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SOCIAL SCIENCES

Socio-environmental disasters and their impacts: socioeconomic consequences of the oil spill in the northeast region of Brazil

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Abstract: The 2019 oil spill was the biggest in Brazilian history. Oil was found along more than 3,000 km of the Brazilian coastline, mainly in the Northeast, in more than 1,000 localities. This article analyzes the disaster's damage using a sample of interviewers who were impacted - fishers, tourism and beach hawkers - distributed along 40 of the affected municipalities in the Northeast Region of Brazil. The socio-economic indicators obtained by the research show that the impacts were not homogeneous between the segments and cities researched. Localities specialized in tourism and with a workforce relatively more specialized in fishing were the most affected. Accordingly, the populations of fishers and beach hawkers suffered the most severe impacts in terms of income reduction and the sale of products. These agents report a negative impact of the disaster on their work activities of 73% (fishers) and 65% (beach vendors), while the lodging and food sectors reported losses in about 38% of the cases. The interviewees' health indicators demonstrated that the volunteers at the oil spill clean- up suffered damage due to the exposure experienced, evidencing the public health emergency dimension of the disaster.

Key words: Beach pollution, environment, fisheries, oil spill, petroleum pollution, socio-economic impacts.

INTRODUCTION

In 2019, the Northeast region was struck and washed by crude oil. On August 30 came the first reports of erratic oil slicks hitting the coastline of the state of Paraíba. This event started to call attention as of September 30, until then seen as a possible orphan slick - common ship spill.

The last occurrence of oil, reported on March 19, 2020 (GAA 2020) registered 1,009 places impacted by the oil, between the states of Maranhão and Rio de Janeiro, in 130 cities, reaching more than 3,000 km of coastline. Due to its main environmental qualities, the Northeast region has important Marine Protected Areas, 57 of which were impacted by the oil spill. Fishers and the beach economy (tourism and beach hawkers) are considered the main actors affected. Moreover, the Brazilian coast corresponds to a busy route of ship traffic, which demands constant surveillance for oil spill acidentes (Galieriková & Materna 2020).

Volunteers that cleaned the beaches in emergency time were almost all seafood consumers, who at the end of the fishing value chain will be directly affected by the possibility of seafood contamination. Official figures mention that 5,379.76 tons of waste were removed from these beaches, mainly in the states of Alagoas (2, 564.58 tons) and Pernambuco (1, 676.26 tons)

(GAA 2020), although many believe these are underestimated numbers.

On March 20, 2020, the government ceased its efforts to handle the spill; however, there is still oil on the coastline, which appears especially at high tides, which dig up the product that percolated and settled below the strip of sand and on corals (Lourenço et al. 2020). The tides of June 2020 and July 2021, for example, brought slicks to the beaches between Rio Grande do Norte and Bahia (CNN, 2021; UOL, 2021). The cleaning was done by the Municipal Governments, as the Federal Government stopped the efforts.

The investigation of the cause was carried out by the Navy, whose first theory was a spill from an offshore ship carrying oil and that the leak could have been accidental or deliberate. The leak probably took place at a distance of 700 km from the Brazilian coast. Approximately 2.5 million metric tons of oil with characteristics that resemble those of Venezuelan oil (Fioravanti 2019) were mentioned by Escobar (2019), but the Brazilian Government has not yet confirmed this information. Several oil spill took place around world oceans last decades as the Arabian Gulf Al-Ahmadi oil spill in 1991 (0.5-1.0 million tonnes of oil) (Danish 2010) and the Deepwater Horizon disaster (4.4 million barrels) that hemorrhaged oil into the open ocean at 1500 m depth in the northern Gulf of Mexico (Crone & Tolstoy (2010).

Since the 1950s, Brazilian coastal areas have coexisted with oil impacts, mainly in the states of Rio de Janeiro and Bahia. However, this disaster is considered to be one of the biggest impacts affecting biodiversity (Magris & Giarrizzo 2020), the coastal communities' quality of life (Araújo et al. 2020) and overall economic activities (Soares et al. 2020a, b). Andrews et al (2021) noted that studies carried out in different contexts suggest that coastal communities, when affected by the impacts of oil exploration and trade, suffer locally, with negative effects on their livelihoods. Furthermore, they do not participate in the positive process results, including the access to the jobs generated by the sector, mainly due to the lack of qualification of the local communities.

The oil spill is one more problem that adds to past historical impacts on the national coastal resources: pollution, real estate speculation, monocultures, mass tourism, among others (Quinamo 2017, Pedrosa et al. 2013, Lira et al. 2010). The blue economy intensification affects the marine ecosystem's structure, negatively impacting their functioning and productivity. Also, coastal and ocean territories and resources are shared by different users with distinct interests. Together with the environmental impacts, these actions of some may have adverse effects on the others activities (Arbo & Thuy 2016).

In relation to coastal areas, there is an alert regarding the impacts on health, food and socioeconomic security (Araújo et al. 2020). Considering the resulting environmental and socioeconomic damage, this paper aimed to describe and estimate the oil spill impacts on social, economic and health variables of the main affected populations in the Northeast coast to answer questions like: What are the impacts to the economy and coastal communities? What are the affected actors characteristics? How were they affected? What are their views on the disaster?

MATERIALS AND METHODS

The 2019 oil spill distribution pattern is shown in Figure 1. It is explained by the marine currents dynamics. The oil was probably released in the South Equatorial Current, transported north by the North Brazil Current until Maranhão state, and south by the Brazil Current to the waters of

