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Scientific collaboration networks in research on human threats to cetaceans in Brazil

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ABSTRACT

To better understand the threats posed by human activities on cetaceans, we compiled published studies and determined where, how, and by whom the research on this subject has been conducted in Brazil. We also determined which cetacean species were mostly investigated in these studies. We gathered the available scientific literature published from 1986 to 2016 that contained search terms in English that depicted major cetacean threats. Then, we developed a collaboration network among the authors' institutions and generated a distribution map of the investigated threats and study areas. From the 1047 compiled publications, we selected 103 studies that precisely addressed cetacean threats. The selected studies were carried out by 82 institutions from 12 countries. Most of these institutions were universities (n = 55), followed by non-governmental organizations (n = 15) and research institutes (n = 12). Among the two cetacean suborders, odontocetes were the most representative, with *Sotalia guianensis* and *Pontoporia blainvillei* present in 50 and 38 publications, respectively. For mysticetes, publications on *Megaptera novaeangliae* (n = 6) and *Eubalaena australis* (n = 5) were the most common. Among the addressed threats, more than half (54.4%) of the publications focused on pollution, followed by bycatch (19.4%) and vessel traffic (10.7%). Most of the study areas took place in the states of Rio de Janeiro (22.4%), São Paulo (19.7%), and Rio Grande do Sul (12.9%). Six institutions were the most prevalent in the collaboration networks, and their location corresponded to hotspots of cetacean diversity. Our findings may contribute to identifying research priorities and guide the conservation of cetacean species in Brazil.

1. Introduction

Nearly 70% of oceanic regions are severely impacted by humans or are located near key conservation sites for marine and freshwater mammals [1]. The fact that more than half of the world's human population lives in coastal areas has directly fostered negative changes in marine ecosystems [1–3]. Coastal and marine ecosystems are greatly damaged by a synergy of anthropogenic impacts, such as

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overexploitation of natural resources, habitat loss and degradation, and chemical and noise pollution [4,5].

Cetaceans are especially vulnerable, compared to other groups of marine mammals, because of their slow development, low reproductive rates, and potential bioaccumulation of heavy metals [6]. Commercial whaling and accidental capture have led to the extinction of many cetacean species and populations [7,8]. For example, the Gray whale (*Eschrichtius robustus*) has been considered functionally extinct in the Atlantic since the early 18th century [7], and the most recent ecological extinction was that of the Baiji (*Lipotes vexillifer*) of the Yangtze River in China in 2002; both extinctions are mainly attributed to hunting [8]. Currently, the Vaquita (*Phocoena sinus*) is the most critically endangered cetacean species in the world, with an estimated population of 30 individuals, owing to bycatch [9]. In Brazil, the primary threat is fishery activities, especially for the Franciscana (*Pontoporia blainvillei*), which is affected by accidental death events occurring during fishery operations along the south coast of Brazil [10], and for the Amazon river dolphin (*Inia geoffrensis*) and the Tucuxi (*Sotalia fluviatilis*), which are both directly exploited as bait in the Amazon [11].

Concerns about the conservation of cetaceans started to increase in the 1970s [12], notably following the first biennial conference on the biology of marine mammals that took place in 1975. In 1981, the Society for Marine Mammalogy was founded, which led to subsequent conferences and collaborative initiatives among researchers from several institutions and countries [13]. In 1982, to regulate whaling and conserve whale stocks, the International Whaling Commission (IWC) promoted a global moratorium on commercial whaling and in 1986 it was implemented [14]. The moratorium acted as a decisive factor in the recovery of several populations of mysticetes, nevertheless, Iceland, Japan, and Norway still hunt more than a thousand whales every year by using exceptions in the rules imposed by IWC [15].

In order to reaffirm the national interest in cetacean conservation, the Brazilian coast was decreed as a sanctuary for whales and dolphins in 2008 [16]. To provide proper conservation of whale stocks and ensure that whaling become permanently banned, Brazil and several countries lead a proposal to create a South Atlantic Whale Sanctuary. The proposal has been advocated in the International Whaling Commission (IWC) plenary sessions since 2001 [15]. In addition, National Action Plans were created in 2010 to establish and guide priority action for the conservation of cetacean species that are included in the Brazilian list of threatened species [6,17–19]. These plans are of strategic importance to guide conservation efforts because they have been developed based on collaboration between research institutes, non-governmental organizations (NGOs), and universities. They are an excellent example of the product of a scientific collaboration network, which is defined as the participation of researchers working towards a common goal and the production of knowledge [20]. Collaboration networks can improve the quality of research, as they enable the exchange of approaches and innovations in methodology. Thus, the results can be more reliable and expand conservation strategies for a given species [20]. Collaboration networks can be measured at different levels, namely interpersonal, interdepartmental, interinstitutional, and international.

Based on the need to better understand the status of research regarding the impacts of human activities on cetaceans, we aimed to identify studies on this subject and determine where, how, and by whom it has been conducted in Brazil, as well as to determine which species of cetaceans have been studied. Thus, we addressed the following questions: (1) Which institutions are conducting research regarding the impacts of human activities on cetaceans in Brazil, and how are these institutions spatially distributed worldwide? (2) What is the status of scientific collaboration networks among these institutions? (3) What types of human threats have been studied, and which cetacean species have been investigated in Brazil? (4) Where are the surveys being conducted in Brazil?

To achieve this aim, we conducted a systematic bibliographic compilation of published scientific studies since 1986 to 2016. These findings will help to guide future conservation actions and help researchers, universities, and NGOs to identify potential research partners focused on the conservation of cetaceans.

2. Materials and methods

2.1. Defining search terms

A review of the main threats posed by humans to cetaceans in Brazil was conducted using three Brazilian action plans for cetacean conservation [6,18,19] and a guide book for Brazilian cetaceans [21] as references. The main threats identified in these reference books were then classified into seven categories, namely *vessel traffic* (change in behavior based on vessel traffic), *vessel collision*, *bycatch* (accidental death in fishing nets), *hunting* (intentional capture, and slaughter because of resource competition even perceived and real competition), *pollution* (ingestion of marine debris, chemicals, and noise pollution), *dam construction* (construction of hydroelectric power plants), *depletion of fish stocks* (temporal variation in the diet, reduction in the availability of prey, and overfishing), and *several* (when an article addressed more than one threat).

Subsequently, variations of 63 English terms depicting major cetacean threats posed by humans in Brazil were developed. Using a combination of these terms (Table 1), we conducted an initial search for articles published from 1986 to 2016 in two databases, the Web of Science bibliographic platform and the bibliographic database of the Natural History Museum of Los Angeles County [22]. The Web of Science platform was chosen as it is one of the most comprehensive article databases from peer-reviewed journals. The Natural History Museum of Los Angeles County database on marine mammal publications contains scientific literature exclusively related to marine mammals and includes

Table 1
Search information and terms used for initial identification of articles focusing on human threats to cetaceans in the bibliographic databases Web of Science and David Janiger. Symbol - *, named symbol of truncation, is used in the bibliographic search, at the end of the words to find them in the singular, plural and variations of writing of them (recovers any amount of characters, including none).

Sources of bibliographic data	Web of Science bibliographic platform (http://isiknowledge.com/) and the bibliographic database of the Natural History Museum of Los Angeles County
Period of publication	Between 1986 and 2016
Search field	Topic (article titles, abstracts, author keywords, keywords created)
Terms used in search fields	Brazil OR South Atlantic AND cetacea* OR dolphin* OR whale* OR odontocet* OR mysticet* OR toothed whale* AND anthropogenic impact* OR human impact* OR human effect* OR disturbance* OR threat* OR pressure on marine ecosystem* OR habitat loss* OR habitat degradation* OR marine scrap* OR marine rubbish* OR marine trash* OR marine garbage* OR marine rubble* OR pollution by plastic* OR ingestion OR floating solid waste debris* OR bridge construction* OR oil exploration* OR natural gas exploration* OR mining exploration* OR overfishing* OR depletion of fish stock* OR resource competition* OR incidental capture* OR incidental catch* OR accidental capture* OR accidental catch* OR capture in fishing net* OR capture in gillnet* OR capture in trawl net* OR intentional capture* OR hunt* OR slaughter* OR killing by competition* OR intensification of maritime traffic* OR traffic of vessel* OR transit of vessel* OR boat* OR ship* OR collision* with vessel* OR ships collision* OR noise pollution* OR noise of anthropogenic origin* OR seismic prospect* OR dredging* OR perforation* OR chemical pollution* OR contaminant* OR toxic waste* OR oil* OR oil spill* OR micro pollutant* OR uncontrolled OR observation tourism* OR whale watching*

75678 references. We excluded publications prior to 1986, the year when the commercial whaling moratorium for large cetaceans was made effective [14] because this historical landmark for the conservation of cetaceans brought about increased interest in these animals in the scientific community (subsequently leading to a high number of scientific publications).

2.2. Compilation of studies

We found a total of 1047 articles in these two databases during the initial search. Among these, we selectively chose articles that were published in peer-reviewed journals concerning studies conducted in Brazil and those that dealt with anthropogenic impacts on one or more species, thereby resulting in 103 publications (Appendix A). We excluded gray literature (i.e., dissertations, theses, and unpublished reports) to ensure greater data credibility. The criteria and details for inclusion and exclusion of articles were documented based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [23] (Fig. 1).

The following data were extracted from each publication: 1) authors (as recommended by Salinero and Michalski (2016) [24]); 2) respective affiliations, including name of the institution, type (i.e., NGO, university, or research institute), geographic location, and coordinates of the institution; 3) target species, including name, family, and suborder; 4) category of threat (vessel traffic, vessel collision, bycatch, hunting, pollution, dam construction, depletion of fish stock, or several); and 5) study areas, including geographical locations and coordinates. The authors of each publication were categorized according to the institutions with which they were affiliated. The locations of the institutions were obtained from the institutional website or through Google Earth Pro 7.3.2 [25].

