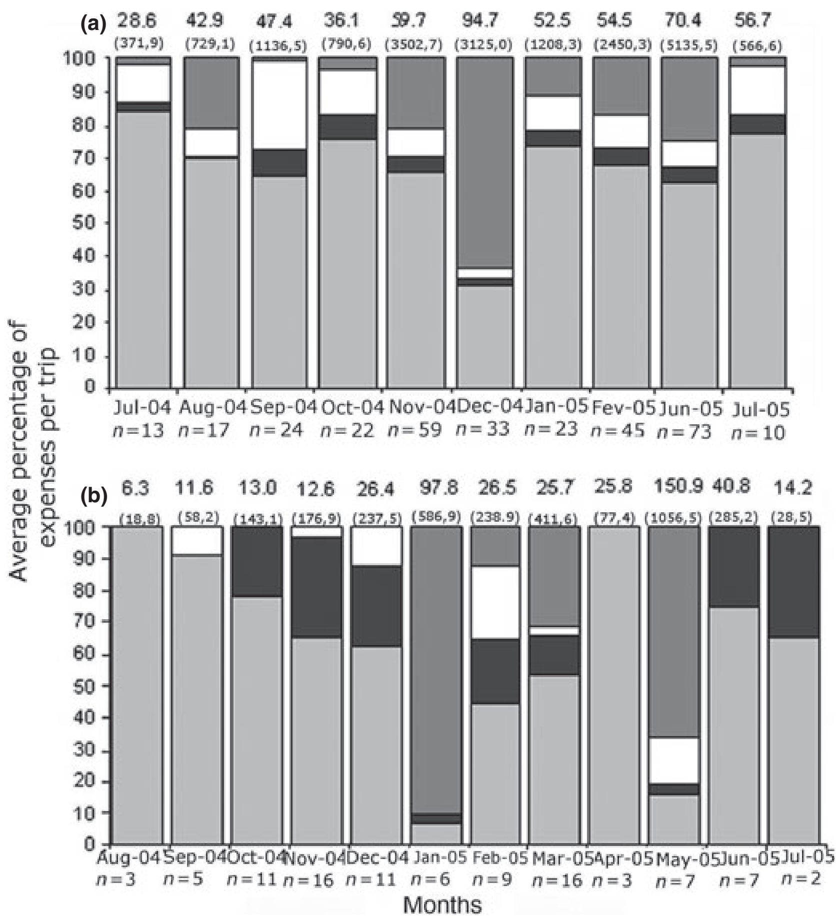


Figure 4. Distribution of different expenses over months for (a) shrimp and (b) fish in Perequê, Guarujá during 2004/2005. Numbers above the bars correspond to the average Brazilian Real (R$) spent on each trip in the specific month, while the number below this average, shown in parenthesis, represents the total expenses in a given month (R$). Under each month, it is shown the number of fish landings sampled. Light grey = fuel; black = ice; white = food; dark grey = maintenance.

and profit: trawlers travelled a shorter time ($H = 11.15$; d.f. = 2; $P = 0.004$) and made less money in the summer ($H = 7.68$; d.f. = 2; $P = 0.02$). The catch from gillnet fishing (kg) was 69% higher in spring than in winter. However, fishermen do not travel far and do not stay fishing

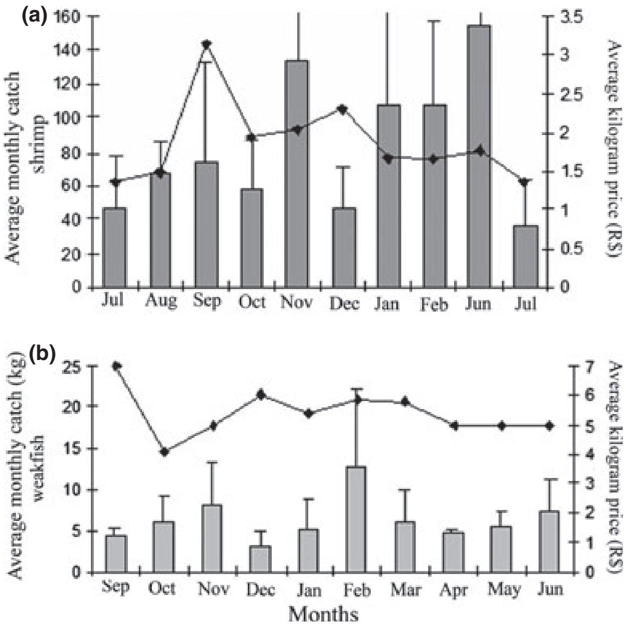


Figure 5. (a) Monthly variation in capture of *Xyphopenaeus kroyeri* and price paid (R$ kg^{-1}) in Perequê, Guarujá in 2004/2005. (b) Monthly variation in the capture of *Cynoscion jamaicensis* and price paid (R$ kg^{-1}) in 2004/2005. Bars = kg; line = price.

for a long time in the winter, resulting in the highest catch in kilogram per hour among all the seasons (almost three times higher than in spring) or in currency per hour (almost six times higher than in spring, $H = 10.06$; d.f. = 3; $P = 0.02$).

