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Original Article

Size matters: fishing less and yielding more in smaller-scale fisheries

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Several factors influence catches and the sustainability of fisheries, and such factors might be different depending on the scale on which fisheries work. We investigated the existence of possible subdivisions within small-scale fisheries (SSF) themselves, regarding their economic performance and relative social and environmental impacts to understand which categories of these two types of fleets are best positioned to support sustainability. By doing so, we investigated if it is a good strategy for SSF to aim to grow towards larger scales. We obtained economic and ecological data from landing samplings and information on technological efficiency of this fleet, using a northeastern Brazilian state as a case study. We defined a cut-off point to separate the SSF into two categories of boats, according to their size and gear. We compared their cpue and the factors affecting it within each category; we also compared economic (number of boats, number of landings, jobs, gears, catch, travel time and total time of the fishery, revenues, costs, profits, revenue per unit of effort, and profit per unit of effort) and ecological factors (vulnerability of species caught) between the two categories. We found that small boats spent less time fishing and employed comparatively more people per landed value and catch. The cpue and profits of small boats were also higher. Both large and small boats exploit species with the same overall vulnerability. Therefore, being smaller, even within the SSF category, seems to be a more advantageous social and economic strategy for guaranteeing higher catches and more employment opportunities per catch. These findings need to be taken into account when defining new policies, such as the distribution of subsidies that support or not the sustainable use of fishery resources.

Keywords: fishing scale, policy objectives, socio-economic variables.

Introduction

All fisheries consist of a variety of fleet types that differ greatly in terms of vessel size, gears used, technology employed, fishing grounds reached, and degree of expertise of the fishers. All these factors are also highly dependent on the market characteristics the fishery delivers to, and on a range of social aspects such as local culture and the availability of investment capital (Therkildsen, 2007). While these factors are also a product of the targeted fish stocks, they also affect the stocks themselves.

Unfortunately, studies assessing trends in catches, especially those using vulnerability indicators and their relation with fleet technological efficiency, are only common in industrial fisheries. Small-scale fisheries (SSF) are usually ignored when compared with industrial fisheries, not only by policy-makers, but also by scientists (Abernethy *et al.*, 2007; FAO/World Fisher Center, 2008; Villasante *et al.*, 2012). Therefore, SSF social, economic, and ecological impacts are poorly known. Such neglect is worrisome due to the role that SSF play in food security and poverty alleviation, especially in coastal and rural communities in developing countries (Béné *et al.*, 2007). For example, it is estimated that SSF take half of the total global fish catch and employ nearly 10 million people worldwide both in the harvest and post-harvest sectors (Berkes *et al.*, 2006; Teh and Sumaila, 2013).

Subsidies are a common governmental policy adopted worldwide for maintaining, incentivizing, or adapting fisheries (Sumaila *et al.*, 2010). However, most of these subsidies tend to be biased, as they are usually directed to the large-scale fishing sector, mainly with effects on the structure of the fishing fleet (Abdallah and Sumaila, 2007). Changes in the fleet structure, on its turn, can have important implications on the viability of fisheries and on the marine resources (Ward *et al.*, 2001). Although much speculated, it is not clear yet what fleet structures are more conducive to ecosystem sustainability, while generating higher social and economic benefits from the limited fish resources (Therkildsen, 2007). To answer such question, studies of the different fishing sectors in different regions regarding their "real" economic and environmental contributions are needed.

Many different criteria exist to divide fleets into sectors to be compared and analysed. For instance, artisanal fleets in Madagascar are those consisting of "motorized, non-traditional vessels with inboard engines of up to 50 Hp", whereas in Cameroon the same category is formed by "beam trawlers, small to medium engines up to 300 Hp" (Teh and Sumaila, 2013). That shows that there is still no single or widely accepted definition of what should be classified into SSF or large-scale fisheries, with most studies being highly context dependent: what is considered small scale in one location or country could be understood as large somewhere else (FAO, 2005; Johnson, 2006).

One important and more logical attempt to do such a division adopted a relative rather than an absolute scale to categorize SSF and large-scale fisheries (Ruttan *et al.*, 2000). In that study, the authors used catch per vessel per year, reasoning that low catches are associated with smaller boats that travel shorter distances and employ a less numerous crew, thus capturing the essence of "smallness" with just one figure. While these authors also compared the economic performance of the two sectors, they did not, however, take into account social and environmental parameters, issues that are also basic to regulate fisheries. Such specific shortcoming was later addressed in subsequent investigations (Sumaila *et al.*, 2001), which also examined how small- and large-scale fishing operations differ in many policy-relevant parameters (Therkildsen, 2007; Carvalho *et al.*, 2011).

Here, we adapted Ruttan *et al.*'s (2000) methodology to investigate the existence of possible variations and subdivisions within SSF themselves, regarding their economic performance and relative social and environmental impacts, using data from Brazil as a case study. We understand that any division is arbitrary, including the broad categories of SSF and large-scale fisheries, as there is possibly a continuous from the smallest to the largest profile. However arbitrary, such divisions have guided the adoption of subsidy policies, among other initiatives (Abdallah and Sumaila, 2007), raising concerns about the fairness and sustainability of such measures (Sumaila and Pauly, 2006). By investigating the non-homogeneity of a sector that has been treated in such a clear-cut manner, we hope to show that large is not necessarily better, and that subsidies, bad, ugly, and good ones (Sumaila *et al.*, 2010) need to be reconsidered according to the impact a given fleet has on its social–ecological environment.

Material and methods

Study area

To assess the divergent impacts of SSF on social, economic, and environmental aspects, we used data from Brazil, specifically from Rio Grande do Norte State. This northeastern state has 25 towns and 93 fishing communities along ~410 km of coastline divided into eastern and northern coast, subjected to different environmental influences (Vital, 2006), which consequently affected the development of different fishing fleets and their target species.