When the data collection for a study (i.e., publication) was carried out in more than one location or across extensive areas of a specific Brazilian state, we considered the central geographic coordinates of these locations. When the data collection for a study was carried out in more than one Brazilian state, we considered one central geographical point per state. When no geographic coordinates were reported, we searched for the closest coordinates using Google Earth images, supported by maps and landmarks mentioned in the publication, such as municipalities, rivers, or estuaries. Geographic coordinates for mapping the distribution of the studies were obtained from Google Earth Pro 7.3.2 [25] and georeferenced on the QGIS 2.18.7 platform [26].

2.3. Data analysis

Graphical images of the scientific collaboration networks between the institutions associated with the 103 publications were analyzed using the methodology developed by Salinero and Michalski (2016) [24]

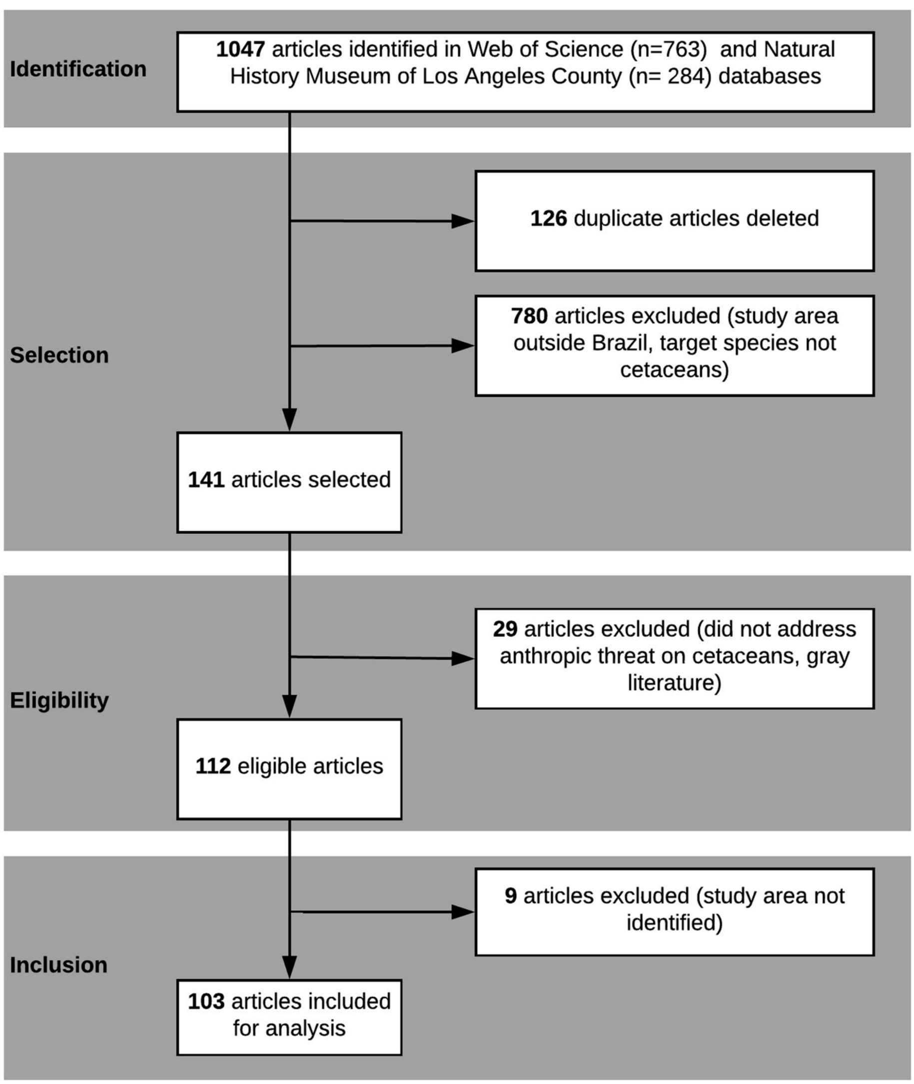

Fig. 1. Flowchart of all phases of the systematic review according to PRISMA guidelines (left) and the respective exclusion criteria (right).

and the Igraph package [27] in R [28]. Within this network, each node represents an institution. The interactions between the institutions were based on a combination of the number of intermediate nodes and binding weights. In this study, two measures of the centrality of nodes were used to calculate the degree of influence of each institution, namely the degree of centrality (degree) and the centrality of intermediation (betweenness). The degree refers to the number of adjacencies for each node in a network, in other words, the number of nodes to which the focal node is connected. The higher the degree, the larger the area of the circle depicted in the graphs. Betweenness is the measure of influence that a node has on the propagation of information flow through the network. The greater the value of betweenness, the more centralized the circle is on the graph [29]. Therefore, in our study, the degree represents the number of times an institution had direct contact with the others, and betweenness represents the communication potential of an institution to act as a bridge of information.

3. Results

The 103 scientific papers that met the inclusion criteria in this study (i.e., dealing with human impacts on cetaceans in Brazil) were published from 1996 to 2016. No publications that met these inclusion criteria were found between 1986 and 1995.

Almost half (47.6%) of the publications on threats posed by humans to cetaceans in Brazil (n = 49) were published between 2011 and 2016. The highest number of publications that were published in a single year (2012) was 13, while no publications were found between 1999 and 2001 (Fig. 2).

3.1. Institutions involved

In total, 257 authors were involved in these publications (mean ± SD = 5.9 ± 3.6, range = 1–16 authors). We identified 82 affiliations linked to these authors. The number of institutions per publication ranged from 1 to 11, with a median of three institutions per publication (mean = 3.2 ± 2). These institutions were distributed in 12 different countries; 55 institutions were national (Brazilian), and 27 were international (Fig. 3 and Appendix B).

Overall, 35% (n = 36) of the 103 publications were (co-) authored by at least one author from an international institution. Most of the institutions were universities (n = 55), followed by NGOs (n = 15), and research institutes (n = 12).

3.2. Scientific collaboration networks

Six institutions contributed most to this scientific collaboration network in terms of research regarding anthropogenic threats to cetaceans in Brazil (i.e., they had a large number of partnerships and publications) (number of publications = 66; 64.1%). Among these institutions, there were five universities, namely the Federal University of Rio de Janeiro (UFRJ) (degree: 41; betweenness: 657.95), the State University of Rio de Janeiro (UERJ) (degree: 39; betweenness: 540.40), the Federal University of Rio Grande (FURG) (degree: 31; betweenness: 427.47), the State University of Norte Fluminense Darcy Ribeiro (UENF) (degree: 28; betweenness: 448.65), the University of São Paulo (USP) (degree: 21; betweenness: 219.85), and one NGO, the BioPesca Project (BioPesca) (degree: 25; betweenness: 130.15) (Fig. 4 and Appendices C and D).

3.3. Target species and categories of threat

Most publications (89.3%; n = 92) focused on one or more odontocete species, while only 8.7% (n = 9) of the publications focused on one or more mysticete species; only 1.9% (n = 2) studied both mysticetes and odontocetes (Table 2). The first publication regarding threats posed by humans related to mysticetes in Brazil was published in 2006, but most publications in subsequent years considered odontocetes (Fig. 5).

The compiled studies covered 28 of the 48 species of cetaceans present in Brazil, namely one Balaenidae, three Balaenopteridae, and 24 odontocetes, including the families Delphinidae, Iniidae, Kogiidae, and Pontoporiidae (Table 2). The number of species investigated per publication ranged from 1 to 15 [30]. Thirty-five publications investigated more than one target species. The most comprehensively studied odontocete species was the Guiana dolphin (*Sotalia guianensis*), which was included in 50 publications, followed by the Franciscana (*P.* blainvillei) included in 38 publications, the bottlenose dolphin (*Tursiops*

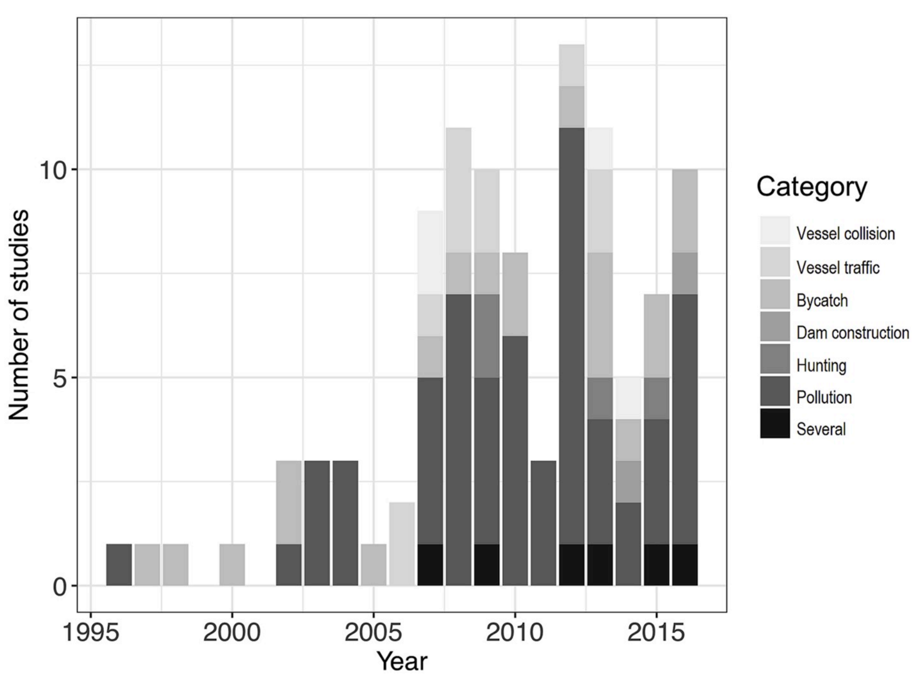

Fig. 2. Annual number of publications on human threats to cetaceans in Brazil, published between 1996 and 2016 (n = 103) separated by category of threat. The gray scale represents different research categories.