Discussion

The fishing history from Guarujá is peculiar because of the shift from subsistence to commercial fishing, adapting most of its features into a market economy. Faced with similar economic pressure to change their lifestyle, most coastal Brazilian villages either adapt their livelihoods to other sources of income (tourism) or suffer increased poverty (Diegues 1999).

The predominant influence on economic aspects of the Perequê's fisheries was the low number of targeted species ($n = 16$), and especially the overwhelming dependence on shrimp. Typically, fish landings in this part of the coast record 50–100 target fish species (Begossi & Figueiredo 1995; Seixas & Begossi 2000). However, in other parts of the world, artisanal fisheries can focus on a small number of species. This is the case for many species of benthic shellfish in Latin America, exploited mostly under an open-access situation (Castilla & Defeo 2001). Some South Brazilian fishing villages show the same features presented here (i.e. similar kind of boats and equipment, the presence of fish processing plants and a high dependence on *X. kroyeri* (Branco *et al.* 2006). This suggests that the migrant fishermen have brought not only their knowledge and techniques, but a whole system that mimics the situation they were used to in the 1970s at their place of origin.

The results from the trawl CPUE suggest the importance of time in the definition of effort. More trawling attempts implied more fishing time on average, which was confirmed by the participant observation (linear regression of number of trawls against time fishing; $n = 21$, $r^2 = 0.74$; $P < 0.001$). In the case of gillnetters, the net size best defined CPUE, which agrees with other studies (Silvano & Begossi 2001). Although not tested, the factors that predict CPUE and the determinants of the number of trips per day may shed some light on why this was the best CPUE series. A rough sea may influence the catch, which was also indicated by fishermen. Moses *et al.* (2002), studying fisheries in Nigeria, also found that hydroclimatic seasonal factors affect the CPUE.

The gillnetters worked harder in the summer, which corresponds to the *C. jamaicensis* season (the main target species) and also to the least productive season. In winter, fishermen can make more money with less effort by fishing high-valued species, such as mullet, *Mugil platanus* (Günther). One possible explanation for working more in the summer is the increased demand for *C. jamaicensis* as a result of increased tourism. Trawlers, on the other hand, often fish for 12 h in the winter, which follows the closed season so they are short of money and shrimp is more abundant. Greater winter abundance (reflected by increased landings) may be a result of slightly higher productivity. However, it is more likely that higher winter abundance is the outcome of the closed season, because studies about the same species suggest higher abundance and biomass during the autumn and summer months, and not necessarily in the winter (Branco 2005). Fishermen's perceptions, as indicated here by their belief of higher abundance in the winter, are an important source of information, although they are easily affected by market speculation and even the personal observational skills of each fisherman. For example, Catalan trawlers perceived that they would catch more shrimp on Fridays than on other weekdays (Sardà & Maynou 1998). They were correct about this, but the higher catches on Fridays were achieved by the removal of competitors (accompanying fish species) during the week and by improvements in the ability of finding shrimp shoals during the week by trawlers (Sardà & Maynou 1998). As such, the trawlers' workload observed here and elsewhere may not be a simple function of abundance and effort, but rather determined by the interaction of biological and social/economic factors.

There was no correlation between the prices paid and the monthly capture of shrimp and fish. Having the product in stock may contribute to the low price even when the fish/shrimp supply is not high. However, this is not always the case in the Brazilian shrimp market. Seixas and Troutt (2003) demonstrated that the pink shrimp, *Farfantepenaeus brasiliensis* (Latreille) and *F. paulensis* (Pérez-Farfante), price in the Brazilian south coast is delineated by market supply and demand, shrimp size and buyer type. The higher shrimp quantities captured in the season in Perequê, likely explain why there is no correlation between prices and capture, as the supply of shrimp is higher than the local demand. By contrast, the *C. jamaicensis* price in Perequê is almost constant, as it is only local market demand, and is commercialised without middlemen.