We chose this state because fisheries have been, for a long time, one of its main economic activities, operated both by small scale and by large scale. While in the past the lobster fishery (now overexploited) led the export records for the region, nowadays the main market is dominated by tuna and tuna-like fish caught by industrial fleets, which land the vast majority of its catch in the capital (Natal). On the other hand, SSF focus on the catch of sardines, flying fish, the scarce but still profitable lobsters, groupers, snappers, and blackfin tuna, with several landing ports distributed along the coast (MMA, 2006).

Here, we specifically chose two of the main landing ports of SSF on Rio Grande do Norte coast, one in the eastern (Baía Formosa—2.3% of all landings) and another on the north coast (Caiçara do Norte—6.9% of all the state landings). We excluded the major port, Natal, which accounts for 34% of the total catch of the State, because this is mainly an industrial port. The ports we chose also encompass a variety of types of small-scale fishing, capable of tapping into different stocks, from more sedentary reef fish, such as groupers, to large migratory pelagic, such as juvenile yellow tuna (Damasio *et al.*, 2015). By doing so, we hoped to represent not only the geographical variability of the region, but also the variability within SSF themselves, which may have some effect on the fleet development and therefore on the results of our analysis (Figure 1).

Data collection

We monitored landings of the two fishing communities simultaneously from January 2013 to March 2014. The sampling was performed during two consecutive days (from 6:00 am to 6:00 pm, approximately) in each place every month. Harbour observers recorded information directly from interviews with fishers about fishing gear used, date, duration of the fishing operation (the number of hours spent in the fishing), round trip time to fishing grounds (i.e. travel time in h), species caught (in kg), fishing grounds, and ex-vessel price (in Real, the Brazilian currency—BRL). In addition, to determine the technological potential for each vessel, information about the presence/absence of an engine, engine power (in cubic centimetre—cm^3), ice, and fish storage capacity (in kg) were collected for all the sampled vessels.

We aggregated the gears used into four different groups. The first group includes handline (hereafter "Line"). The second group is formed by longlines. Gillnets represent the third group, and include nets that are generally made of monofilament nylon and could be fixed to the bottom or drift. The fourth group (hereafter "Mixed") included fishery operations that apply more than one type of these gears.

For statistical purpose, we created a unique data matrix by merging the information of the vessels to the landing data. Furthermore, we related the characteristics of the vessel and the information of each fishery operation. Since the catch statistics varied markedly between different vessels, we computed the catch per unit effort (cpue) as the total catch in a fishing operation (in kg), and standardized it per number of fishers and per haul duration (in h).

Statistical analysis

The analytical strategy we adopted involved five steps: (i) the definition of a cut-off point to separate landings of what has been originally treated as SSF; this allowed us to investigate if such fisheries are really homogeneous; (ii) a Wilcoxon rank-sum test to explore if the total cpue of the two categories differed; (iii) a Bayesian general linear model to evaluate if different factors influence the cpue of the two categories; (iv) an analysis of the similarity (ANOSIM) of

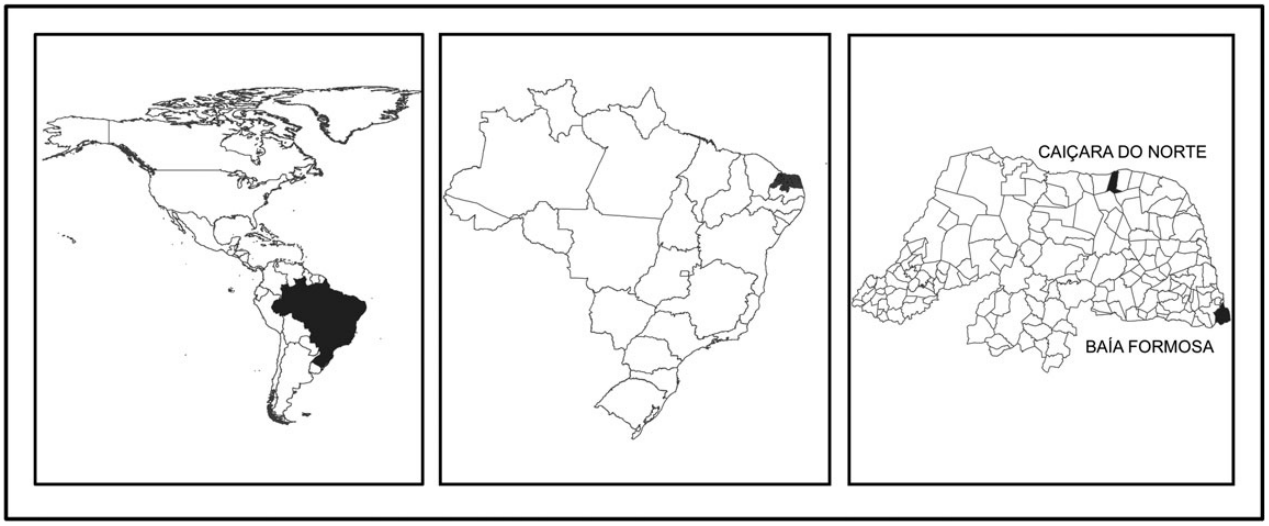

Figure 1. Fishing communities sampled in the north (Caiçara do Norte) and in the eastern (Baía Formosa) of the Rio Grande do Norte State, Brazilian northeast.

Table 1. Loadings of the components of the technological factors used in the PCA.

Factors	Comp1	Comp2	Comp3	Comp4
Boat length	0.75	0.49	0.47	−0.17
Engine power	0.49	−0.31	−0.14	−0.93
Ice tonnage	–	−0.64	–	0.30
Crew size	0.37	0.31	−0.87	−0.77

the fish assemblages of the two categories regarding species composition and vulnerability; and (v) a Wilcoxon rank-sum test to compare if economic and production factors differed between the two groups.

1. Step one: finding the cut-off point of the fleet

To define the cut-off point, we first had to choose a variable that would be the most representative of the data variability, among the boat technology features (engine power, ice tonnage, crew size, and boat length). First, we computed Pearson's correlations among all the variables. The results showed that such variables were all autocorrelated by $>50\%$ ($p < 0.0001$). We then ran a principal component analysis (PCA) using the "princomp" function in R software (R Development Core Team, 2015). This showed that boat length was the most representative factor among the considered variables, with ~70% of the data variability explained by the first component (Table 1).