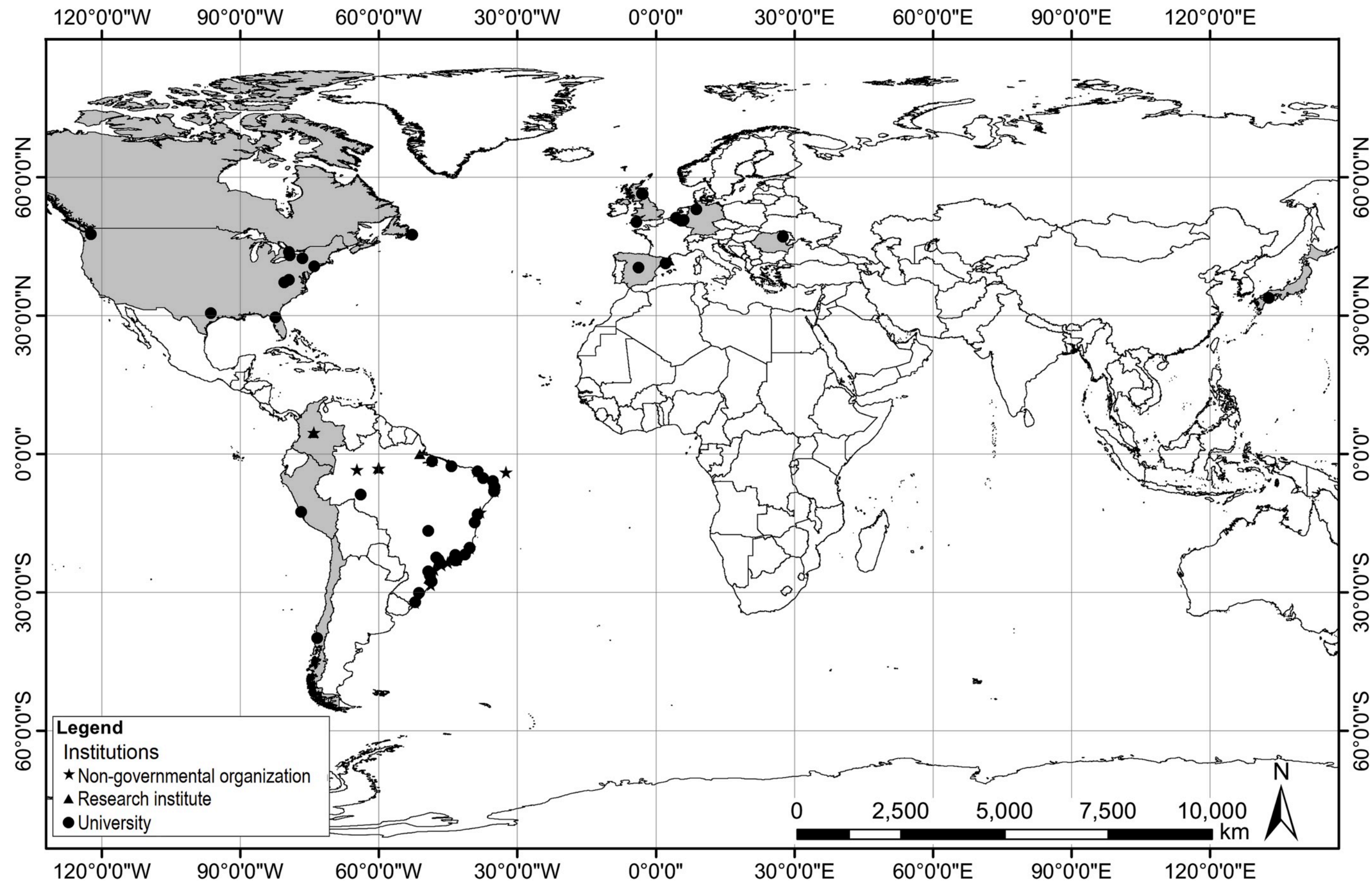

Fig. 3. Geographic distribution of national (n = 55) and international (n = 27) institutions involved in 114 researches on human threats to cetaceans in Brazil. Institution types are represented by different symbols.

truncatus) included in 17 publications, and the Atlantic spotted dolphin (*Stenella frontalis*) included in 16 publications. The most comprehensively studied mysticete species were the humpback whale (*Megaptera novaeangliae*) included in 6 publications, and the southern right whale (*Eubalaena australis*) included in 5 publications. These numbers add up to 121 publications, which is larger than the total of 103 scientific papers investigated because some publications included more than one species.

The publications were classified into seven different categories of anthropogenic threats, with more than half (54.4%) of these articles focused on pollution (n = 56), followed by bycatch (n = 20; 19.4%), vessel traffic (n = 11; 10.7%), several (n = 6; 5.8%), vessel collision (n = 4; 3.9%), hunting (n = 4; 3.9%), and dam construction (n = 2; 1.9%) (Appendix A). No studies were found on the category depletion of fish stock.

3.4. Spatial distribution of studies

We referenced only one geographical point for 82 of the publications and more than one geographical point for 21 of the publications, when more than one state (min-max = 2–6) was investigated (Appendix A). From the publications with only one geographical point, we determined a central position between points of 19 of them (average distance between geographical points = 144 km; min-max = 12–443 km). Overall, we identified 63 study areas (Fig. 6 and Table 3).

The spatial distribution of these studies indicates that they cover large areas of Brazilian coastal waters, with the exception of one Brazilian coastal state (Piauí state) and some riverine areas. These publications were concentrated in the state of Rio de Janeiro (n = 33; 22.4%), followed by the states of São Paulo (n = 29; 19.7%), Rio Grande do Sul (n = 19; 12.9%), Amazonas (n = 11; 7.5%), Bahia (n = 9; 6.1%), Ceará (n = 9; 6.1%), and Paraná (n = 9; 6.1%). The Brazilian states of Alagoas, Amapá, Maranhão, and Sergipe were only represented by one publication each.

4. Discussion

Financial resources from federal and state sources for research in Brazil were abundant between 2007 and 2014 [31], which may explain the increase in the number of publications from 2007 compared to previous years. However, an economic crisis that began in 2014 in Brazil resulted in a progressive decrease in funding for research from almost all funding agencies [32]. Therefore, a reduction in the number of studies conducted on Mysticetes in the subsequent years, (see 2015 and 2016, Fig. 5), may be attributed to the decrease in funding for research as those require expensive resources. These studies involve detailed logistical planning, higher equipment costs, and a specialized team since mysticetes are found further from the coast than many odontocetes.

Scientific studies conducted on Mysticetes, such as those on humpback whales, began only in the late 1980s in Brazil [33]. A few decades ago, information regarding the distribution of mysticetes in Brazil was obtained from data collected on animals stranded along with the coast, occasional observation efforts, or reports from the time when commercial whaling was permitted [34].

The investments in the internationalization of higher education in Brazil started in 1998 [35], a factor that may have contributed to the increase in the number of publications. We found that almost one-third of the compiled publications had some international contribution. Leimu and Koricheva (2005) [36] showed that the involvement of two or more institutions in the development of ecological studies favors

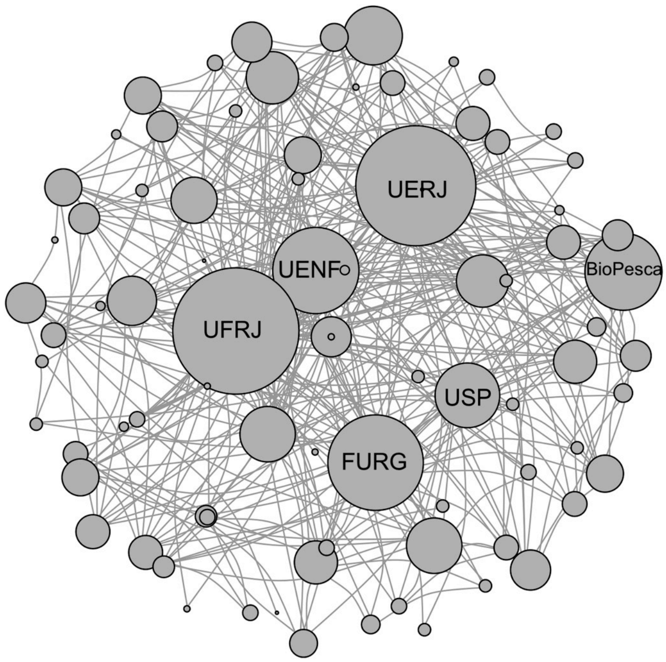

Fig. 4. Networks of scientific collaboration in researches on human threats to cetaceans in Brazil based on 103 publications. Each circle represents an institution (n = 82), and the connection link the institutions that collaborate. The area of the circles is proportional to the degree of centrality of the institution. The acronyms of the six institutions that contribute most to the network are shown, namely: UENF - Universidade Estadual do Norte Fluminense Darcy Ribeiro; UERJ - Universidade do Estado do Rio de Janeiro; UFRJ - Universidade Federal do Rio de Janeiro; FURG - Universidade Federal do Rio Grande; USP - Universidade de São Paulo and, BioPesca - Projeto BioPesca.

productivity, quality, and impact in scientific publications. Also, several authors have shown that research involving international institutions is cited more often when compared to research involving collaborators from the same country since international collaborations provide greater visibility in the scientific community [20,37]. Although our study was not intended to evaluate correlations between the number of institutions, internationalization and the impact of publications we recommend, when possible, broad network collaboration, including international participation of co-authors for future research.

According to a preliminary survey (Marega-Imamura, personal communication), there are 21 Brazilian NGOs involved with cetacean conservation and they have an important role in Brazilian research. In fact, a Brazilian NGO (i.e. BioPesca Project) was ranked as one of the tops sixthly institutions from our compiled publications that contributed most to the scientific collaboration network. NGOs focused on environmental conservation have played an important participatory role in the management of biodiversity preservation, recovery, and research. In addition, the involvement of this type of institution in research favors the dissemination of research, increases social pressure against harmful activities, and stimulates environmental awareness in society [38].