The decision-making processes addressed in this research, focused on when, where and how to fish or sell the catch which occurred at the individual level and were differentiated according to the type of fishery. The decision about when and how long to fish was common to both trawlers and gillnetters. Economic rationale here seems to denote the most important role. Fishermen will fish longer hours if they anticipate good profit opportunities and/or if they want to compensate the loss of the closed season (trawlers). In the case of gillnetters, although a higher CPUE and productivity will imply more fuel expenses (Spearman Correlation, $r = 0.34$; $P = 0.001$), it is still worth fishing longer if the returns are sufficient. Trawlers, once fishing, must assess their actual and prospective catch and weigh up fuel consumption against the advantages of trawling a little longer. In the case of a gillnetter, expenses and the alternative use of time are weighed up relative to the advantages of checking the nets more times per day. As pointed out by Boyd and Richerson (1985), people infer about their world through rational choices that have some probability distribution (with averages and variances) based on previous experiences. Begossi & Oliveira (unpublished data) showed that not all the fishermen will visit the same grounds that yielded the best shrimp harvest on the previous day, although the ones that do usually return home with a higher catch.

The positive correlation between variance of return and profit with the number of fishermen going fishing on a given day suggests that trawlers also make risk prone choices when deciding to fish. This probably happens because trawlers observe their fellows with good catches on the previous day, which is interpreted as a possibility of success on the next day. However, such choices also imply higher chances of loss, because of the higher variance of the catch. Risk proneness is not a common behaviour among human groups, as such behaviour is only expected when the person does not meet his daily minimum requirement in calorific (or monetary) terms (Winterhalder *et al.* 1999).

Cultural factors can be important determinants of not fishing on Sundays, which would not be a deliberate decision process, just a widespread habit of holidays (Guest 2003). Sunday is the day that fishermen take recreational fishermen to the sea, assuring an easier and less risky source of income. Such an economic-cultural decision may help moderate the effort, as recreational fishermen target different species. Weather is another determinant in not fishing; fishermen will not risk their lives and boats when they think it is not safe.

Another type of decision shown here is related to pre-processing the shrimp. Cleaning the catch implies selling it for a higher price, but also spending more time that could be allocated to fishing or returning home earlier. If they are having a good fishing day, fishing longer is preferred to processing (MacCord & Begossi 2006b). A comparison of the costs and benefits of processing the shrimp showed that although fishermen who partially process the shrimp in the boat did better in economic terms, most of them chose otherwise because they consider this activity boring (MacCord & Begossi 2006b).

Understanding the decision-making processes helps anticipate the fishermen's behaviour concerning environmental, economic and social change, which is critical for management plans (Béné & Tewfik 2001). Among the most important behaviour to be understood is how fishermen allocate effort (Opaluch & Bockstael 1984), which has been shown to be a complex and dynamic variable. Béné and Tewfik (2001) showed that Caribbean fishermen switch between lobster and conch fisheries, allocating a different effort to them according to economic constraints. However, other factors such as individual skills and status also played a significant role in their behaviour. Béné (1996) also showed that shrimp fishery effort in French Guiana was a function of stock availability, the crew remuneration system and markets. Another example showed that pink shrimp trawlers in California decided on where to fish based on the fleet position on the preceding day (Eales & Wilen 1986). Guest (2003) showed that increasing effort of existing fishermen in an Ecuadorian community can have worse consequences than adding new fishermen to the fishing system every year. This is a very important point to be considered in management initiatives, especially in places like Guarujá, where both factors, increasing the effort of the existing fishermen and the arrival of new fishermen, play a role.

Another approach used to understand fishermen's behaviour is the optimal foraging theory, which encompasses a series of different models that create predictions accounting for decisions that foragers make (e.g. areas used and the time spent fishing in them). One of the studies using this approach showed that the I-Kiribati shell gatherers from Micronesia usually left a fishing spot when the marginal catching rate dropped to the average catching rate of the entire set of patches used (Thomas 2007). Another study in the Solomon islands showed that fishermen visit more fishing grounds during periods of high returns and their stay in each spot decreases, doing otherwise in less productivity season (Aswani 1998). Such studies spread through different regions have some common aspects, but they have all peculiarities, proving how complex the decision-making process can be.

This study shows that artisanal fishermen are influenced by economic constraints and opportunities, environmental factors such as wind and wave height, and also by cultural and social motives including different migrant groups and the institutional arrangements that place them in an open-access regime. However, it is important to highlight that cultural and social reasons were only qualitatively observed here. Such complex situations determine effort and the way the resource is extracted. The results highlight how the impacts of economic and environmental variables in the decision-making process by fishermen can be more significant than usually considered in studies of small-scale fisheries. Knowing fishermen's decisions regarding effort and the factors influencing such decisions is essential to develop management measures, especially in open-access situations in tropical regions, where management is non-existent and there is lack of fundamental data.

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