We then used the method developed by Ruttan *et al.* (2000) to find the cut-off point of the fleet. The methodology is based on a division of the fishing fleet into a series of gear type/vessel size combinations as follows: (i) vessel classes were defined by length in metres; (ii) the total catch and revenue produced by those vessels of same size and using the same gear were summed and each gear type/vessel size combinations were ranked according to annual landings and landed value; and (iii) the cut-off point between the two categories was set at 50% cumulative landed weight and landed value. As mentioned before, the method developed by Ruttan *et al.* (2000) reasons that low catches are associated with SSF, so the first 50% of cumulative landed were chosen to be the category of small boats.

For this case study, vessel size was accounted for in terms of length rather than tonnage gross Register tonnage (GRT), as done in previous studies (Therkildsen, 2007; Carvalho *et al.*, 2011). Here, however, such choice is also supported by the PCA that showed that length is the variable that explains most of the data variability.

2. Comparison of cpue between the two categories

After detecting the non-normality of the data with a Kolmogorov–Smirnov test, we compared the cpue of the two categories using a Wilcoxon rank-sum test using R software (R Development Core Team, 2015).

3. Understanding which factors affect the cpue in the two categories

To understand if different factors explain the cpue of each of the two categories, we first log-transformed the cpue values to allow us to put less weight on extreme values and thereby ensure a normal distribution.

To model the cpue, we opted for GLMs using a Bayesian approach, as it allows both the observed data and model parameters to be considered as random variables, resulting in a more realistic and accurate estimation of uncertainty (Banerjee *et al.*, 2004).

The expected values of cpue in each fishery operation and for each category were related to the independent variables: type of gear, fishing grounds, landing harbours (the two sampled sites), month, engine power, presence/absence of an engine, and ice storage capacity (kg), according to the general formulation:

$$\mathrm{cpue}_i = \alpha + X\beta + Z_i$$

where X is the vector of covariates for each survey i, α is the intercept, β is the vector of the model parameters, and Z_i is a random factor that represents the vessel or fishers' effect. Indeed, the remaining potential source of variation on cpue data could be due to the fishers themselves. These differences can be due to fishers' behaviour (caused by random aspects, experience, age, and social needs) or unobserved gear characteristics. Ignoring such non-independence of the data may lead to invalid statistical inference. Then, to remove this bias, a random vessel effect was included.

After determining the model, the next step was to estimate its parameters and assign them a prior distribution. For the parameters involved in the fixed effects, we used non-informative Gaussian distributions N (0.100).

We started with a complete model, with all the variables just described, and we then proceeded with the model selection, using both backward and forward approaches to select relevant variables. Specifically, we used the deviance information criterion (DIC), a well-known Bayesian model-choice criterion for comparing complex hierarchical models (Spiegelhalter *et al.*, 2002). DIC is inversely related to the compromise between fit and parsimony.

To fit Bayesian models, we used the integrated nested Laplace approximation (INLA) methodology and software (http://www.r-inla.org).

4. Analysing the impacts on vulnerability of species between the two categories

To ensure that species with very low catches would not compromise the results, we only included species with catches above 100 kg year^{-1} in the analyses.

To check the vulnerability of the species sampled in landings, we used the vulnerability index available in FishBase (Froese and Pauly, 2015). This index integrates ecological characteristics (maximum size at first maturity age, longevity, growth parameter K von Bertalanfly, natural mortality, fertility, energy spatial behaviour, and geographic reach) of a species with its life history, using the "Fuzzy Expert System" software (Cheung *et al.*, 2005). The vulnerability of a species is expressed on a scale that varies from 1 to 100. Values up to 35 are considered low vulnerability; 36–55 are considered moderate; 56–75 are considered high vulnerability, and values above 76 species are classified as very high vulnerability. With these values, we checked if our two predefined SSF categories were targeting species of different vulnerabilities.

To check possible differences in the quantity (in kg) of the vulnerable species caught between the two categories of vessels, ANOSIM was performed. For this purpose, the "anosim" function of the "vegan" package (Oksanen *et al.*, 2013) of the R software was used.

5. Comparing the economic factors between categories

To determine whether there was any difference between the two categories of SSF, we compared: number of boats, number of registered landings, jobs created per ton of species landed, and per $10,000 (in BRL) produced, gear used, data of fishery operations (average capture, travel time, and total time of the fishery), revenues, costs, profits, revenue per unit of effort (RPUE), and profit per unit of effort (PPUE). The RPUE was computed as the total revenue for a fishing operation (in BRL), standardized per number of fishers and per haul duration (in h). The PPUE followed the same logic of RPUE, but excluded the costs from the revenue.

We compared all of these variables between the two categories through a Wilcoxon test, because the data were not normally distributed. (Kolmogorov–Smirnov was used to test data normality.)

Results

Among the 542 landings sampled, 183 landings could be related to the technological information of the vessels in the two communities. The 59 vessels examined were evenly distributed in the eastern and northern parts of the State (26 in Baía Formosa and 33 in Caiçara do Norte; Table 2).

The small-scale fishing sector assessed here had a cut-off point for boats at 8 m length both in terms of landed (BRL) and weight (kg) values (Figure 2).

Following this cut-off point, 118 landings were analysed for the small boats category (vessels <8 m) and 65 were evaluated for the large boats category (vessels >8 m). The studied sites had more small boats ($N = 46$) than large ones ($N = 30$). Thirty-three job positions are supported per tonne of fish landed by the smaller-scale fishery, whereas the larger-scale sector supports 28 jobs per landed tonne of fish. Regarding revenues, the smaller-scale fishery sector supports fewer employees for every BRL 10 000 worth of fish caught (43 jobs) than the larger-scale one (56 jobs).

The mean cpue (in kg effort unit^{-1}) differed between smaller (mean cpue = 1.44) and larger boats (mean cpue = 0.87; Wilcoxon test; $p = 0.06$).