The six institutions (UFRJ, UERJ, FURG, UENF, USP, and BioPesca) which contributed with more publications and had higher network collaboration can be justified by financial and temporal reasons. All these institutions are located in the south of Brazil, a region that historically receives more federal investments in research [39,40]. Besides, UFRJ and USP are between the oldest Brazilian Universities, founded in 1920 and 1934, respectively [41,42]. Furthermore, FURG and UERJ established the first Brazilian oceanography courses. The supply of financial resources and the long time of the establishment of research groups in the south of Brazil may have favored a bigger scientific production and research networking. The locations of these institutions are of main importance as it corresponds to locations of diversity hotspots

Table 2
List of 48 species that occur in Brazilian jurisdictional waters. Twenty eight species were target of studies on human threats to cetaceans in Brazil, published between 1986 and 2016. The number of institutions involved on these studies, the threat categories in the ICMBio Brazilian list (Brazilian List) and in the World Conservation Union list (IUCN Red List) is informed for each species. Threat categories: CR - Critically endangered; DD - Data deficient; EN - Endangered; LC - Least concern; NT - Near threatened and VU - Vulnerable. Symbols: * - Species is included in State lists of endangered species (Bahia and Paraná); ** - Species occurring in Brazilian waters, but not included in the Brazilian national list.

Taxon	Common name	Number of institutes	Brazilian List	IUCN Red List
Suborder Mysticeti				
Family Balaenidae				
Eubalaena australis	Southern right whale	12	EN	LC
Family Balaenopteridae				
Balaenoptera acutorostrata	Minke whale	6	DD	LC
Balaenoptera bonaerensis	Antarctic minke whale	0	DD	NT
Balaenoptera borealis	Sei whale	0	VU	EN
Balaenoptera edeni	Bryde's whale	3	DD	DD
Balaenoptera musculus	Blue whale	0	CR	EN
Balaenoptera physalus	Fin whale	0	EN	VU
Megaptera novaeangliae	Humpback whale	14	VU	LC
Suborder Odontoceti				
Family Delphinidae				
Cephalorhynchus commersonii	Commerson's dolphin	0	**	LC
Delphinus capensis	Long-beaked common dolphin	9	DD	DD
Delphinus delphis	Short-beaked common dolphin	14	DD	LC
Delphinus sp.	Delphinus sp	6	DD	DD
Feresa attenuata	Pygmy killer whale	9	DD	DD
Globicephala macrorhynchus	Short-finned pilot whale	0	DD	DD
Globicephala melas	Long-finned pilot whale	7	DD	DD
Grampus griseus	Risso's dolphin	9	DD	LC
Lagenorhynchus australis	Peale's dolphin	0	**	DD
Lagenodelphis hosei	Fraser's dolphin	13	DD	LC
Lissodelphis peronii	Southern right whale dolphin	0	**	LC
Orcinus orca	Killer whale	11	DD	DD
Peponocephala electra	Melon-headed whale	7	DD	LC
Pseudorca crassidens	False killer whale	17	DD	DD
Sotalia fluviatilis	Tucuxi	10	**	LC
Sotalia guianensis	Guiana dolphin	61	VU*	NT
Stenella attenuata	Pantropical spotted dolphin	13	DD	LC
Stenella clymene	Clymene dolphin	4	DD	DD
Stenella coeruleoalba	Striped dolphin	21	DD	LC
Stenella frontalis	Atlantic spotted dolphin	33	DD	LC
Stenella longirostris	Spinner dolphin	22	DD	DD
Stenella sp.	Stenella sp	1	DD	DD
Steno bredanensis	Rough-toothed dolphin	30	DD	LC
Tursiops truncatus	Common bottlenose dolphin	29	DD	LC
Family Iniidae				
Inia geoffrensis	Amazon river dolphin	24	**	VU
Family Hyperoodontidae				
Hyperoodon planifrons	Southern bottlenose whale	0	DD	LC

(*continued on next page*)

Table 2 (*continued*)

Taxon	Common name	Number of institutes	Brazilian List	IUCN Red List
Family Kogiidae				
Kogia sima	Dwarf sperm whale	8	DD	DD
Kogia breviceps	Pygmy sperm whale	0	DD	DD
Family Physeteridae				
Physeter macrocephalus	Sperm whale	0	VU	VU
Family Phocoenidae				
Phocoena dioptrica	Spectacled porpoise	0	**	LC
Phocoena spinipinnis	Burmeister's porpoise	0	**	NT
Family Pontoporiidae				
Pontoporia blainvillei	Franciscana	40	EN	VU
Family Ziphiidae				
Berardius arnuxii	Arnoux's beaked whale	0	DD	DD
Mesoplodon europaeus	Gervais' beaked whale	0	DD	DD
Mesoplodon densirostris	Blainville's beaked whale	0	DD	DD
Mesoplodon grayi	Gray's beaked whales	0	DD	DD
Mesoplodon hectori	Hector's beaked whale	0	DD	DD
Mesoplodon layardii	Strap-toothed beaked whale	0	DD	DD
Mesoplodon mirus	True's beaked whale	0	**	DD
Ziphius cavirostris	Cuvier's beaked whale	0	DD	LC

for cetaceans (i.e. subtropical waters of southeastern and southern Brazil, see Ref. [43]).

A total of 48 cetacean species are found in Brazilian jurisdictional waters (see Ref. [21]). Only 28 species, however, were investigated by the publications discussed here. That means that the effects of threats on the other 20 species occurring in Brazil [44] have not been published in articles that meet the criteria of our analysis (Table 2). A potential reason for the non-existence or inadequacy of studies carried out on several species of cetaceans in Brazil is methodological challenges. Many species swim at high speeds, travel long distances daily, or migrate seasonally over thousands of miles. These behaviors make it difficult to obtain basic information and determine factors that may be impacting these populations. For example, the smaller number of publications on mysticetes compared to odontocetes might be directly related to the higher cost of studying mysticetes. Nonetheless, there is a need to intensify research efforts to increase our knowledge of and understand the conservation needs of mysticetes in Brazil.

More than half of the publications from our compilation focused on pollution as an anthropogenic threat to cetaceans. According to Schipper et al. (2008) [45], pollution is the second major threat to marine mammals. Although pollution research involves high costs for laboratory analyses, cetacean carcasses are often available and tissue collection can be easily done on-site. Several publications described strandings in Brazilian coastal, commonly involving more than one species and requiring various expertise and equipment to analyses data on chemical pollution, consequently involving large collaboration networks [46–48].

There was only one published article addressing the consequences of debris ingestion [49]. Unlike chemical pollution analyses, which require few tissue samples of cetacean carcasses, the sampling of debris data demands exhausting access and collection of gastrointestinal tracts and depends on the carcass level of decomposition. Although the available evidence suggests events of debris ingestion and high death rates, there is a substantial knowledge gap regarding the impact of this threat [50]. Debris in the oceans continues to grow, therefore, collection and publication on the interaction of cetaceans with the debris are strongly recommended [51].

We found two publications addressing the consequences of noise pollution, one of them dealing with seismic [52]. Therefore, there is a need to access more related data as seismic activities, which are associated with a significant impact on cetaceans [53].

We found bycatch as the second most studied anthropogenic threat. Bycatch in fishing nets is another serious threat to marine mammals, affecting 78% of species [45], and is also the main cause of death in cetaceans [54–56]. Odontocetes that are found in coastal and estuarine distributions, such as the Guiana dolphin and the Franciscana, are threatened by a greater variety of human activities (habitat loss, pollution, and vessel traffic) and are most vulnerable to fishing gear in Brazil [56]. Despite the high impact rate of fishing activity on cetacean

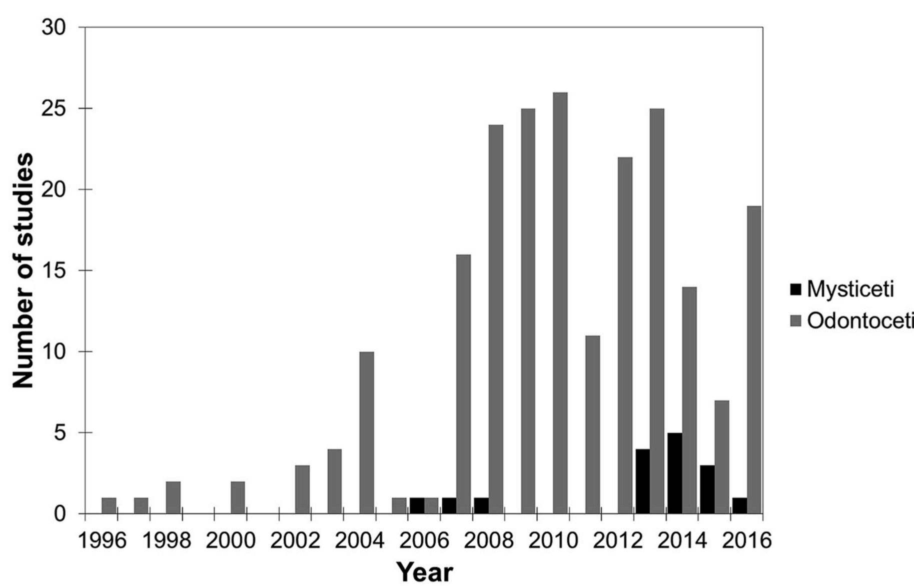

Fig. 5. Annual number of studies on human threats to cetaceans in Brazil published between 1996 and 2016, separated by cetaceans groups of the target species. As each publication could target more than one species the total number presented here is 228. Gray and black bars represent publications on odontocetes and mysticetes species, respectively.