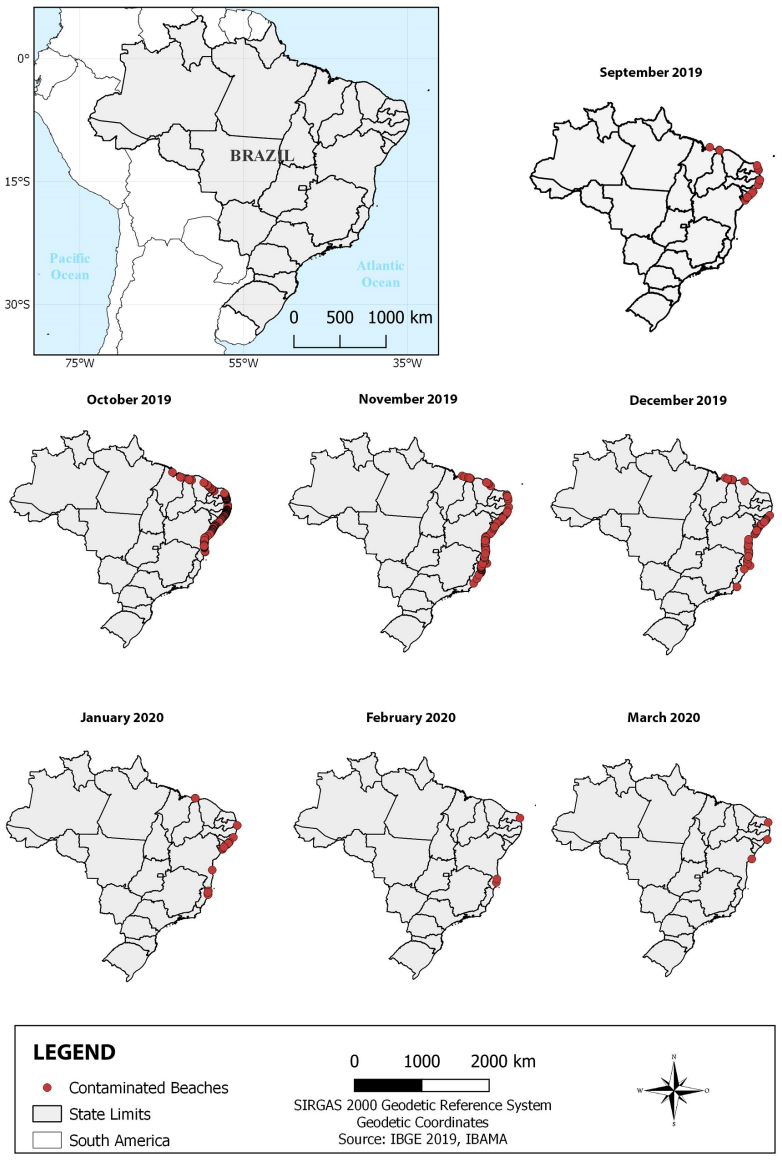

Figure 1. 2019 oil spill distribution pattern.

Rio de Janeiro (Soares et al. 2020a, b), reaching from Maranhão state to Southeastern Brazil.

The field research that originated the database used in this article was carried out between December 2019 and February 2020 and involved the application of structured questionnaires with four different types of agents who are more likely to be directly impacted. They are bars/restaurants; hotels/lodgings; artisanal fishers, and beach vendors. Such surveys have the desired characteristic of randomness. Nevertheless, there are no available or reliable records on these types of economic agents for the large number of affected cities. Additionally, it was necessary to go to the field as quickly as possible in order to obtain the most reliable responses to the impacts felt.

We decided, then, to make a random sample of the cities to be visited based on the Probability Proportional to Size method. The sampling universe was composed of the cities with beaches impacted by the end of October 2019, according to data published in the site of the Brazilian Institute of Environment and

Renewable Natural Resources (IBAMA 2019). The population size, the number of tourism establishments and the number of workers in tourism establishments were tested as criteria for defining the probability of being drawn. The three criteria showed high correlation, which would lead to similar samples. The composition between the number of establishments in tourism and the number of fishermen according to the General Fishing Registry (Ministry of Agriculture) was also tested in a single indicator. We chose this procedure because we considered that it contemplated the two production chains with the major potential for impact from the oil spill, fishing, and tourism (Chang et al. 2014).

Once the cities were selected, quotas of interviews were set for each type of segment per city. This procedure skips the stage of obtaining the registries of facilities, fishers, and beach vendors. The quota of bars/restaurants and hotels/lodgings was calculated from data provided by the Annual Corporate Information Report (RAIS) of the Ministry of Economy. The number of interviewed facilities respected the structure of the number of employees (a proxy for the facility's revenue capacity).

The quota of fishers, on its turn, respected the information of the General Fishing Registry. The total lack of statistics on beach hawkers meant that a fixed number was chosen for each city.

The procedure was that the interviews should start close to the points where the oil was first reported and then move away until the quota was completed. The interviews were conducted electronically, with time records and georeferenced points.

The research was carried out in 40 cities impacted by the oil spill, spatially distributed over nine states of the Northeast Region of Brazil, as seen in Figure 2.

Data were collected through four types of questionnaires, which can be accessed on https://www.fundaj.gov.br/index.php/banco-de-dados. For each type of interview, a specific database was generated, critical treatments were carried out, and the validity of the answers checked. Data without personal and georeferenced information are available to other researchers. Information about the sample by segment is further described in Tables II to V.

Data analysis strategy by localities

The sampling strategy prevents treatments from considering the state level, as stratification criteria were not adopted. At the same time, one can assume that the impacts are not homogeneous between the cities, given the enourmous differences in size and cultural

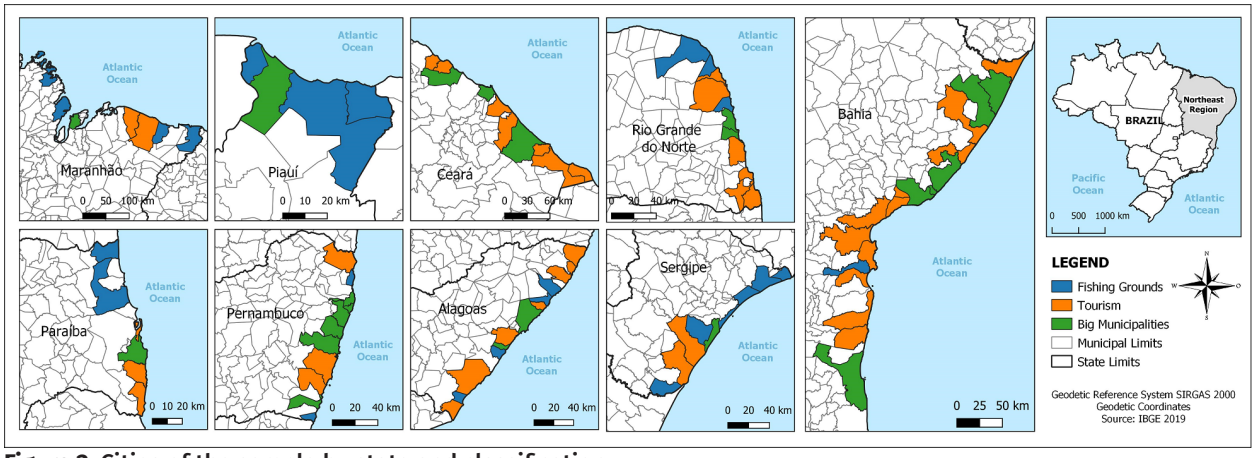

Figure 2. Cities of the sample by state and classification.

and economic characteristics between them. Therefore, we decided to classify these cities in a way in which it would be possible to create a typification that shows common characteristics and makes it possible to check if the impacts were different for each classification.

In order to do this, a multivariate procedure was employed. The variables adopted were: 1) participation of the number of fishers in the city's population; 2) population of the city; 3) participation of formally employed persons in the tourism in the total population; and 4) degree of the cities' risk response capacity, considering the existence of Risk Response Plans, grouping of fire department, civil defense units, etc.

Continuous variables were transformed into discrete after the percentiles were analyzed. Two multiple correspondence analyses were applied. The first for the size of the fishing workforce and the second to summarize the dimensions of population, participation of tourism, and degree of risk response capacity in two dimensions. Based on these three dimensions, we applied a cluster analysis procedure, resulting in three types of cities in the sampling universe.

To better understand how this classification can be useful in the data analysis, an assessment of secondary data from official statistics was performed and descriptive statistics were calculated for each group. The first group of cities shall be called "Fisheries", as those are the ones with the largest share of the fishing workforce in the population (Table I). It is worth mentioning that this denomination does not

Table I. Characterization of the types of cities researched.