After selecting the best Bayesian model, the cpue of smaller boats was explained by the variables: landing harbours, type of gear, and presence/absence of an engine as covariates. Specifically, the northern village ("Caiçara") showed higher estimated cpue (posterior mean = 0.89; 95% CI = [0.04, 1.73]) than the eastern one (Baía Formosa). Longlines had lower estimated cpue (posterior mean = −0.22; 95% CI = [−0.68, −0.01]) than the mixed gears. Finally, having an engine on the boat also contributed to a higher estimated cpue (posterior mean 0.54; 95% CI = [0.04, 1.26]).

For the larger boat category (vessel >8 m), the final model included the engine power and the ice storage capacity, with both contributing directly to increasing cpue (engine posterior mean = −0.97; 95% CI = [0.35, 1.78]; ice storage capacity posterior mean = 1.20; 95% CI = [0.34, 1.95]).

As expected, larger boats carried more powerful engines (2.44 cylinders) than the smaller ones (1.38; $p = 0.0001$), and also had greater ice tonnage (327.9 × 228.1 kg; $p = 0.0007$). Twenty different species were identified as the most commonly caught by both categories of fleet (>100 kg year^{-1}). Three species were exploited only by smaller boats, two of medium vulnerability and one of high vulnerability; whereas six species are exploited only by larger boats, three of high, two of medium, and one of low vulnerability (Table 3).

Although nine species are caught exclusively by one or another size category, no difference was observed in their abundance and there was no difference in the vulnerability index (Figure 3).

There was almost no variation in the type of gear used by both boat categories. The use of handlines, for example, was almost the same (small = 40%; large = 31%), whereas the use of gillnet was exactly the same (small = 46%; large = 46%).

Although larger boats stayed longer at sea, their landings and revenues were not different from those of smaller boats (Table 3). On the other hand, the higher average costs with ice, fuel, and food incurred by larger boats did not result in different profits, when compared with smaller boats (Table 4).

Discussion

In this study, we examined how homogeneous the SSF are in relation to their economic performance, and to social and ecological impacts, using a northeastern state in Brazil as a case study. While similar studies have evaluated the economic difference between SSF and large-scale fishery in different parts of the world (Thompson, 1980; Ruttan *et al.*, 2000; Sumaila *et al.*, 2001; Therkildsen, 2007; Carvalho *et al.*, 2011), this is the first one to investigate the possible

Table 2. Data of catch (kg) and value of landings.

Vessel size in metres (gear type)	Cumulative proportion of catch (in %)	Proportion of catch (in %)	Total catch (kg)	Profit (BRL)	Proportion value (in %)	Cumulative value (in %)	Number of landings
4.5 m (Gillnet)	2.00	2.00	301.0	2062.9	2.75	2.75	7
5 m (Gillnet)	2.32	0.32	47.5	7274.5	9.71	12.46	5
5.1 m (Line)	2.49	0.17	26.0	543.5	0.73	13.19	4
5.1 m (Gillnet)	2.80	0.31	46.9	822.0	1.10	14.29	1
5.9 m (Gillnet)	3.13	0.32	48.8	345.8	0.46	14.75	5
6 m (Gillnet)	5.69	2.57	386.1	2755.7	3.68	18.43	13
6.15 m (Line)	5.93	0.23	35.0	398.5	0.53	18.96	3
6.2 m (Gillnet)	6.03	0.11	16.0	0.0[a]	0.00[a]	18.96	2
6.4 m (Gillnet)	6.41	0.38	57.0	300.3	0.40	19.36	6
6.5 m (Line)	6.92	0.51	76.1	106.5	0.14	19.50	1
6.8 m (Line)	8.62	1.70	255.2	745.3	0.99	20.50	3
7 m (Mixed)	9.20	0.58	87.9	314.4	0.42	20.92	1
7 m (Line)	12.60	3.40	510.6	7502.7	10.01	30.93	9
7.2 m (Line)	15.33	2.73	410.3	3853.0	5.14	36.07	6
7.25 m (Longline)	15.64	0.31	47.0	20.5	0.03	36.10	1
7.25 m (Line)	15.96	0.32	47.9	283.0	0.38	36.48	1
7.25 m (Mixed)	17.79	1.84	276.4	376.0	0.50	36.98	1
7.4 m (Line)	20.82	3.02	454.6	5175.8	6.91	43.89	5
7.5 m (Gillnet)	20.89	0.08	11.4	961.8	1.28	45.17	1
7.77 m (Longline)	21.16	0.27	40.0	162.5	0.22	45.39	2
7.77 m (Gillnet)	24.49	3.33	500.7	230.0	0.31	45.70	2
7.8 m (Line	28.93	4.44	668.3	495.0	0.66	46.36	3
8 m (Gillnet)	35.70	6.77	1018.0	504.5	0.67	47.03	15
8 m (Line)	50.24	14.53	2185.3	941.5	1.26	48.29	13
8 m (Mixed)	52.37	2.13	321.0	5883.4	7.85	56.14	4
8 m (Longline)	55.01	2.64	396.7	9012.9	12.03	68.17	3
8.1 m (Mixed)	56.47	1.46	218.9	454.5	0.61	68.78	1
8.1 m (Longline)	59.22	2.75	414.0	3219.5	4.30	73.08	3
8.2 m (Gillnet)	60.87	1.65	247.8	482.0	0.64	73.72	5
8.2 m (Line)	62.75	1.88	283.0	1383.9	1.85	75.57	2
8.4 m (Mixed)	65.31	2.56	385.4	742.5	0.99	76.56	3
8.5 m (Line)	71.57	6.26	941.0	366.0	0.49	77.05	3
8.75 m (Gillnet)	73.46	1.90	285.0	0.0[a]	0.00[a]	77.05	5
9 m (Mixed)	73.92	0.45	67.9	2263.5	3.02	80.07	3
9 m (Gillnet)	80.46	6.54	983.9	3726.6	4.97	85.04	11
9 m (Line)	84.22	3.76	565.3	4755.8	6.35	91.39	13
9.3 m (Gillnet)	86.26	2.04	307.0	982.5	1.31	92.70	2
9.5 m (Gillnet)	90.72	4.46	671.0	1893.0	2.53	95.23	3
9.6 m (Gillnet)	94.13	3.41	513.0	537.5	0.72	95.95	5
9.6 m (Longline)	94.49	0.36	53.5	1048.5	1.40	97.35	1
10 m (Gillnet)	98.88	4.39	660.5	0.0[a]	0.00[a]	97.35	4
10 m (Longline)	100.00	1.12	168.0	1987.2	2.65	100.00	1

Values are shown in Brazilian currency (BRL). The average dollar conversion rate for the period is 1 USD = BRL 2.30. Gear type "mixed": various types of fishing gear used in the same fishery.