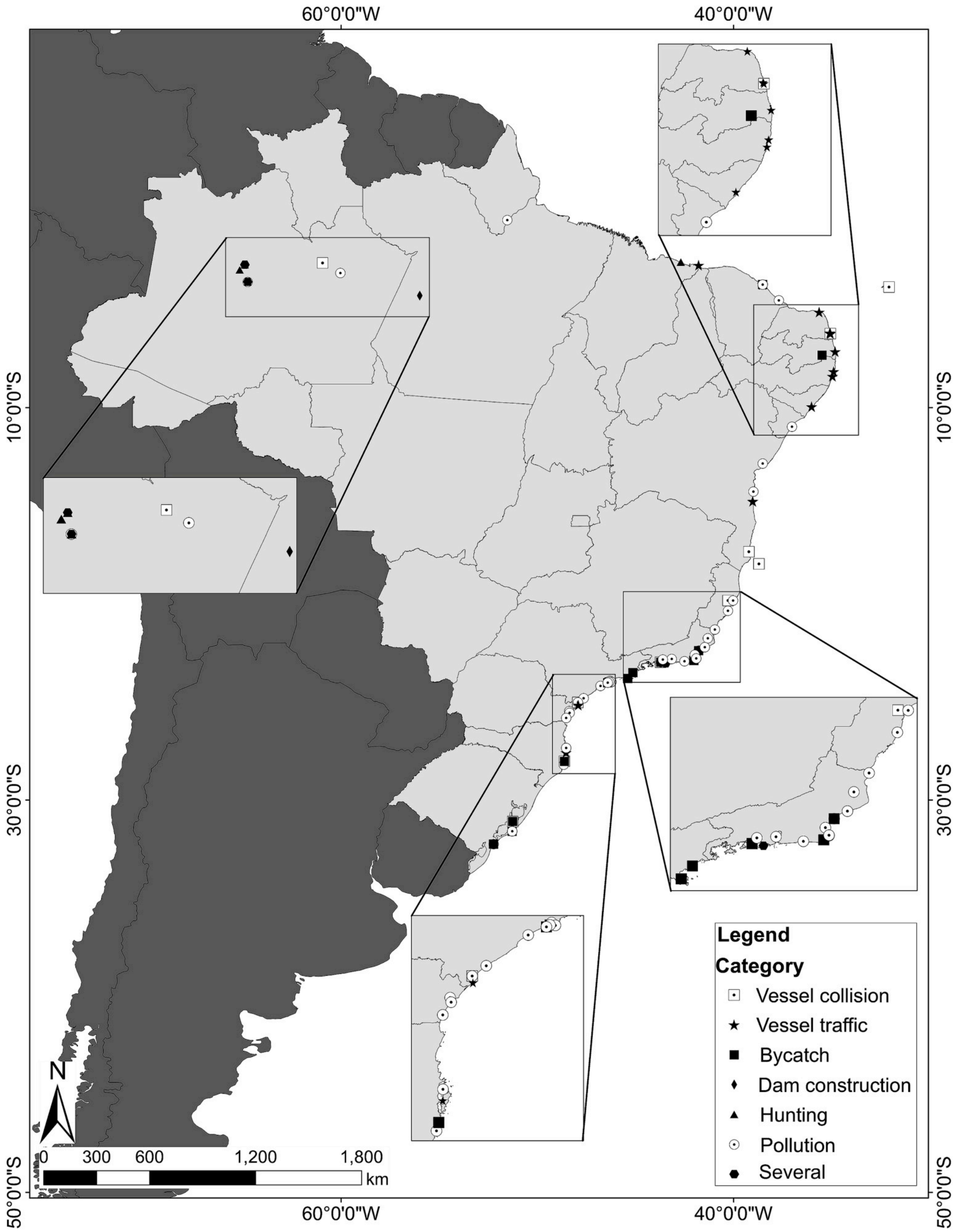

Fig. 6. Geographic distribution maps of the study areas of 103 publications on human threats to cetaceans in Brazil. Coverage of Brazilian publications, the square presents the region with the highest concentration of publications; each symbol represents the category of threat addressed.

populations, this was not the predominant category of threats among the evaluated published studies.

Dolphins that inhabit fluvial environments are considered the most threatened cetaceans because they inhabit areas of high human occupation. Conflicts and anthropogenic pressure on natural resources are more intense [57]. Four of the publications identified here regarding hunting focused on Piracatinga bait. The use of *I. geoffrensis* (Amazon River dolphin) as bait for the Piracatinga fishery in the Amazon region has been observed in recent years, leading to several studies [58–61] for the establishment of public conservation policies, such as a moratorium on Piracatinga fishing for five years (i.e. since January of 2015 until January of 2020 [62]).

The Amazon is among 20 key conservation sites for marine mammal diversity [1]. Despite the high threat to river species, our analysis indicated that studies on the Amazon River dolphin are only the fifth most commonly conducted studies. A greater effort to conduct studies, especially on river dolphins, is needed to better assess the impact of potential threats and to design effective measures for conservation [63].

As discussed at the Society Latin American of Specialists in Aquatic Mammals Meeting (XII SOLAMAC - Peru, November 2018) there is a lacking data on bycatch. As long as there is a lack of legislation in Brazil to monitoring onboard for assesses the impacts of bycatch, Brazil is one of the worst-performing Latin American countries in terms of monitoring artisanal and industrial fishery activities.

The incidence and degree of human impacts vary considerably among populations and species of cetaceans [64], and it poses a greater threat to populations that are already vulnerable. Endemic and restricted species are prioritized for conservation, as they are generally more vulnerable to anthropogenic impacts [65,66]. Some of the species that were more frequently studied are listed as threatened in Brazil [44]: the Guiana dolphin (*S. guianensis*) and humpback whale (*M. novaeangliae*), which are categorized as vulnerable, and the

Table 3
List of 63 study areas relating to 103 researches on human threats to cetaceans in Brazil with their names, Brazilian states, and geographical coordinates.

N	Name of study area	State	Latitude (degrees)	Longitude (degrees)
1	Amapá	AP	0°25′46.57″S	51°31′38.43″W
2	Aracaju	SE	10°58′15.67″S	37° 2′7.04″ W
3	Arquipélago dos Abrolhos	BA	17°57′45.40″S	38°42′15.83″ W
4	Baia de Guanabara	RJ	22°48′41.66″S	43° 9′16.07″ W
5	Baia de Paranaguá	PR	25°27′50.57″S	48°22′57.84″ W
6	Baia de Santos	SP	23°58′32.91″S	46°20′8.62″ W
7	Baia de Sepetiba	RJ	22°58′15.43″S	43°43′9.26″ W
8	Baia de todos os Santos	BA	12°50′36.42″S	38°31′28.95″ W
9	Baia Norte	SC	27°34′23.50″S	48°32′3.06″ W
10	Barra de São João	RJ	22°35′48.92″S	41°59′23.16″ W
11	Barra do Furado	RJ	22°12′25.73″S	41°28′22.67″W
12	Barra do Riacho	ES	19°49′22.69″S	40°16′47.54″W
13	Cabo Frio	RJ	22°53′12.32″S	42° 1′34.54″W
14	Caburé	MA	2°34′53.56″S	42°41′31.53″W
15	Cananéia	SP	25° 1′14.59″S	47°55′55.09″W
16	Costa ES	ES	19°49′31.67″S	40° 2′9.48″W
17	Costa PB	PB	7° 8′3.38″S	34°49′21.13″W
18	Costa PE	PE	8°23′49.84″S	34°57′48.33″W
19	Costa PR	PR	25°48′59.88″S	48°32′1.18″W
20	Costa RJ	RJ	31°35′6.08″S	51°17′2.31″W
21	Costa RN	RN	5° 7.267′S	35° 38.154′W
22	Costa RS	RS	31°35′6.08″S	51°17′2.31″W
23	Costa SC	SC	27° 20.493′S	48° 31.816′W
24	Costa SP	SP	23°58′50.96″S	46°13′39.52″W
25	ETA Guandu	RJ	22°50′22.13″S	43°36′36.70″W
26	Fernando de Noronha	PE	3°51′0.02″S	32°25′0.00″W
27	Fortaleza	CE	3°43′4.15″S	38°31′12.87″W
28	Garopaba	SC	28° 1′24.27″S	48°37′2.99″W
29	Ilha Comprida	SP	24°48′36.55″S	47°38′43.11″W
30	Ilha do Cardoso	SP	25° 9′34.75″S	47°55′2.60″W
31	Itacaré	BA	14°16′40.52″S	38°59′38.81″W
32	Itanhaém	SP	24°10′54.49″S	46°47′6.14″W
33	Lagoa dos Patos	RS	31° 5′59.92″S	51°15′2.05″W
34	Macaé	RJ	22°23′8.51″S	41°47′4.19″W
35	Manacapuru	AM	3°17′23.02″S	60°37′54.87″W
36	Novo Airão	AM	2°37′0.01″S	60°56′0.00″W
37	Pontal do Sul	PR	25°33′28.77″S	48°21′51.12″W
38	Porto do Malhado	BA	14°46′8.02″S	39° 1′33.03″W
39	Porto São Sebastião	SP	23°48′12.57″S	45°23′10.52″W
40	Prado	BA	17°20′24.58″S	39°13′1.33″W
41	Praia Canoa Quebrada	CE	4°31′28.35″S	37°42′5.61″W
42	Praia da Piedade	PE	8° 8′55.50″S	34°54′24.24″W
43	Praia da Pipa	RN	6°13′21.18″S	35° 4′15.93″W
44	Praia da Ribanceira	BA	28° 11.438′S	48° 39.743′W
45	Praia do J F. do Quissamã	RJ	22°12′25.73″S	41°28′22.67″W
46	Praia Grande	SP	24° 0′51.79″S	46°24′44.37″W
47	Recreio dos Bandeirantes	RJ	23° 1′30.99″S	43°27′17.08″W
48	Reserva Mamirauá	AM	3°35′0.01″S	64°45′0.03″W
49	Rio Amazonas	AM	3° 8′8.96″S	60° 1′51.34″W
50	Rio Araguaia	AM	11°41′58.35″S	50°41′32.34″W
51	Rio Grande	RS	32°14′57.48″S	52°13′55.01″W
52	Rio Japurá	AM	2°43′13.22″S	64°53′46.64″W
53	Rio Paraíba	PB	7°19′16.36″S	35°29′50.17″W
54	Rio Paraíba do SuL	SP	21°45′19.83″S	41°19′6.14″W
55	Rio São Francisco	AL	9° 56.716′S	36° 1.356′W
56	Rio Tapajós, Itaituba	PA	4°16′59.31″S	55°59′32.07″W
57	S. F.de Itabapoana	RJ	21°18′19.39″S	40°57′35.77″W
58	Saco da Ribeira, Ubatuba	SP	23°30′11.18″S	45° 7′35.42″ W
59	São Paulo (estuário)	SP	23°55′26.42″S	46°18′27.46″ W
60	Saquarema	SP	22°55′12.02″S	42°30′37.00″ W
61	Tibau do Sul	RN	6°11′15.48″S	35° 5′43.11″ W
62	Urani	AM	2°58′56.08″S	65° 9′33.72″ W
63	Vila Velha	ES	20°20′48.48″S	40°17′41.23″ W

Franciscana (*P. blainvillei*) and Southern right whale (*E. australis*), which are categorized as endangered.