Variable	Fisheries	Touristic	Major Centers
Population	19,300	40,056	722,581
Employment participation – Fishing	0.06	0.03	0.02
Employment participation – Tourism	0.04	0.13	0.05
Human Development Index (HDI) – City	0.59	0.61	0.71
HDI – Income	0.57	0.59	0.69
HDI – Longevity	0.75	0.77	0.81
HDI -– Education	0.49	0.51	0.63
Gini Index	0.57	0.59	0.61
Illiteracy - 10 to 17 years of age	7.45	6.29	3.31
Illiteracy – 18 years of age or older	28.06	23.7	11
Percentage of employed persons with Basic Education	38.41	44.47	67.07
Percentage of employed persons with Secondary Education	24.01	28.7	51.05
Percentage of employed persons with Higher Education	4.42	5.48	13.27
Infant Mortality	29.65	24.43	17.2
Dependency Ratio	58.38	54.5	43.16
Hospital Beds	16	38	1,533
Number of primary medical offices	12	22	449

Source: Authors' calculation using secondary data.

imply that the main economic activity in the city is fishing, instead these types of municipalities are the ones whose workforce is relatively more specialized in fishing. The second group shall be called "Touristic", because those are the ones with the highest participation of formal jobs in bars, restaurants, hotels, and lodgings in the city's total formal employment in 2018. The third group, called "Major Centers", got this name due to the huge difference in the average population average of these cities.

Generally, the "Major Centers" are the state capitals and their metropolitan regions. They are, therefore, the richest cities, with less dependence on transfers of funds from the Federal Government, whose population has higher average education, are provided with better health infrastructure, lower infant mortality rates, higher degree of human development, despite having higher income inequality measured by the Gini Index.

Cities considered touristic have an intermediary position in terms of population, dependence on transfers of funds from the Federal Government, and socio-economic infrastructure. The cities classified as fisheries, on their turn, concentrate a smaller portion of the investigated population, have low HDI levels, lower income concentration, higher illiteracy rates, lower schooling of employed people, higher infant mortality rates, higher dependency ratio, and small health infrastructure. These are the cities with higher socio-economic and environmental vulnerability.

RESULTS AND DISCUSSION

This section presents the main results found by the research carried out for this study and organizes the analyses in four main stages. In the first one, a discussion on the characteristics of disaster in the Northeast of Brazil is presented; then, a socio-demographic characterization is made for each of the segments of the research: fishing, food, lodging, and beach hawkers. And, finally, the third and fourth steps consist of an assessment of the impacts caused by the oil spill on economic and health indicators, by type of segment and city.

Characterization of the oil spill in the coastline of the northeast region of Brazil

Since the disaster with the ship Exxon Valdez in 1989, society has experienced a series of tragedies with oil spills causing damage to local socio-environmental systems: the British Petroleum oil spill in the Gulf of Mexico in 2011 (Tenorio 2019), the Prestige oil tankers, in Spain in 2002, and Erika, in France in 1999, among others. Additionally, a number of less harmful spills occur every year, such as the oil spills at the Campos Basin, in Brazil. If its consequences are added, the constant impact becomes huge.

Despite the foreign examples and the fact that this is a high traffic route for oil tankers, the Northeast of Brazil was not prepared for the greatest socio-environmental disaster ever seen on its coast. For example, the Deepwater Horizon disaster in the Gulf of Mexico in 2010 generated a greater amount of waste (Fodrie & Heck 2011, Hale et al. 2016), however, in the Northeast of Brazil the geographic impact was greater, reaching twice the length of the coast.

The oil washed up on the coastline was heavy and highly weathered, and its main properties were: high viscosity, high density, and low concentrations of volatile compounds (aromatic hydrocarbons) (IBAMA 2019). These characteristics caused the slicks to move below the surface, appearing on the beaches with decreasing depth. Moreover, when in contact with the low salinity of the estuaries, the substance would sink further, which meant that the slicks were not affected by containment

structures initially used at the mouths of the rivers.

Four characteristics indicated that this was a single disaster: 1) the characteristics of the spill; 2) the tropical aspects of the affected region; 3) the number of impacted protected areas; and 4) the lack of action of the federal government (Soares et al. 2020b). Add this to the vulnerability of the northeastern coastal populations who live from artisanal fishing and the high regional economic dependence on tourism activities. A poor health network should be taken into account as well, given the high incidence of volunteers that were exposed to the oil.

The event resulting from the massive quantity of crude oil washed up on the coastline of the Northeast Region, characterized an environmental and public health emergency (IAM/FIOCRUZ 2019). In addition to the danger of contamination of the entire ecosystem, this situation also posed a risk to the health of fishers, beach workers, tourists, bathers, and, in general, the entire coastal population. The results of this study, specifically regarding the health of the interviewees that were exposed to oil, showed that there was participation in the clean-up and found reports of exogenous intoxication. In the literature, the impact of the offshore oil spill is widely recognized and poses risks to the society, economy, and environment of the polluted regions (D'Andrea & Reddy 2014, Kapsalis et al. 2021).

The uncertainty about the source of the spill, the lack of a coordinated action and adequate guidelines by the Federal Government, resulted in an extremely slow response, which possibly intensified the environmental and socio-economic impacts (Soares et al. 2020a, Brum et al. 2020). In cases of offshore oil spill, coordinating the fight and the mitigation is the responsibility of the federal government. The National Contingency Plan for oil pollution incidents in waters under national jurisdiction is the risk management tool for oil pollution in waters under federal jurisdiction, which is provided for in Decree 8,127/2013. It establishes the duties of public and private entities for spill to deal with the problem. The Plan should be implemented by a council, which was extinguished by decree 9,759/2019. Thus, it was not triggered for the event by the above mentioned council. The delay to trigger this plan by the federal government may have been the main factor in the difficulty to respond for containing the oil.

This Plan was only implemented on October 11, 2019, under the coordination of the Navy. Another aggravating circumstance was that this implementation did not follow the protocol, as it should have been led by the Ministry of the Environment. The Contingency Plan created was discontinued in March 2020, after the federal government deemed the activities adequate.

Characterization of the segments researched

Artisanal fishing sector

The sample of the artisanal fishing sector was composed of 1,999 fishermen and fisherwomen. The latest statistics in Brazil estimate the number of fishers close to one million, and 62% of them are in the Northeast region (MPA 2012a). The interviewees of this study were predominantly men (82%), with an average age of 47 years, self-declared Afro-Brazilians and brown colored (87,2%), with brown skin majority (67%), and an average of 27 years of working in fishing (Table II).

Bearing an RGP made by the Ministry of Agriculture, which is required for the activity and used to have access to public policies, was reported by 51% of the interviewees. In this case, the RGP, although outdated since 2015, proved its

Table II. Descriptive statistics of fishermen's characteristics.