[a] The fish landed was not sold but used for own consumption.

variations and subdivisions within SSF themselves. This assessment is valuable for management purposes although in a few countries governments have reduce their level of subsidies recently, this still happens in many countries, mainly in developing countries, such as in Mexico and Brazil (Corrêa *et al.*, 2014; Cisneros-Montemayor *et al.*, 2015; Sumaila *et al.*, 2016), instead of supporting the conservation of fish stocks.

Overall, the results showed that smaller boats within the SSF spend less time at sea per fishing trip and provide higher social contribution by creating more employment opportunities. Furthermore, smaller boats have lower costs in general and the same cpue. Conversely, larger boats spend longer periods at sea since their more powerful propulsion system allows them to reach more distant grounds, likely searching for sites with greater abundance of fish. Larger boats need to target larger quantities of fish to cover their higher expenses (Table 5).

The cpue did not differ between smaller and larger boats, but surprisingly neither did the catches. The reasons varied between the categories of vessels. For smaller boats, social (numbers of jobs created), cultural factors (harbour of landing), and the presence or absence of an engine seem to be important predictors for the cpue. The gear used also affected the variability of the cpue, which is an expected outcome whenever there are different gears being used (Lapointe *et al.*, 2006). This gear effect can be attributed to many interacting factors, such as the ability of certain species to avoid or escape certain gears due to morphological and behavioural characteristics and the fact that gears are not equally effective in all habitats.

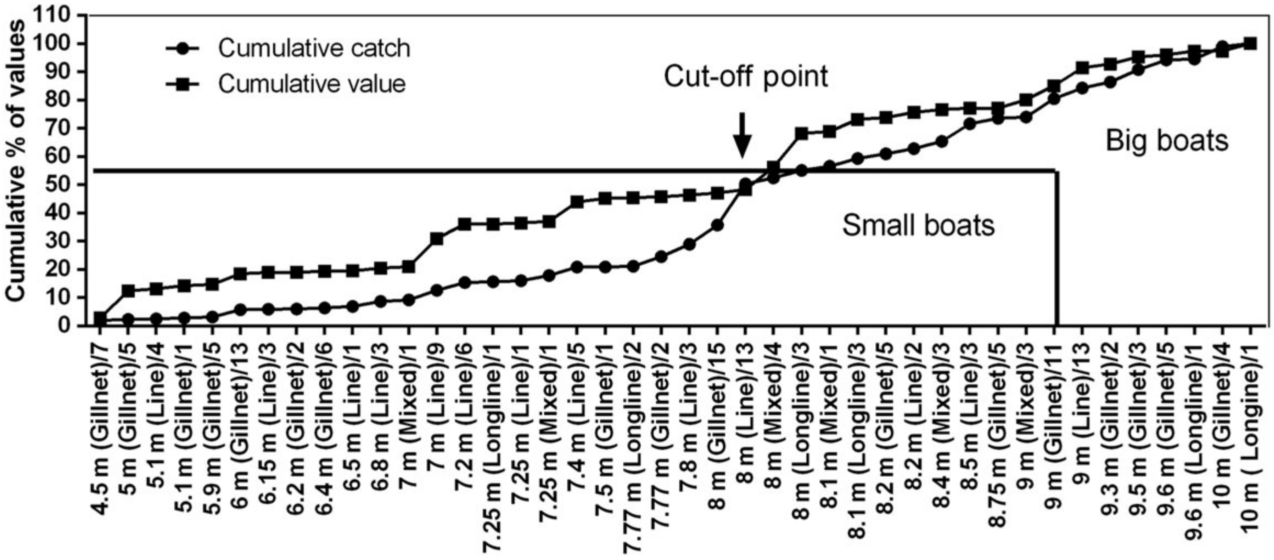

Figure 2. Gear type/vessel size against cumulative percentage of landed value (line with squares) and landed weight (line with circles). The cut-off point between the two categories is shown at 52.37% cumulative weight (to ensure that all vessels of the same size were in the same category). The corresponding cumulative percentage in landed value is shown at 56.14%.

Table 3. Low (L), medium (M), and high (H) vulnerability and catch of species exploited by small and large boats.

			Total catch in kg per species	
Common name	**Scientific name**	**Vulnerability**	**Small**	**Larger**
Flying fish	*Hirundichthys affins*	L	1970.00	1046.44
Blue runner	*Caranx crysos*	L	63.00[a]	126.00
Dolphinfish	*Coryphaena hippurus*	M	811.25	505.5
Mutton snapper	*Lutjanus analis*	M	590.75	540.5
Lesser amberjack	*Seriola fasciata*	M	279.3	322.5
Blackfin tuna	*Thunnus atlanticus*	M	524.7	242.5
Lane snapper	*Lutjanus synagris*	M	256.2	53.5[1]
Common snook	*Centropomus undecimalis*	M	165	0.00[1]
Coney	*Cephalopholis fulva*	M	0.00[a]	150.00
Coco sea catfish	*Bagre bagre*	M	53.00[a]	316.00
Black grouper	*Mycteroperca bonaci*	H	1752.5	257.00
Spanish mackerel	*Scomberomorus brasiliensis*	H	871.00	1551.10
King mackerel	*Scomberomorus cavalla*	H	199.10	196.90
Atlantic little tunny	*Euthynnus alletteratus*	H	250.00	305.00
Shark	*Galeocerdo cuvieri*	H	239.20	522.00
Southern red snapper	*Lutjanus purpureus*	H	119.00	122.00
Whitemouth croaker	*Micropogonias furnieri*	H	126.00	0.00[1]
Atlantic sailfish	*Istiophorus albicans*	H	61.00[a]	218.00
Yellowtail snapper	*Ocyurus chrysurus*	H	53.50[a]	181.00
White grunt	*Haemulon plumieri*	H	12.00[a]	144.00

[a] Catches below 100 kg year^{-1} are not considered.