Interactions between cetaceans and vessels have increased since the 1990s due to accelerated growth in human activities in coastal regions [57]. In Brazil, publications related to this category of threat were observed only after 2006. An increase in the interest in whale watching highlights the need for studies on the possible impacts of vessel traffic during whale watching [67]. The interest in this activity doubled worldwide between 1991 and 1998, and by the year 2006, it was increasing at an average annual rate of 11.3% [68]. Whale watching is currently carried out in at least 119 countries worldwide [69].

Several of these threats are complex and interrelated processes that may interact synergistically, occur simultaneously, or be a consequence of another threat [21]. For example, we classified a given publication in the vessel traffic category if it addressed behavioral changes in cetaceans at the individual or group level concerning a vessel traffic situation. However, vessel traffic can also lead to other threats as noise pollution, chemical pollution, collisions, or release of marine debris. Some categories of threat require further investigation. Although seismic activity significantly impacts cetaceans [53], we found only one published article dealing with this category of threat [52]. No studies were found concerning the depletion of fish stock.

It is noteworthy that other impacts related to human activities, such as climate change, have not been addressed in this study but are also of critical importance [70–72]. Deforestation of riparian forests and the cascading implications for cetacean species, the introduction of exotic species, and swimming with cetaceans are also threats of concern, but were not included in our analyses, because they were not highlighted or discussed in detail in the four books that we used as references [6,18,19,21] while defining categories of anthropogenic threats to cetaceans.

Very few study areas were found along the coast of Bahia state, even though this state has the longest coastline. Similarly, the state of Maranhão presented only one study site despite having the second-longest stretch of coastline. The largest numbers of study areas were identified in Rio de Janeiro, even though it is the Brazilian state with the third-longest stretch of coastline. The concentration of both institutions and areas of study in certain regions of Brazil may be related to the availability of financial resources, and consequently, the establishment of more research groups. This distribution of institutions and areas of study may be limiting knowledge of human impacts on cetaceans in other Brazilian regions. The southeast region contains the largest number of institutions (Fig. 3) of higher education and research, as well as a greater number of researchers. As highlighted by Salinero and Michalski 2016 [24], over half of the study sites with aquatic vertebrates in the Brazilian Amazon were located within 500 km of the research institute/university of the first and last authors of the study. Thus, there is a need to expand the spatial distribution of studies on marine mammals across other Brazilian states, minimizing the bias of centralization of studies in areas with a higher concentration of universities, research centers, and researchers.

5. Conclusions

This study analyzes the main topic of published research from the last 31 years regarding human threats to cetaceans in Brazil, intending to point out gaps in studies focused on the conservation of cetaceans. Brazil is a country with large coastal territories, but, as pointed out here, the northern and northeastern regions have a knowledge gap regarding studies on the impacts of human activities on cetaceans with only 29% of the studies carried out in these regions. The coast of Bahia state is an important breeding ground for humpback whales [73], and other cetaceans occur in this region, thereby indicating that it is an area of great ecological importance concerning the conservation of cetacean species [74]. Thus, the region should be a priority for future studies and conservation efforts. We recognize and recommend the need to increase the number of studies on cetaceans along the coast of Bahia state.

Research on marine mammals has become a complex undertaking, such that each project requires a group of researchers with different knowledge (e.g., behavioral observations, statistical skills, and laboratory techniques, among others). Thus, partnerships between different laboratories could yield more research projects and allow for high-quality research to be conducted [13]. Our results may help researchers define priorities that need to be addressed, identify partnerships for future research, and identify species and regions in Brazil experiencing knowledge gaps. The scientific collaboration networks and partnerships among institutions involved, and those that have not yet been identified, should be broadened and strengthened. With these collaborative efforts and the exchange of information, studies on cetaceans in Brazil could lead to more effective conservation of these species.

Declaration of competing interest

The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

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Appendix A. List of 103 researches on human threats to cetaceans in Brazil published between 1996 and 2016 with the respective category of threat, information on the geographic coordinates of the study areas and target species

Source	Central point	Reported coordinates	Name of study area	State	Category of threat	Target species
1	NO	NO	Costa RJ	RJ	pollution	*T. truncatus* *S. bredanensis* *S. guianensis* *P. blainvillei*
3	YES	YES	Praia Grande	SP	bycatch	*P. blainvillei*
5	NO	NO	Costa PR	PR	pollution	*S. guianensis*
5	NO	NO	Costa RJ	RJ		
5	NO	NO	Vila Velha	ES		
5	NO	NO	Fortaleza	CE		
6	NO	NO	Costa RJ	RJ	pollution	*P. blainvillei*
7	YES	YES	Ilha Comprida	SP	pollution	*S. frontalis*
8	NO	NO	Cananéia	SP	pollution	*S. guianensis*
9	YES	YES	Praia da Pipa	RN	vessel collision	*S. guianensis*
10	NO	NO	Rio Amazonas	AM	pollution	*I. geoffrensis*
11	YES	YES	Fortaleza	CE	pollution	*S. guianensis*
12	YES	YES	Rio Tapajós, Itaituba	AM	dam construction	*I. geoffrensis* *S. fluviatilis*
13	YES	YES	Praia da Ribanceira	BA	pollution	*E. australis*
14	NO	NO	Fortaleza	CE	bycatch	*S. guianensis* *S. bredanensis*
16	NO	NO	Rio Grande	RS	bycatch	*P. blainvillei*
17	YES	YES	Praia Grande	SP	bycatch	*P. blainvillei*
18	NO	NO	Costa PR	PR	pollution	*S. guianensis*
18	NO	NO	Costa SP	SP		*P. blainvillei* *S. frontalis* *D. capensis* *S. coeruleoalba*
21	YES	YES	Costa RS	RS	pollution	*P. blainvillei*
23	NO	NO	Costa SP	SP	pollution	*P. blainvillei* *S. guianensis* *S. frontalis* *D. capensis*
24	NO	NO	Baia de Santos	SP	bycatch	*O. orca*
25	NO	NO	Costa RS	RS	pollution	*P. blainvillei*
25	NO	NO	São Paulo (estuário)	SP		
28	NO	NO	Fortaleza	CE	pollution	*S. guianensis* *L. hosei* *S. longirostris* *S. frontalis* *S. coeruleoalba*
29	YES	YES	Recreio dos Bandeirantes	RJ	several	*E. australis*
30	YES	YES	Cabo Frio	RJ	bycatch	*O. orca* *M. novaeangliae* *E. australis* *B. acutorostrata* *B. brydei* *P. blainvillei*

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(*continued*)

Source	Central point	Reported coordinates	Name of study area	State	Category of threat	Target species
						T. truncatus
						S. bredanensis
						S. frontalis
						Delphinus sp.
31	YES	YES	Rio Grande	RS	pollution	*P. blainvillei*
33	YES	YES	Fortaleza	CE	pollution	*S. bredanensis*
34	YES	YES	Baia Norte	SC	vessel traffic	*S. guianensis*
35	YES	YES	Costa RJ	RJ	pollution	*S. guianensis*
35	YES	YES	Costa SP	SP		*S. frontalis*
35	YES	YES	Costa PR	PR		*T. truncatus*
35	YES	YES	Costa SC	SC		*S. bredanensis*
						S. attenuata
						S. longirostris
						S. coeruleoalba
						D. capensis
						K. sima
40	NO	NO	Costa RJ	RJ	pollution	*S. guianensis*
41	NO	NO	Costa RJ	RJ	pollution	*P. blainvillei*
41	NO	NO	Costa SP	SP		
41	NO	NO	Costa PR	PR		
41	NO	NO	Costa RS	RS		
41	NO	NO	Costa SC	SC		
41	NO	NO	Costa ES	ES		
42	YES	YES	Fortaleza	CE	vessel traffic	*S. guianensis*
42	YES	YES	Costa RN	RN		
42	YES	YES	Rio São Francisco	AL		
42	YES	YES	Costa PE	PE		
42	YES	YES	Costa PB	PB		
43	NO	NO	Baia de Guanabara	RJ	pollution	*S. guianensis*
44	YES	YES	Costa RJ	RJ	pollution	*P. blainvillei*
						S. guianensis
45	YES	YES	Praia da Piedade	PE	vessel traffic	*S. guianensis*
46	YES	YES	Costa RS	RS	pollution	*P. blainvillei*
46	YES	YES	Costa RJ	RJ		
47	YES	YES	Caburé	MA	hunting	*L. hosei*
48	YES	YES	Arquipélago dos Abrolhos	BA	vessel traffic	*M. novaeangliae*
50	YES	YES	Costa RS	RS	bycatch	*T. truncatus*
52	NO	NO	Costa ES	ES	pollution	*P. blainvillei*
52	NO	NO	Costa SP	SP		
52	NO	NO	Costa RS	RS		
52	NO	NO	Costa SC	SC		
53	YES	YES	Arquipélago dos Abrolhos	BA	vessel traffic	*M. novaeangliae*
54	YES	YES	Fortaleza	CE	several	*S. guianensis*
						S. frontalis
						P. crassidens
						T. truncatus
						S. bredanensis
						D. delphis
						S. attenuata
						S. longirostris
						S. coeruleoalba
						L. hosei
						G. griseus
						K. sima
						P. blainvillei
						P. electra
						G. macrorhynchus
56	YES	YES	Macaé	RJ	bycatch	*S. guianensis*
57	NO	NO	Costa RJ	RJ	pollution	*O. orca*
						P. crassidens
						T. truncatus
						S. bredanensis
						D. capensis
						L. hosei
61	NO	NO	Macaé	RJ	pollution	*P. blainvillei*
						S. guianensis
62	YES	YES	Lagoa dos Patos	RS	bycatch	*T. truncatus*
63	NO	NO	Barra de São João	RJ	pollution	*S. guianensis*
67	NO	YES	Baia de Guanabara	RJ	pollution	*S. guianensis*
67	NO	NO	Costa ES	ES		*S. frontalis*
						P. crassidens
						T. truncatus
						S. bredanensis
						D. delphis
						S. attenuata
						S. longirostris