Variable	Statistics
Gender (dummy 1= female)	0.18 (0.38)
Race (dummy 1= brown skin)	0.67 (0.47)
Age	47 (13)
Education[1]	3.67 (1.95)
Proportion of illiterate persons	0.09 (0.29)
Time working as a fisherman	27 (15)
Registered with the General Fishing Registry	0.51 (0.50)
Activity is the family's main source of income	0.88 (0.33)
Develops any other paid activity	0.23 (0.42)
Monthly household income (BRL)	1,200 (971)
People per household	3.6 (1.9)
Coastal areas (estuaries and inland sea) are the main fishing grounds	0.66 (0.48)
Uses a boat to fish	0.81 (0.39)
Fish both for their own consumption and for sale	0.84 (0.37)
(i) Direct sale to consumer	0.56 (0.50)
(ii) Middlemen	0.26 (0.44)
Had access to a financing for the activity	0.11 (0.31)
Says that fishing activity has been decreasing over the last ten years	0.82 (0.38)
Learned about the oil spill	0.97 (0.16)
Interviewed No. 1,999	

Notes: [1] Education range 3 corresponds to the first cycle of complete elementary and middle school (or 5th year of elementary and middle school) and range 4 corresponds to the second cycle of incomplete elementary and middle school. In parentheses, the standard deviation.

importance for the distribution of the emergency aid. In a late action, the Federal Government (Provisional Measure No. 908, published on November 29, 2019) granted an allowance of a minimum wage for two months to 60 thousand registered fishers. One problem, however, was the fact that it covered only cities considered affected by the oil. However, areas considered clean by the environmental authority were also economically affected by the reduced fishing activity and its marketing, as a result of the lack of security for consumption (Araújo et al. 2020).

The formal educational profile of fishers in the area affected by the oil is below the average for the country and the Northeast region. Among the segments analyzed, this is the group with lowest education, equivalent to incomplete elementary and middle school, and the highest illiteracy rate (9%) (Table II). This suggests that the fishing segment is more vulnerable to face adverse events, such as the oil spill, including considering the importance of education in the search for other work alternatives.

Fishing is intrinsically dependent on environmental conditions and is also a family activity, developed at the community level, which cannot be assessed by sector (FAO 2020). For example, in this research, the interviewees showed low mobility (76% have been living the community for more than 30 years), long time of labor in the activity (average of 27 years), and that the activity is developed in the family (71% learned to fish with family members), variables that indicate that the activity is developed traditionally. In this regard, Diegues (2000) highlights that one of the characteristics of traditional populations is the housing and occupation of the territory for several generations, even if certain individual members may have moved to the urban centers and returned to the land of their ancestors.

The fishermen and fisherwomen interviewed do not develop another paid activity (77%) and fishing is their main source of income (88%) (Table II). As fishing is a family activity, income was questioned in an integrated manner. On average, each family interviewed is composed of 3.6 persons and lives with BRL1,200.00/month. The largest proportion of interviewees works with estuarine fishing and in the area inside coral reefs (inland sea) (66%). Most of them use vessels (81%). A percentage of 11% had access to credit despite the activity requiring fishing materials, boats, cold equipment, and others.

The interviewees consume their products and also sell them (84%), citing that this sale is made to the end consumer (56%), to middlemen (26%), and other strategies at a lower proportion. When questioned whether inventories and fishery decreased or increased in the last 10 years, most of them (82%) agreed that it decreased. This direct marketing strategy (in addition to consumption) shows the vulnerability of the activity to impacts on the coastal region such as the one analyzed herein. Only 3% did not know about the oil disaster on the coast.

Food sector

The sample food sector consisted of 869 bars and restaurants. According to Table III, 45% of the interviewees are women, 57% are self-declared brown skin color with an average age of 45 years and average education equivalent to incomplete high school. On average, the facilities are 13 years old, are small-sized, and have about five permanent employees and two temporary. In terms of revenue, the interviewees report a wide variation between the high and low seasons. In the high season, the average weekly revenue is around BRL8,558, falling by half in the low season months (BRL 4,258).

Table III. Descriptive statistics of the characteristics of interviewees in the food segment.

Variable	Statistics
Gender (dummy 1= female)	0.45 (0.50)
Race (dummy 1= brown skin)	0.57 (0.50)
Age	45 (13)
Education[1]	5.79 (1.84)
Lifetime of the establishment	13 (13)
No. of permanent employees	5 (8)
No. of temporary employees	2 (3)
Weekly revenue in high season (BRL)	8,558 (14,879)
Weekly revenue in low season (BRL)	4,258 (7,558)
% of revenue attributed to tourism	0.32 (0.30)
% of seafood from local fishermen	0.20 (0.40)
Perception of the oil spill as a crime	0.54 (0.50)
Interviewed No.: 869	

Notes: [1]The educational level 5 corresponds to complete elementary school and 6 to incomplete high school. The standard deviation is in parentheses.

Tourism is responsible for about 1/3 of the revenue of the researched facilities. Local fishers provide approximately 20% of the seafood of the bars and restaurants that work with this type of food. These data reveal that these touristic facilities have an important dependence on the local supply of seafood, which already gives evidence of how the oil spill had a negative impact on this economic sector. More than half of the interviewees (54%) see the oil spill as an environmental crime.

Accommodation sector

The sample of the accommodation sector was composed of 134 hotels and lodgings. According to data on table IV, a percentage of 51% of interviewees are women, 56% declare themselves to have brown skin color, have an average age of 44 years old, and average education equivalent to complete high school. On average, the facilities are 12 and a half years old, small, have about 8 permanent employees and 3 temporary employees.

Table IV. Descriptive statistics of the characteristics of interviewees in the lodging segment.

Variable	Statistics
Gender (dummy 1= female)	0.51 (0.50)
Race (dummy 1= brown skin)	0.56 (0.50)
Age	44 (13)
Education[1]	7.43 (1.72)
Lifetime of the establishment	12.50 (10.35)
No. of permanent employees	8 (15)
No. of temporary employees	3 (5)
Weekly revenue in high season (BRL)	10,056 (14,555)
Weekly revenue in low season (BRL)	4,107 (5,375)
% of establishments that sell reservations online	0.71 (0.46)
% of establishments that sell packages to major operators	0.22 (0.42)
Perception of the oil spill as a crime	0.46 (0.50)
Interviewed No.: 134	

Notes: [1]The educational level 7 corresponds to complete high school and 8 to incomplete secondary education. The standard deviation is in parentheses.

In terms of revenue, the interviewees report a wide variation between the high and low seasons. In the high season, the average weekly revenue is around BRL10,000, falling by more than half of the amount in the low season months (BRL4,107). Most reservations for the surveyed hotels and lodgings come from Internet websites and a smaller portion of approximately 20% goes to packages sold to major tour operators. Compared to the food sector, a smaller (although expressive) percentage of interviewees (46%) perceived the oil spill as an environmental crime.

Câmara et al. (2021) found more than 50,000 establishments that may have been affected and that the economic sectors related to food (35.3%), accommodation (17.4%) and tourism/leisure (3.8%) were probably the most affected. As a result of a socioeconomic vulnerability analysis, the five most impacted states were identified: Bahia, Pernambuco, Ceará, Rio Grande do Norte and Paraíba. Ribeiro et al (2020) also analyzed local sectors such as restaurants, accommodation, and fishing and estimated a loss of 1.3% in the gross regional product.