Socially, smaller boats in the small-scale sector provide not only more jobs in general but also per tonne of fish landed. This first one was expected, as it is a well-known fact that when SSF are considered as a whole they generate more jobs than the industrial sector. In fact, it is estimated that SSF provides over 90% of all fisheries jobs in the world (FAO/World Fisher Center, 2008). What is interesting here is that this pattern is repeated even within what is commonly seen as a homogeneous group of SSF boats. Moreover, smaller boats are also more socially efficient, for employing more people per tonne of fish that reaches the ports. On the other hand, the smaller boats generate fewer jobs for every BRL 10 000 produced, meaning that fewer people share the money proportionally. Thus, from a social perspective, the smaller boats are more efficient at generating jobs with a better income distribution among fishers.

Although well known in general and repeated here under a zooming lens inside the SSF sector, managers and policy-makers do not seem to grasp the meaning of having more jobs in a sector than in another, because the common tactic is to always stimulate growth and increase fleet size as a way to increase catches and profits (Khan *et al.*, 2006). By such policies, not only overfishing becomes a closer threat, but also the distribution of income becomes more unequal, by concentrating wealth in the hands of those few who can afford larger boats. Moreover, in developing countries, if fishers do not have easy access to bank loans and

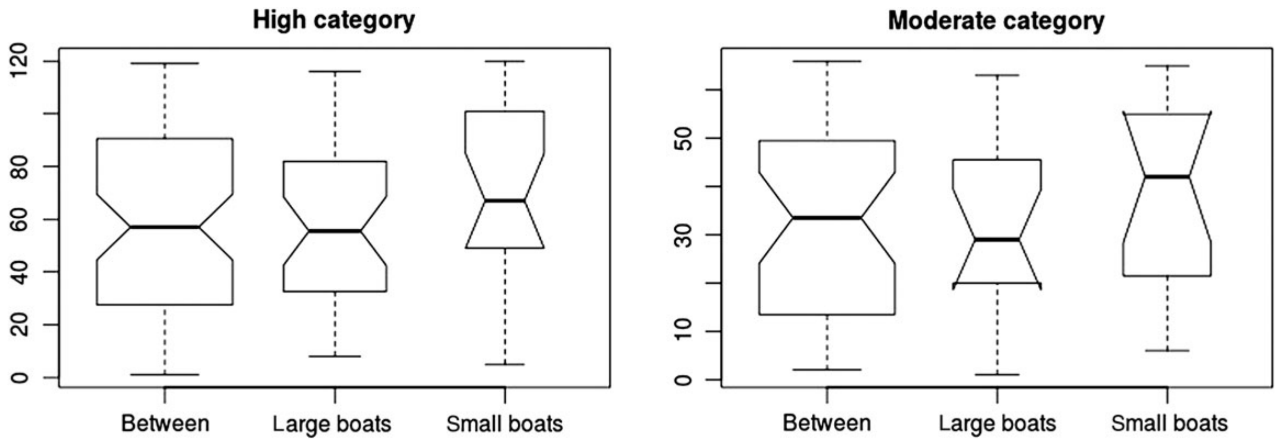

Figure 3. ANOSIM results for each categories of vulnerability between vessel categories. Values presented refer to high vulnerability ($R = 0.07$; $p = 0.80$) and moderate vulnerability ($R = 0.09$; $p = 0.70$).

Table 4. Information on fishery features, production, and the economy of the two categories of boats operating in the two communities assessed.

	Small boats		Larger boats		
Variables	**Average**	**SD**	**Average**	**SD**	***p*-value**
Time trip (h)	4.5	3.75	6.00	3.36	**<0.01**
Time fishery (h)	30.0	27.0	49	27	**<0.001**
Crew size	2.44	0.65	2.95	0.41	**<0.001**
Catch (kg)	73.24	89.39	106.95	91.84	0.22
Cpue	1.44	2.38	0.87	0.84	0.06
Revenue (BRL)	559.0	828.0	532.3	468.0	0.22
Cost (BRL)	99.25	117.0	182.71	161.40	**<0.001**
Ice cost (BRL)	30.8	57.37	39.2	18.52	**<0.001**
Fuel cost (BRL)	46.0	49.29	107.90	96.3	**<0.001**
Food cost (BRL)	49.11	40.62	53.85	35.21	0.20
Profit (BRL)	470.65	829.0	369.23	474.4	0.57
RPUE (BRL)	22.76	76.57	6.48	7.99	0.051
PPUE (BRL)	21.43	76.4	5.21	7.6	0.056

The cpue was estimated by: catch × (no. of fishers × fishing hours)$^{-1}$. *P*-value refers to the Wilcoxon test. Values are shown in Brazilian currency (BRL). The average dollar conversion rate for the period is 1 USD = 2.30 BRL. RPUE, revenue per unit of effort; PPUE, profit per unit of effort. Values in bold are significant.

Table 5. Summary of variables compared between the category of small boats (<8 m) and the category of large boats (>8 m) operating in the two communities assessed.