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Source	Central point	Reported coordinates	Name of study area	State	Category of threat	Target species
						S. coeruleoalba
						L. hosei
						G. griseus
						K. sima
						P. blainvillei
68	NO	NO	Costa RS	RS	pollution	*P. blainvillei*
70	NO	NO	Reserva Mamirauá	AM	pollution	*I. geoffrensis*
						S. fluviatilis
73	YES	YES	Praia da Pipa	RN	vessel traffic	*S. guianensis*
74	YES	YES	Costa RS	RS	pollution	*P. blainvillei*
74	YES	YES	Costa RJ	RJ		*P. blainvillei*
76	NO	NO	Saquarema	SP	pollution	*S. guianensis*
						S. frontalis
						P. crassidens
						T. truncatus
						S. bredanensis
						D. delphis
						S. attenuata
						S. longirostris
						S. coeruleoalba
						L. hosei
77	NO	NO	Saco da Ribeira, Ubatuba	SP	bycatch	*S. frontalis*
						S. longirostris
						P. electra
						F. attenuata
						T. truncatus
78	YES	YES	Cananéia	SP	pollution	*S. guianensis*
78	YES	YES	Baia de Paranaguá	PR		
80	NO	NO	Baia de Sepetiba	RJ	pollution	*S. guianensis*
81	NO	NO	Rio Japurá	AM	hunting	*I. geoffrensis*
						S. fluviatilis
82	YES	YES	Ilha do Cardoso	SP	vessel traffic	*S. guianensis*
83	NO	NO	Baia de todos os Santos	BA	pollution	*S. guianensis*
						S. clymene
84	YES	YES	Praia do J F. do Quissamã	RJ	pollution	*S. guianensis*
85	NO	NO	Itanhaém	SP	pollution	*P. blainvillei*
						S. frontalis
						S. guianensis
						T. truncatus
						S. bredanensis
86	NO	NO	Costa SP	SP	pollution	*S. frontalis*
						S. bredanensis
						S. guianensis
						T. truncatus
						P. blainvillei
						S. clymene
						Delphinus sp.
						D. delphis
						S. coeruleoalba
87	NO	NO	Amapá	AP	pollution	*S. guianensis*
88	YES	YES	Baia de Santos	SP	pollution	*S. frontalis*
88	YES	YES	Baia de Paranaguá	PR		
88	YES	YES	Costa SC	SC		
89	YES	YES	Baia de Sepetiba	RJ	bycatch	*S. guianensis*
90	NO	NO	Rio Paraíba do SuL	SP	pollution	*I. geoffrensis*
90	NO	NO	ETA Guandu	RJ		
91	NO	NO	Macaé	RJ	pollution	*P. blainvillei*
						S. guianensis
92	NO	NO	Costa RJ	RJ	pollution	*S. guianensis*
93	YES	YES	Tibau do Sul	RN	vessel traffic	*S. guianensis*
94	YES	YES	Rio Grande	RS	pollution	*P. blainvillei*
96	YES	YES	Rio Grande	RS	bycatch	*P. blainvillei*
98	YES	YES	Pontal do Sul	PR	pollution	*P. blainvillei*
98	YES	YES	Praia Grande	SP		
100	NO	NO	Reserva Mamirauá	AM	hunting	*I. geoffrensis*
101	YES	YES	S. F.de Itabapoana	RJ	pollution	*S. guianensis*
102	NO	NO	Costa SP	SP	pollution	*P. blainvillei*
102	NO	NO	Costa RS	RS		
103	NO	NO	Costa RJ	RJ	pollution	*P. blainvillei*
103	NO	NO	Costa SP	SP		
103	NO	NO	Costa PR	PR		
103	NO	NO	Costa RS	RS		
103	NO	NO	Costa SC	SC		
103	NO	NO	Costa ES	ES		
104	YES	YES	Fernando de Noronha	PE	vessel collision	*S. longirostris*
105	NO	NO	Praia da Pipa	RN	vessel traffic	*S. guianensis*

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Source	Central point	Reported coordinates	Name of study area	State	Category of threat	Target species
106	YES	NO	Baia de Santos	SP	pollution	*S. guianensis*
106	YES	NO	Praia Grande	SP		
108	YES	YES	Porto do Malhado	BA	vessel traffic	*S. guianensis*
						S. frontalis
						Stenella sp.
						S. bredanensis
109	YES	YES	Fortaleza	CE	pollution	*S. guianensis*
110	YES	YES	Garopaba	SC	bycatch	*E. australis*
111	YES	YES	Rio Grande	RS	bycatch	*P. blainvillei*
112	NO	NO	Manacapuru	AM	several	*I. geoffrensis*
						S. fluviatilis
113	NO	NO	Baia de Guanabara	RJ	pollution	*P. blainvillei*
						S. guianensis
115	YES	YES	Porto do Malhado	BA	vessel traffic	*S. guianensis*
116	YES	YES	Barra do Furado	RJ	bycatch	*P. blainvillei*
						S. guianensis
117	YES	YES	Praia do J F. do Quissamã	RJ	pollution	*F. attenuata*
						O. orca
						P. blainvillei
						S. guianensis
						S. frontalis
						S. bredanensis
						T. truncatus
120	NO	NO	Rio Japurá	AM	several	*I. geoffrensis*
						S. fluviatilis
121	YES	YES	Novo Airão	AM	vessel collision	*I. geoffrensis*
121	YES	YES	Prado	BA		*S. guianensis*
121	YES	YES	Barra do Riacho	ES		*T. truncatus*
121	YES	YES	Baia de Sepetiba	RJ		*E. australis*
121	YES	YES	Cananéia	SP		*M. novaeangliae*
121	YES	YES	Garopaba	SC		
121	YES	YES	Lagoa dos Patos	RS		
123	NO	NO	Costa SP	SP	pollution	*P. blainvillei*
						S. guianensis
						S. bredanensis
						P. crassidens
124	YES	YES	Porto São Sebastião	SP	bycatch	*B. acutorostrata*
125	YES	YES	Itacaré	BA	pollution	*M. novaeangliae*
125	YES	YES	Aracaju	SE		
126	YES	YES	Arquipélago dos Abrolhos	BA	vessel collision	*M. novaeangliae*
127	NO	NO	Rio Araguaia	AM	dam construction	*I. geoffrensis*
						S. fluviatilis
128	YES	YES	Praia do J F. do Quissamã	RJ	pollution	*P. blainvillei*
						S. guianensis
129	NO	NO	Reserva Mamirauá	AM	several	*I. geoffrensis*
130	YES	YES	Rio Paraíba	PB	bycatch	*G. griseus*
131	NO	NO	Urani	AM	hunting	*I. geoffrensis*
133	NO	NO	Praia do J F. do Quissamã	RJ	pollution	*S. guianensis*
						S. bredanensis
134	YES	YES	Pontal do Sul	PR	several	*S. guianensis*
						P. blainvillei
						S. frontalis
						S. longirostris
						T. truncatus
						G. melas
136	YES	YES	Porto São Sebastião	SP	bycatch	*B. acutorostrata*
138	YES	YES	Lagoa dos Patos	RS	bycatch	*T. truncatus*
139	NO	NO	Praia do J F. do Quissamã	RJ	pollution	*P. blainvillei*
140	NO	NO	Baia de Santos	SP	pollution	*P. blainvillei*
140	NO	NO	Baia de Sepetiba	RJ		*S. guianensis*
140	NO	NO	Praia Canoa Quebrada	CE		
141	YES	YES	Lagoa dos Patos	RS	bycatch	*T. truncatus*

Appendix B. List with full names, acronyms and geographic coordinates of the 82 institutions involved in conducting 103 publications on human threats to cetaceans in Brazil, published between 1986 and 2016

n	Type, country, Abbreviation	Institution	Latitude (degrees)	Longitude (degrees)
Non-governmental organizations				
Brazil:				
1	AVN	Associação Ambiental Voz da Natureza	20°18′52.03″S	40°18′10.79″O
2	AQUASIS	Associação de Pesquisa e Preservação de Ecossistemas Aquáticos	3°41′31.81″S	38°37′38.25″O
3	PGR	Centro Golfinho Rotador	3°50′54.40″S	32°25′37.70″O
4	FMA	Fundação Mamíferos Aquáticos	8° 1′45.68″S	34°54′26.37″O