Beach hawkers

The category of "beach hawkers" interviewees is, of all those addressed in the research, the most heterogeneous and the one with the least systematized information about them. Within this category are those people who walk the beach offering products and/or services in the most varied ways. Most of them offer food products (including local seafood), perhaps the most visible ones. Another part comprises different types of services, such as temporary tattoos, hair styling, kayak rentals, swimming pools, toys. Some of them offer handmade products made by themselves or their relatives, others offer manufactured products purchased from middlemen or even nearby markets.

This diversity of activities implies that there are different economic logics making the analysis more complex. The strategy adopted in this research was to gather information that could generate a first approach to the study of professionals who live partially or totally dependent on the number of people on the beach. The proportion of interviewees who declared to be registered at the city hall is small, confirming the informality already expected. Being informal at times like this when an external action prevents them from exercising their economic activity or directly affects the size of their market implies that they are unlikely to be assisted by compensatory public policies.

The sample of street salesmen was composed of 325 individuals. According to data on Table V, most interviewees are male (74%), 65% stated they were brown colored, and they are 39 years old on average. It is a group with low education: 4% of the interviewees are illiterate and, on average, have not completed elementary school.

On average, the interviewed beach vendors have been working in this segment for 10 years and most of them (81%) have this activity as the main source of income for the family, which has an average of 3.6 people. Most beach hawkers are informal workers, only 1 in 4 interviewees are registered with the city hall. In high season, the average weekly income is BRL685 and drops to less than half in the low season, around BRL269. As for the perception that the oil spill is an environmental crime, this is the group of interviewees with the lowest percentage of perception, approximately 43% of beach vendors see the event as a crime.

Assessment of the impacts of the disaster on economic indicators

This section presents an assessment of the economic impacts that could be assessed from

Table V. Descriptive statistics of beach hawker's characteristics.

Variable	Statistics
Gender (dummy 1= female)	0.26 (0.44)
Race (dummy 1= brown skin)	0.65 (0.48)
Age	39 (13)
Education[1]	4.53 (2.05)
Percentage of illiterate persons	0.04 (0.20)
Activity is the family's main source of income	0.81 (0.39)
Time as a beach hawker	10 (10)
Registration at the City Hall	0.25 (0.44)
Weekly income in low season (BRL)	269 (218)
Weekly income in high season (BRL)	685 (709)
Perception of the oil spill as a crime	0.43 (0.50)
Interviewed No..: 325	

Notes: [1]The educational level 4 corresponds to incomplete elementary school and 5 to complete elementary school. The standard deviation is in parentheses.

the field research conducted for this study. Based on the interviews with the four investigated segments - fishing, food, accommodation, and beach vendors - a series of indicators was constructed in order to measure, in quantitative terms, the magnitude of the damage that these agents suffered as a result of the oil spill. The analyses were conducted in two main sections: the effects on each of the investigated segments and by type of city according to the classification adopted in this work (Fisheries, Touristic, and Major Centers).

Figure 3 reports the agents' perception of the effect of the oil spill on their work activities. The interviewees answered "yes" or "no" when asked if the oil spill had harmed their main activity in any way. On the part of the fishers, this perception was evaluated from the following question "Has this spill harmed or is it harming your fishing activity?"; for the owners or managers of bars and restaurants, it was asked "Has your business been affected by the oil?"; the owners or managers of accommodation facilities answered to the question "Were there any cancellations of daily rates or packages with major operators as a result of the oil spill?"; and the beach hawkers answered to "Did you notice a difference in the weekly income after the oil?"

Data on Figure 3 reveal that the perception of the impact is not uniform according to the surveyed segments; the populations of fishers and beach hawkers report greater damage to their main activity (73% and 65%, respectively), while the segments of food and accommodation facilities perceive themselves as relatively less affected (37% and 38%, respectively).

In order to assess whether the chances of reporting damages on the main activity vary between the interviewed segments, logistic probabilistic models were estimated and the results are shown in Figure 4a. Estimates reveal that the fishing population was substantially more affected than the others surveyed. In this group, the chances of reporting negative impacts are 300% higher than the others investigated. In comparison, the segments of accommodation, bars, and restaurants have relatively less chance of reporting negative impacts, around 67% to 77%. For the interviewed beach hawkers, there was no statistically significant difference with respect to the relative chances of perceiving damage suffered.

When the impact assessment is carried out according to the type of city (Figure 4b), what is perceived is that the locations classified as Fisheries and Touristic have a higher relative

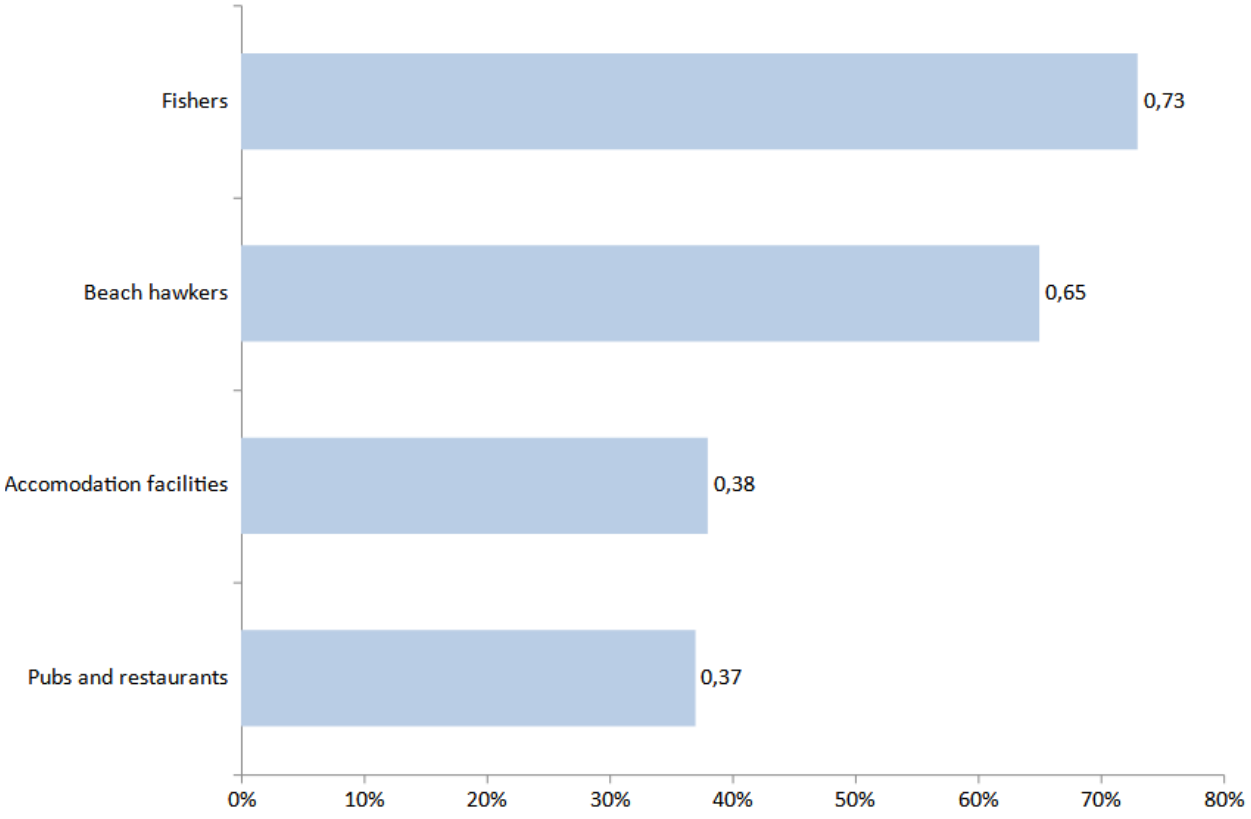

Figure 3. Relative chances of being impacted by oil on activity developed according to interviewed agents and type of city.