Variables	**No difference**	**Higher in large boats**	**Higher in small boats**
Time trip		X	
Time fishing		X	
Cpue	X		
Crew size		X	
Catch	X		
Cost		X	
Revenue	X		
Ice cost		X	
Food cost			
Fuel cost		X	
Profit	X		
RPUE	X		
PPUE	X		

The cpue was estimated by: catch × (no. of fishers × fishing hours)$^{-1}$. RPUE, revenue per unit of effort; PPUE, profit per unit of effort.

credit, this may also establish a "patronage" partnership. In these cases, one individual or company funds fishers, by paying for their gas, ice, or equipment, and the fishers have to pay back with their own labour and catches, creating an undesirable economic dependence and professional attachment (Lapointe *et al.*, 2006).

Highly vulnerable species suffer the same pressure from both vessel categories. Although there was some difference in relation to the species targeted by smaller and larger boats, both groups targeted an important proportion of high vulnerable species (small boats—50%; large boats—53%). Another relevant point to consider is the fact that if only larger boats are present in a system, fewer economic and social benefits will be generated under the same fishing pressure upon the most threatened species. Consequently, any subsidies allocated to improve the SSF fleet may be fatefully financing overfishing on highly vulnerable species while disregarding the economic and social benefits generated by small size boats practising SSF.

According to recent estimates (Sumaila *et al.*, 2013), USD 35 billion of subsidies was provided by public entities around the world to the fishing sector in 2009. Most of this subsidy went to fishers in developed countries. Also, a hefty 80% of the total is addressed as capacity-enhancing subsidies, with fuel subvention constituting the largest of 13 different types of subsidies (Sumaila *et al.*, 2013). Countries such as Chile and Vietnam direct most of their subsidies towards the purchase and modernization of vessels (Phi Lai *et al.*, 2009; Mondaca-Schachermayer *et al.*, 2011). This happens although the international community clearly recognizes that excess capacity and modernization of the fleet negatively affect conservation efforts and management of fisheries, threatening their sustainability in the long run (FAO, 1995).

Currently, three types of subsidies are available for SSF in Brazil: (i) a fuel subsidy, which can represent from 25 to 80% of a boat's operational cost; (ii) a boat construction, renewal, and modernization subsidy (the so-called Revitaliza Program); and (iii) fishery and aquaculture subsidy, which is directed towards fisheries enterprise development (Plano Safra; MPA, 2015). However, most poor fishers, which are the majority, will not have access to such subsidies. That is because most of these initiatives will require a minimum level of organization through fisher's associations or through a fisher becoming a legal person. In some instances, institutions and non-profits have taken the initiative of helping fishers go through the messy bureaucracy they have to deal with, especially, regarding those related to a possible transition to aquaculture, which is the third kind of subsidy mentioned here. Except for a few cases, such initiatives have collapsed after a certain time, again for the lack of organization or understanding of the cultural background (MPA, 2015). Additionally, when having access to the second type of subsidies, fishers tend to decide for a larger boat and more powerful engine, to expand the number of fishing grounds they have access to and time spent fishing, due to their false expectation (shared with governmental managers) of catching more fish with larger boats. In the social imaginary, subsidies directed to buy gas to reach farther fishing grounds and/or to modernize the fleet are still perceived as positives; therefore, fishers will try different ways to have access to them (Clark *et al.*, 2005; Beddington *et al.*, 2007).

Even without access to most of the available subsidies, small-scale fishing has an important role in maintaining their cultural value (FAO, 2005; Béné *et al.*, 2007) and in generating a social benefit greater than what is generated by the fishing fleet that have access to official subsidies. The higher expenses of these latter vessels decrease the fishers' profits, showing that having a smaller boat can be more advantageous than having a larger one. Hence, choosing to subsidize the growth of SSF can backfire. Environmentally, overfishing is more easily achieved under a bad subsidy policy. Socially and economically, fishers will incur more costs, not always balanced by better profits, besides the fact that wealth distribution tends to become more unfair, with fewer jobs being generated overall and therefore fewer opportunities in the sectors, with the few wealthier fishers benefitting from subsidies. This is not to say subsidies should be disregarded altogether in SSF, but they should be directed to more positive improvements. Specifically, subsidies would be better applied if social or more ecological criteria were taken into account, for example, through financing local fish processing, fisheries management, and fish certification, which can add value to their product and improve wealth distribution without compromising fish stocks even further.

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References

Abdallah, P. R., and Sumaila, U. R. 2007. An historical account of Brazilian public policy on fisheries subsidies. Marine Policy, 31: 444–450.

Abernethy, K. E., Allison, E. H., Cote, I. M., and Molloy, P. P. 2007. Why do fishers fish where they fish? Using the ideal free distribution to understand the behaviour of artisanal reef fishers. Canadian Journal of Fisheries and Aquatic Sciences, 64: 1595.

Banerjee, S., Carlin, B. P., and Gelfand, A. E. 2004. Hierarchical Modeling and Analysis for Spatial Data. Chapman & Hall/CRC, Boca Raton.

Beddington, J. R., Agnew, D. J., and Clark, C. W. 2007. Current problems in the management of marine fisheries. Science, 316: 1713–1716.

Béné, C., Macfadyen, G., and Allison, E. H. 2007. Increasing the Contribution of Small-Scale Fisheries to Poverty Alleviation and Food Security. Food and Agriculture Organization of the United Nations. http://41.89.141.5:80/dspace/handle/0/6146 (last accessed 22 August 2014).

Berkes, F., Mahon, R., McConney, P., Pollnac, R., and Pomeroy, R. 2006. Gestão da pesca de pequena escala: diretrizes e metodos alternativos. Editora Furg, Rio Grande. 359 pp.

Carvalho, N., Edwards-Jones, G., and Isidro, E. 2011. Defining scale in fisheries: Small versus large-scale fishing operations in the Azores. Fisheries Research, 109: 360–369.

Cheung, W. W. L., Pitcher, T. J., and Pauly, D. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biological Conservation, 124: 97–111.

Cisneros-Montemayor, A. M., Sanjurjo, E., Munro, G. R., Hernández-Trejo, V., and Sumaila, U. R. 2015. Strategies and rationale for fishery subsidy reform. Marine Policy, in press.

Clark, C. W., Munro, G. R., and Sumaila, U. R. 2005. Subsidies, buybacks, and sustainable fisheries. Journal of Environmental Economics and Management, 50: 47–58.

Corrêa, M. A. A., Kahn, J. R., and Freitas, C. E. C. 2014. Perverse incentives in fishery management: The case of the defeso in the Brazilian Amazon. Ecological Economics, 106: 186–194.

Damasio, L. M. A., Lopes, P. F. M., Guariento, R. D., and Carvalho, A. R. 2015. Matching fishers' knowledge and landing data to overcome data missing in small-scale fisheries. PLoS ONE, 10.

FAO. 1995. Codigo de conduta para la pesca responsible. FAO, Rome. 41 p.

FAO. 2005. Increasing the Contribution of Small-Scale Fisheries to Poverty Alleviation and Food Security. FAO Technical Guidelines for Responsible Fisheries. 10, Rome.

FAO/World Fisher Center. 2008. Small-Scale Capture Fisheries—A Global Overview with Emphasis on Developing Countries. A Preliminary Report of the Big Numbers Project. FAO, Rome.

Froese, R., and Pauly, D. 2015. FishBase. World Wide Web electronic publication. www.fishbase.org,version (last accessed 2 2015).

Johnson, D. S. 2006. Category, narrative, and value in the governance of small-scale fisheries. Marine Policy, 30: 747–756.

Khan, A., Sumaila, U. R., Watson, R., Munro, G., and Pauly, D. 2006. The nature and magnitude of global non-fuel fisheries subsidies. *In* Catching More Bait: A Bottom-up Re-estimation of Global Fisheries Subsidies, pp. 5–37. Ed. by U.R. Sumaila, and D Pauly. Fisheries Centre, University of British Columbia, Vancouver, Canada.

Lapointe, N. W. R., Corkum, L. D., and Mandrak, N. E. 2006. A comparison of methods for sampling fish diversity in shallow offshore waters of large rivers. North American Journal of Fisheries Management, 26: 503–513.

MMA. 2006. Relatório final do projeto de monitoramento da atividade pesqueira no litoral do Brasil. Projeto ESTATPESCA, Brasilia.

Mondaca-Schachermayer, C. I., Aburto, J., Cundill, G., Lancellotti, D., Tapia, C., and Stotz, W. 2011. An empirical analysis of the social and ecological outcomes of state subsidies for small-scale fisheries: A case study from Chile. Ecology and Society, 16: 17.

MPA. 2015. World Wide Web from Ministério da Pesca e Agricultura. http://www.mpa.gov.br/index.php/infraestrutura-e-fomento (last accessed May 2015).

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'Hara, R. B., Simpson, G. L., *et al.* 2013. vegan: Community Ecology Package. R. http://CRAN.R-project.org/package=vegan (last accessed August 2015).

Phi Lai, T., Tuan, P. N., Dilu They, N. T., Tri, D. L., and Hong Van, P. T. 2009. Fisheries Subsidies, Supply Chain and Certification in Vietnam—Summary Report. WWF, Ha Noi.

R Development Core Team. 2015. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Ruttan, L. M., Gayanilo, F. C., Jr., Sumaila, U. R., and Pauly, D. 2000. Small versus large scale fisheries: A multi-species, multi-fleet model for evaluations and potential benefits. *In* Methods for

Evaluating the Impacts of Fisheries on North Atlantic Ecosystems, pp. 64–75. Ed. by D. Pauly, and T. J. Pitcher. Fisheries Centre Research Reports, University of British Columbia, Canada.

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., and Van Der Linde, A. 2002. Bayesian measures of model complexity and fit. Statistics Society Series B Statistical Methodology, 64: 583–639.

Sumaila, U. R., Khan, A. S., Dyck, A. J., Watson, R., Munro, G., Tydemers, P., and Pauly, D. 2010. A bottom-up re-estimation of global fisheries subsidies. Journal of Bioeconomics, 12: 201–225.

Sumaila, U. R., Lam, V., Le Manach, F., Swartz, W., and Pauly, D. 2013. Global Fisheries Subsidies. European Parliament, European Union. 46 pp.

Sumaila, U. R., Lam, V., Le Manach, F., Swartz, W., and Pauly, D. 2016. Global fisheries subsidies: An updated estimate. Marine Policy, in press.

Sumaila, U. R., Liu, Y., and Tyedmers, P. 2001. Small versus large-scale fishing operations in the North Atlantic. *In* Fisheries Impacts on North Atlantic Ecosystems: Evaluations and Policy Exploration. Ed. by T. J. Pitcher, U. R. Sumaila, and D. Pauly Fisheries Centre Research Reports, University of British Columbia, Canada. 9 pp.

Sumaila, U. R., and Pauly, D. 2006. Catching more bait: A bottom-up re-estimation of global fisheries subsidies. Fisheries Centre Research Reports, UBC Vancouver. 115 pp.

Teh, L. C. L., and Sumaila, U. R. 2013. Contribution of marine fisheries to worldwide employment: Global marine fisheries employment. Fish and Fisheries, 14: 77–88.

Therkildsen, N. O. 2007. Small- versus large-scale fishing operations in New England, USA. Fisheries Research, 83: 285–296.

Thompson, D. 1980. Conflict within the fishing industry. ICLARM Newsletter, 3: 3–4.

Villasante, S., Rodríguez, D., Quaas, M., and Österblom, H. 2012. The Global Seafood Market Performance Index: A theoretical proposal and potential empirical applications. Marine Policy, 36: 142–152.

Vital, H. 2006. Erosão e progradação do litoral brasileiro - capítulo: Rio Grande do Norte. *In* Erosão e progradação do litoral brasileiro, p. 476. Muehe, D. MMA, Brasília.

Ward, J. M., Brainerd, T., Milazzo, M., Thunberg, E., Kitts, A., Walden, J., Travis, M., *et al.* 2001. Identifying harvest capacity and overcapacity in federally managed fisheries: A preliminary and qualitative report. National Marine Fisheries Service. Offices of Science and Technology and Sustainable Fisheries, MD.

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