chance of reporting the impact suffered by the oil spill, around 94% and 65%, respectively. Major Centers, where capitals and metropolitan regions are concentrated, have relatively less chance of being negatively impacted and their agents are 50% less likely to report losses.

In addition to the individual perception of each agent interviewed about the impact suffered by the disaster, the discussion that follows includes indicators quantifying the magnitude of the shock in terms of percentage reductions in production, sales, income, revenue, and dismissals. When the analysis is made by type of city, hypothesis tests are applied in order to verify whether there is a statistically significant difference in the indicators between the types of cities surveyed.

Artisanal fishing sector

Starting with the fishing segment, the first indicator shows the effects of the disaster on the fish supply: on average 35% of the interviewed fishers stated that the oil spill reduced their fish production (Table VI). It is also noted that the shock is relatively more adverse in Touristic cities compared to Fisheries and Major Centers. With respect to production, in the latest statistics, Brazil was the 18th largest producer of fish in the world, with around 65% of production from marine fishing, with more than 60% of the total estimated amount from small-scale fishing (MPA 2012b). Since this last survey, there have been no fishing statistics for the entire country (FAO 2020), which is indispensable for the good planning of the sector.

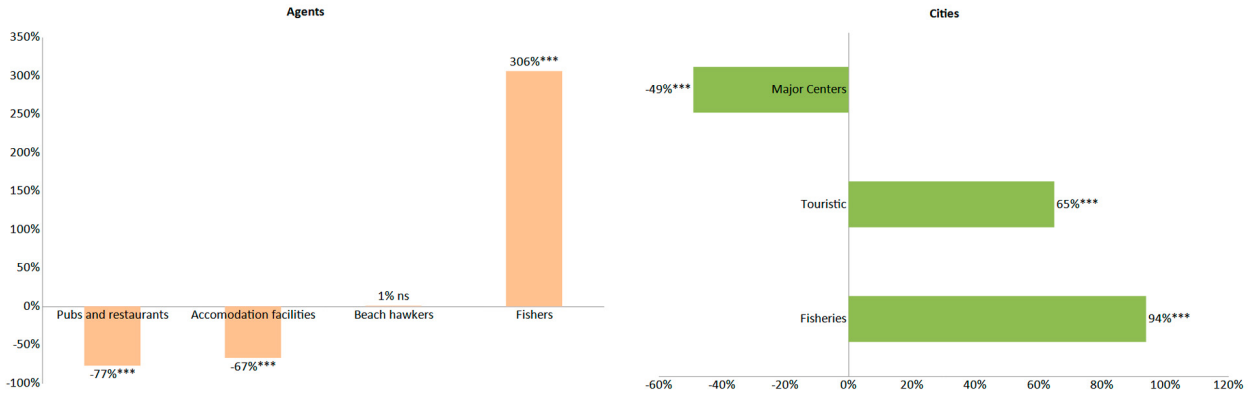

Figure 4. Relative chances of being impacted by oil on activity developed according to interviewed agents and type of city.

The impact on demand was assessed based on the decrease in the sales of fish as almost 70% of interviewees reported a drop in sales of their production, this impact being relatively bigger in Fisheries and Touristic cities than in Major Centers. Losses in marketing were also reported by Araújo et al. (2020) and Estevo et al. (2021). Regarding household income, fishers report a 38% drop in monthly income and there were no statistically significant differences in this reduction between those living in different types of cities (Table VI).

The impact of the market, unlike the local impact of temporary fishing restriction due to contamination, affected the entire Northeast coastal region, most strongly in the most impacted regions. Inadequate communication has raised doubts about the health of products and has created uncertainty, further increasing the fall in demand. The fish analysis (hydrocarbons and metals) was carried out in an uncoordinated way by the government. For artisanal fishing, the result was even worse, given that the Ministry of Agriculture carried out tests on products from the fishing industries and disclosed as being free of contaminants, supporting the consumption of industrialized fish. At the same time, artisanal fishing products were submitted to health tests carried out late by local governments, which did not guarantee the society's trust.

Food sector

The impact for the food sector, which includes bar and restaurant facilities, in fact seems to have been lower, according to the interviewees' perception discussed above. On average, managers or owners interviewed claim that there was a 15% drop in turnover due to the reduced number of clients as a result of the oil disaster (Table VII). The drop in revenue was especially felt in Touristic and Fisheries cities: the interviewees from these locations report a drop of 25% and 23%, respectively, a statistic well above the average of Major Centers (14%). This dynamic is probably related to economic diversity and market size. In large cities, the number of clients in bars and restaurants is not so dependent on tourism and/or the facilities are not so specialized in local fish. The calculation of the elasticity of the restaurant's dependence on the tourist flow reveals that, for every 1% more importance of tourism in the restaurant's revenue, the chance of the restaurant having been affected by the oil spill increases by 1%.

Furthermore, when looking at the type of establishment, it was shown that bars and restaurants specialized in seafood reported an average loss in revenue of 30%, as opposed to

Table VI. Descriptive statistics of economic indicators for the artisanal fishing sector by type of city.

Fishers	Fisheries	Touristic	Major Centers	All[1]
Did this spill decrease fish production?	0.37 (0.03) N=307	0.41*** (0.02) N=528	0.32*** (0.01) N=1164	0.35 (0.48) N=1999
Did this spill decrease the sale of fish?	0.76*** (0.02) N=307	0.72** (0.02) N=528	0.64*** (0.01) N=1164	0.68 (0.47) N=1999
Percentage of reported income reduction	0.39 (0.03) N=198	0.41 (0.03) N=341	0.38 (0.02) N=693	0.38 (0.27) N=1232

Notes: The standard errors of hypothesis testing are reported in parentheses. [1]: Standard deviation of the entire sample. *** p<0.01, ** p<0.05, p<0.1.

11% for restaurants without this specialization. In a logistic regression model, it was found that restaurants specializing in seafood were 284% more likely to have responded that they suffered negative impacts on the turnover. On average, 21% of bars and restaurants indicated that there was a change in the type of dish requested: in units located in touristic cities, the change in dish requested was 24% and, in Fisheries cities, 17%. This indicator shows that establishments in fisheries cities probably have less capacity to adapt the menu.

Establishments in Fisheries cities are actually heavily dependent on fish from local fishers (67%). In Touristic cities, this indicator drops to 38% and 19% for Major Centers. This difference in the supply profile reveals not only the difference in the economic dynamics of the cities, but also that the impacts suffered by fishers as a result of the loss of revenue from bars and restaurants is more direct in the Fisheries cities than in the Touristic and Major Centers.

Among those who report that the turnover of bars or restaurants was affected by oil, 75% say that the turnover has not yet returned to normal at the time of the survey (Table VII). Once again, the impact on the turnover of bars and restaurants was detected mainly in touristic cities, with percentages well above the average for the entire sample.

As a result of reduced client base and revenue, these establishments had to lay off employees, although on a small scale, since dismissal costs can often outweigh revenue losses. In every sample, 6% of bars and restaurants laid off employees from their establishments; this percentage reaches 11% for units in touristic cities. Only six bars and restaurants were surveyed in Fisheries cities, which is why the reported proportions are not statistically significant when compared to those of other types of cities.

Accommodation sector

For the accommodation sector, the impact assessments evidence that the oil spill caused cancellations in the reservations and, consequently, layoffs. For the entire segment, the average booking cancellation rate reached 29%, being significantly higher in touristic cities, which had almost 34% of their reservations cancelled (Table VIII).

When the statistics on the cancellation of reservations and packages are analyzed in a disaggregated manner, the impacts between

Table VII. Descriptive statistics of economic indicators for the food sector by type of city.

Bars and restaurants	Fisheries	Touristic	Major Centers	All
What is the percentage of reduction in typical weekly revenue?	0.23 (0.17) N=6	0.25** (0.05) N=62	0.14** (0.01) N=737	0.15 (0.25) N=805
Percentage that considers that the turnover has not yet returned to normal	1 (0) N=3	0.91** (0.05) N=32	0.74** (0.03) N=285	0.75 (0.43) N=320
Percentage of employees dismissed	0.07 (0.10) N=6	0.11* (0.04) N=64	0.05* (0.01) N=745	0.06 (0.18) N=815

Notes: The standard errors of hypothesis testing are reported in parentheses. Standard deviation of the entire sample. p<0.01, ** p<0.05, * p<0.1.

types of cities are quite different. The cancellation of daily bookings reached 49% of hotels and lodgings in touristic cities, against 25% in Fisheries cities and 30% in Major Centers. The cancellation of packages from major operators showed a much lower rate, with about 10% of establishments reporting this type of occurrence. Once again, the percentage among those located in touristic cities is higher. This behavior is possibly due to the type of contract that exists in the sale of packages. Another possible factor is the conditions of establishments that sell packages with major operators. Medium and large hotels with complete leisure infrastructure may have attractions that reduce the chance of canceling trips.

Among the interviewees who reported that the turnover of the establishment was affected by oil, 78% said that the turnover had not yet returned to normal at the time of the interview. There were no statistically significant differences in these percentages between types of cities (Table VIII).

In the survey, there was a question about the marketing actions taken by hotels and lodgings in response to the oil spill. In 22% of the interviewees, there was some marketing action. The reported actions were: "discounts and special promotions"; "investment in advertising", and "actions in social media". These actions were taken by establishments with a higher number of employees than the sample average.

The accommodation facilities of Touristic cities were relatively more proactive than those of Major Centers. On its turn, the accommodation facilities of Fisheries cities did not take marketing actions. A rate of 30% of the accommodation facilities reported having taken some action to advise guests. The most mentioned actions were "personal conversation with guests on the topic", "indicative of the best beaches for swimming", and "information at the reception about care to be taken".

The impact on the workforce in this segment was relatively lower when compared to the food sector, as only 2% of the accommodation facilities had to lay off their employees. This sector possibly has a higher degree of formalization of its workforce and, therefore, the dismissal costs are comparatively higher.

Beach hawkers

Finally, there is the group of beach hawkers (Table IX). The assessment of the impact of the disaster in economic terms was carried out based on indicators showing drops on the

Table VIII. Descriptive statistics of economic indicators for the accommodation sector by type of city.

Accommodation facilities	Fisheries	Touristic	Major Centers	All
Cancellation fee for reservations or packages	0.06 (0.12) N=4	0.34 (0.07) N=51	0.27* (0.05) N=79	0.29 (0.49) N=134
Percentage that considers that the turnover has not yet returned to normal	1 (0) N=4	0.78 (0.06) N=51	0.76 (0.05) N=79	0.78 (0.42) N=134
Percentage of employees dismissed	0.00 (0.00) N=3	0.02 (0.02) N=45	0.01 (0.01) N=61	0.02 (0.10) N=109

Notes: The standard errors of hypothesis testing are reported in parentheses. Standard deviation of the entire sample. p<0.01 p<0.05, * p<0.1.

weekly sales revenue and the percentage, which considers that the shock still lingers at the time of the survey. On average, the drop in the weekly income of this population was 16%, and the average value of the reported fall was BRL277.00 per week (SD=260.64; n=268). A total of 76% of the interviewees acknowledged that the turnover has not yet returned to normal. In general, there are no statistically significant differences in these two indicators between the types of cities, except for interviewees from Major Centers who have a relatively lower percentage of perceived duration of the shock.

Nonetheless, the research registered differences in the weekly sales revenue per type of city. In high season periods, the average of this segment is around BRL685.00 a week (SD=708.65; n=285); in low seasons, it falls to BRL271.47 a week (SD=217.78; n=268). In high season, the Major Centers and Touristic cities allow an increase of up to 22% higher than that indicated in Fisheries cities. It was noted that the activity is marked by a double seasonality. One weekly and one involving the vacation period. In low season, most interviewees reported working 2 and 3 times a week on the beach, which implies that the turnover is concentrated on weekends. In high season, the vast majority works seven days a week. This difference in days worked translates into a result 150% higher in high season.

In general, in the analysis by type of city, the results revealed that, among beach vendors in Touristic and Major Centers, there is no great difference. The vendors of Fisheries cities, on the other hand, showed some distinction. One that stands out is education. In Fisheries cities, it is observed that 25% of the interviewees were illiterate or with incomplete primary education. As for Touristic and Major Centers, 65% and 60%, respectively, of beach hawkers had completed elementary school. The difference in education is probably due to differences in the profiles of public service provision and household income.

Assessment of the impacts of the disaster on health indicators

Table X shows the impacts of the oil spill on indicators related to the health of the surveyed segments that volunteered to remove the oil that hit the beaches and mangroves. According to Brum et al. (2020), it is estimated that the action of the volunteers removed more than 5,000 tons of the polluting material from the beaches and mangroves, while Zacharias (2021) estimated the loss of volume at 5,000 to 12,500 m.

Table IX. Descriptive statistics of economic indicators for the beach hawkers by type of city.

Beach hawkers	Fisheries	Touristic	Major Centers	All
Percentage of drop in the weekly sales revenue	0.17 (0.09) N=17	0.15 (0.05) N=47	0.18 (0.05) N=65	0.16 (0.33) 129
Percentage that considers that the turnover has not yet returned to normal	0.88 (0.06) N=26	0.81 (0.04) N=85	0.69** (0.05) N=97	0.76 (0.43) N=208

Notes: The standard errors of hypothesis testing are reported in parentheses. Standard deviation of the entire sample. p<0.01, ** p<0.05, p<0.1.

This action was carried out without adequate guidance, coordination, and/or personal protective equipment and often manually, exposing people to pollutants and possible damage to health (Pena et al. 2020, Araújo et al. 2020). A review study on the effects of exposure to oil spills on human health, especially those involved in cleaning activities, highlights the need to biomonitor the immediate consequences, but also the long-term effects (Aguilera et al. 2010).

In the state of Pernambuco, between October 18, 2019 and February 19, 2020, 353 cases of exogenous oil-related poisoning were reported, mainly through skin and respiratory exposure (Pernambuco 2020). The main health consequences include problems in the hematological system, and liver, respiratory, renal, and neurological functions (ATSDR 1999, Levy & Nassetta 2011, Laffon et al. 2016). In addition to physical symptoms, exposure to petroleum chemicals can also cause psychological effects, such as: depression, anxiety, and post-traumatic stress (Laffon et al. 2016).

The results of this study reveal that, of the total of 1,989 fishers, 22% answered that they participated in the voluntary action of oil removal on the beaches (Table X). Most of these fishers (27%) lived in cities classified as Touristic. Of the voluntary fishers, about 2% showed some suspicious sign/symptom of oil poisoning. This proportion was quite similar among the cluster of cities. When asked if relatives had symptoms of suspected oil poisoning, approximately 1% said they did. Only in the group of Touristic cities this proportion was 2%.

With respect to the bar and restaurant segment, 10% of the 896 interviewees revealed that they had participated as a volunteer in the oil removal on the beaches. In the cities categorized as Touristic, this proportion was 25%, with a statistically significant difference (p<0.01). There were no reports of symptomatic intoxication among those who participated in oil removal. When asked to managers and owners of bar and restaurant establishments if any employee showed symptoms of oil poisoning after voluntarily participating in oil removal, there was a 2% report in the Touristic cities (Table X).

As for the segment of beach hawkers, 22% of the interviewees of the total of 324 said they had participated in the voluntary action that removed oil from the beaches. Of these, 3% had symptoms of oil poisoning, with the largest portion (5%) located in Touristic cities. It was asked if a relative had symptoms of intoxication and, on average, 1% described it. In Touristic cities, this proportion was 2% (Table X).

Table X. Descriptive statistics of health indicators by agents and type of city.

Fishers	Fisheries	Touristic	Major Centers	All[1]
Was a volunteer in the oil removal?	0.23 (0.02) N=307	0.27*** (0.02) N=528	0.19*** (0.19) N=1154	0.22 (0.41) N=1989
Did the person have any side effects on health?	0.03 (0.01) N=307	0.03 (0.01) N=528	0.02 (0.12) 1154	0.02 (0.15) N=1989
Did any of the person's relative have any side effects on health?	0.01 (0.00) 305	0.02** (0.01) N=526	0.01 (0.00) N=1128	0.01 (0.11) N=1959
Bars and restaurants	Fisheries	Touristic	Major Centers	All
Was a volunteer in the oil removal?	0.00 (0.00) N=6	0.25*** (0.05) N=67	0.09*** (0.01) N=796	0.10 (0.30) N=869
If volunteer, did the person have any side effects on health?	0.00 (0.00) N=6	0.00 (0.00) N=67	0.00 (0.06) N=796	0.00 (0.06) N=869
If so, did any employee have any side effects on health?	0.00 (0.00) N=6	0.02 (0.02) N=54	0.00 (0.00) N=732	0.00 (0.07) N=792
Accommodation facilities	Fisheries	Touristic	Major Centers	All
Was a volunteer in the oil removal?	0.00 (0.00) N=4	0.22*** (0.06) N=51	0.05*** (0.02) N=79	0.11 (0.32) N=134
Did the person have any side effects on health?	0.00 (0.00) N=4	0.04* (0.03) N=51	0.00* (0.00) N=79	0.01 (0.12) N=134
Did any employee have any side effects on health?	0.00 (0.00) N=3	0.05* (0.03) N=43	0.00* (0.00) N=75	0.02 (0.13) N=121
Beach hawkers	Fisheries	Touristic	Major Centers	All
Was a volunteer in the oil removal?	0.13 (0.05) N=40	0.26 (0.04) N=128	0.22 (0.03) N=156	0.22 (0.42) N=324
Did the person have any side effects on health?	0.00 (0.00) N=40	0.05** (0.02) N=128	0.02 (0.01) N=156	0.03 (0.17) N=324
Did any of the person's relative have any side effects on health?	0.00 (0.00) 40	0.02 (0.01) N=128	0.01 (0.01) N=156	0.01 (0.12) N=324

Notes: The standard errors of hypothesis testing are reported in parentheses. [1]: Standard deviation of the entire sample. *** p<0.01, ** p<0.05, * p<0.1.

CONCLUSION

This study analyzed the social and economic impacts of the oil spill according to the segments of bar/restaurant; hotels/lodgings; artisanal fishers, and beach hawkers on the beaches. The results showed a reduction in revenue and income for all segments surveyed, with a more striking impact on artisanal fishing and beach vendors, who are known to be more socially vulnerable.

The oil spill on the Northeast coast of Brazil is a problem that requires an interdisciplinary approach. Ecological, social, economic, and public health aspects, among others, are necessary to properly analyze the effects. Based on the results of this study, there was a significant contact of the interviewees with the polluting oil and this strengthens the urgency of surveillance and monitoring, for a sufficiently long period of time, in order to enable the early detection of adverse health effects of those who participated in oil cleaning activities in the coast of Northeast Brazil.

This event highlighted the importance of data as a subsidy for public policies and research. Official statistics such as fishery production (interrupted for more than 10 years), as well as an official register of fishers, are important so that, in future events of this nature, there is information that supports a fair compensation. For beach hawkers there is also no type of registration. Coastal management and policies should incorporate this activity and coordinate efforts to gather information.

The Northeast coastal municipalities, especially the smaller ones, will not cope alone with the challenge of managing the increasingly impacted coastal region. Inter-municipal consortia are a current option already used for the solid waste and additional environmental agenda, and they can encompass risk and disaster management, too.

It should be noted that this study sought to contribute with more information to the necessary debate on the socioeconomic effects on communities affected by the oil spill. It is important not only to understand what happened, but also to prepare for the possibility of similar future events. What is needed, above all, is action coordination by the responsible bodies, participation of civil society and integration of surveys that could answer important questions. Research needs to be consonant and committed to society and public policies so that they respond to the entire problem.

Several questions have remained unanswered so far. Where did this material come from and who caused the damage? What trade-offs should be made for the affected socio-ecological systems? What are the lessons learned by society? What changes are needed to prevent further tragedies like this one?

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