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n	Type, country, Abbreviation	Institution	Latitude (degrees)	Longitude (degrees)
5	IBJ	Instituto Baleia Jubarte	12°34′32.68″S	38° 0′28.02″O
6	IDSM	Instituto de Desenvolvimento Sustentável Mamirauá	3°21′19.05″S	64°43′52.15″O
7	IPeC	Instituto de Pesquisas Cananéia	25° 0′56.70″S	47°55′41.81″O
8	ORCA	Instituto ORCA	20°20′6.42″S	40°17′2.78″O
9	Piagaçu	Instituto Piagaçu	3° 5′42.08″S	59°59′27.51″O
10	NEMA	Núcleo de Educação e Monitoramento Ambiental	32°11′15.66″S	52° 9′28.48″O
11	PBF	Projeto Baleia Franca	28°19′53.24″S	48°42′37.00″O
12	BioPesca	Projeto BioPesca	24° 0′31.86″S	46°24′44.86″O
13	TAMAR	Projeto TAMAR	23°27′10.26″S	45° 4′13.79″O
14	WWF	World Wide Fund for Nature	3° 4′25.70″S	59°58′29.10″O
	Colombia:			
15	OMACHA	Fundación Omacha	4°40′20.11″N	74° 3′40.36″O
Research institutes				
Brazil:				
16	EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária	22°58′16.32″S	43°13′24.91″O
17	FIOCRUZ	Fundação Oswaldo Cruz	22°52′32.55″S	43°14′34.76″O
18	IAL	Instituto Adolfo Lutz	23°33′15.10″S	46°40′13.91″O
19	IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis	26°55′7.04″S	48°40′12.54″O
20	ICMBio	Instituto Chico Mendes de Conservação da Biodiversidade	26°57′41.93″S	49° 4′11.28″O
21	INPA	Instituto Nacional de Pesquisas da Amazonia	3° 6′35.74″S	60° 1′16.55″O
22	INT	Instituto Nacional de Tecnologia	22°53′46.31″S	43°11′3.43″O
Canada:				
23	ME-CAN	Ministry of Environment Canadá	43°41′10.59″N	79°24′3.66″O
Colombia:				
24	Humboldt	Instituto de Investigación de Recursos Biológicos	4°36′59.80″N	74° 4′23.47″O
25	IEPA	Instituto de Pesquisa Científicas e Tecnológicas do Estado do Amapá	0° 1′44.37″N	51° 4′2.25″O
26	MPEG	Museu Paraense Emílio Goeld	1°27′3.22″S	48°26′44.42″O
Spain:				
27	ICRA	Catalan Institute for Water Research	41°58′2.29″N	2°50′26.34″L
Universities				
Belgium:				
28	ULG	Université de Liège	50°34′59.25″N	5°33′32.56″L
29	UA	University of Antwerp	51°13′22.11″N	4°24′36.83″L
Brazil:				
30	CetAsia	CetAsia Research Group Ltd	43°48′17.03″N	79°25′22.06″O
31	Everest	Everest Tecnologia em Serviços Ltda	20°18′56.12″S	40°17′43.23″O
32	ECOMAMA	Instituto de Estudos da Ecologia de Mamíferos Marinhos	22°54′27.93″S	43°11′1.88″O
33	IRD	Instituto de Radioproteção e Dosimetria	22°59′33.61″S	43°25′12.39″O
34	PUC	Pontifícia Universidade Católica	22°58′45.09″S	43°13′59.17″O
35	USP	Universidade de São Paulo	23°33′36.23″S	46°43′48.25″O
36	UERJ	Universidade do Estado do Rio de Janeiro	22°54′39.26″S	43°14′8.27″O
37	UERN	Universidade do Estado do Rio Grande do Norte	5°12′19.59″S	37°19′5.49″O
38	UNICAMP	Universidade Estadual de Campinas	22°49′5.33″S	47° 3′53.12″O
39	UESC	Universidade Estadual de Santa Cruz	14°47′50.03″S	39°10′16.63″O
40	UEMA	Universidade Estadual do Maranhão	2°34′34.11″S	44°12′31.46″O
41	UENF	Universidade Estadual do Norte Fluminense Darcy Ribeiro	21°45′48.13″S	41°17′30.22″O
42	UNESP	Universidade Estadual Paulista	22°23′43.10″S	47°32′42.72″O
43	UFBA	Universidade Federal da Bahia	12°59′57.56″S	38°30′26.66″O
44	UFPB	Universidade Federal da Paraíba	7° 8′18.10″S	34°50′41.15″O
45	UFG	Universidade Federal de Goiás	16°36′18.47″S	49°15′39.91″O
46	UFJF	Universidade Federal de Juiz de Fora	21°46′37.02″S	43°22′8.34″O
47	UFPE	Universidade Federal de Pernambuco	8° 3′6.55″S	34°57′1.17″O
48	UNIR	Universidade Federal de Rondônia	8°45′48.40″S	63°54′23.56″O
49	UFSC	Universidade Federal de Santa Catarina	27°36′1.37″S	48°31′10.45″O
50	UFC	Universidade Federal do Ceará	3°44′19.89″S	38°34′9.45″O
51	UFES	Universidade Federal do Espírito Santo	20°16′38.38″S	40°18′15.08″O
52	UNIRIO	Universidade Federal do Estado do Rio de Janeiro	22°57′6.67″S	43°10′27.91″O
53	UFPA	Universidade Federal do Pará	1°28′28.04″S	48°27′11.62″O
54	UFPR	Universidade Federal do Paraná	25°25′36.87″S	49°15′42.36″O
55	UFRJ	Universidade Federal do Rio de Janeiro	22°50′33.04″S	43°14′4.34″O
56	FURG	Universidade Federal do Rio Grande	32° 1′52.27″S	52° 6′6.63″O
57	UFRN	Universidade Federal do Rio Grande do Norte	5°50′5.52″S	35°12′41.05″O
58	UFRGS	Universidade Federal do Rio Grande do Sul	30° 2′1.85″S	51°13′6.84″O
59	UFF	Universidade Federal Fluminense	22°53′49.56″S	43° 7′34.49″O
60	UFRPE	Universidade Federal Rural de Pernambuco	8° 0′49.17″S	34°56′53.49″O
61	UFRRJ	Universidade Federal Rural do Rio de Janeiro	22°46′6.23″S	43°41′6.16″O
62	UNIVILLE	Universidade Regional de Joinville	26°15′14.47″S	48°51′28.58″O
Canada:				
63	Newfoundland	Memorial University of Newfoundland	47°34′25.67″N	52°43′58.46″O
64	Brock	Universidade Brock	43° 7′3.25″N	79°14′51.72″O
Chile:				
65	UACH	Universidad Austral de Chile	39°48′22.51″S	73°15′0.69″O
Germany:				
66	ZMT	Leibniz-Zentrum für Marine Tropenforschung	53° 6′28.82″N	8°50′45.53″L
67	RWTH	RWTH Aachen University	50°46′48.20″N	6° 3′56.47″
Japan:				

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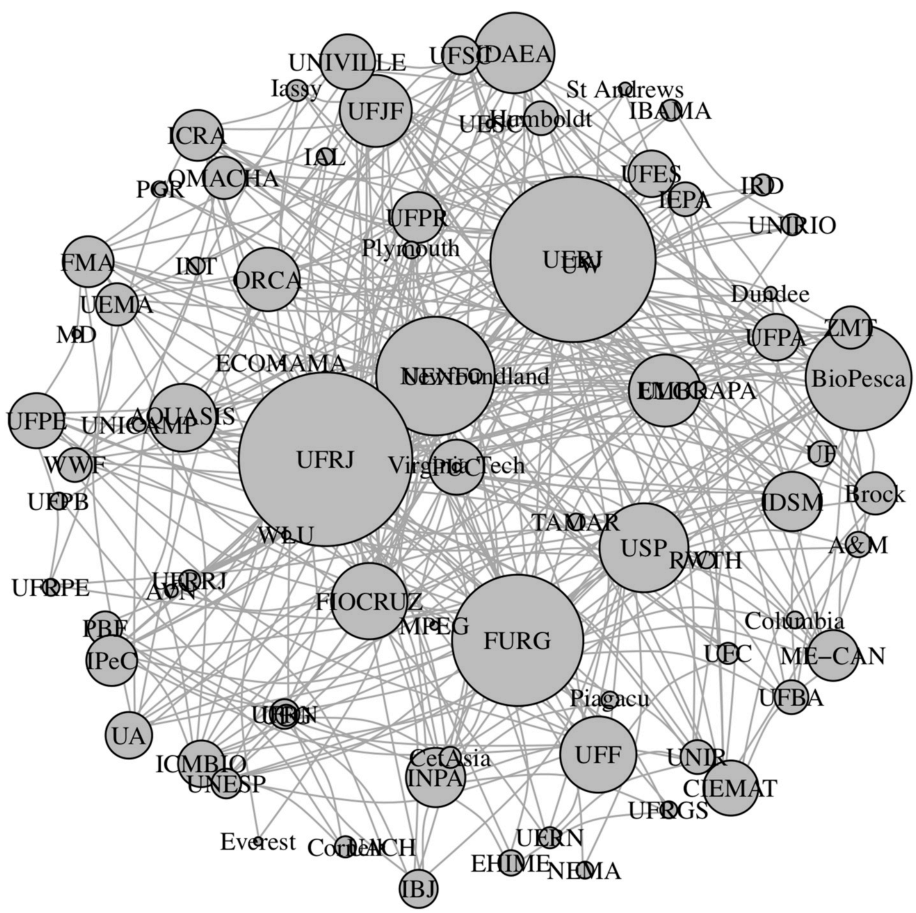
(*continued*)

n	Type, country, Abbreviation	Institution	Latitude (degrees)	Longitude (degrees)
68	EHIME	Ehime University	33°51′0.54″N	132°46′21.04″L
Peru:				
69	MD	Museo de Delfines	12°27′53.73″S	76°46′5.30″O
Romania:				
70	Iassy	University of Iassy	47°10′29.76″N	27°34′26.69″L
Spain:				
71	CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	40°27′18.45″N	3°43′36.02″O
72	IDAEA	Institute of Environmental Assessment and Water Research	41°23′15.23″N	2° 6′53.82″L
United Kingdom:				
73	Plymouth	Plymouth University	50°22′33.07″N	4° 8′22.56″O
74	Dundee	University of Dundee	56°27′29.27″N	2°58′55.83″O
75	St Andrews	University of St Andrews	56°20′24.89″N	2°47′48.15″O
USA:				
76	Columbia	Columbia Univesity	40°42′40.01″N	73°56′29.22″O
77	Cornell	Cornell University	42°27′12.42″N	76°28′24.61″O
78	A&M	Texas A&M University	30°37′6.36″N	96°20′11.41″O
79	UF	University of Florida	29°38′33.99″N	82°21′17.96″O
80	UW	University of Washington	47°39′19.21″N	122°18′12.67″O
81	Virginia Tech	Virginia Polytechnic Institute and State University	37°13′42.18″N	80°25′24.30″O
82	WLU	Washington and Lee University	37°47′25.75″N	79°26′41.84″O

Appendix C. Networks of scientific collaboration in researches on human threats to cetaceans in Brazil based on 103 publications. Each circle represents an institution (n = 82), and the connection link the institutions that collaborate. The area of the circles is proportional to the degree of centrality of the institution. The acronyms of all the institutions are informed



Appendix D. List of 82 institutions involved in 103 scientific articles on human threats to cetaceans in Brazil published between 1986 and 2016 and their respective contributions in the scientific collaboration network detailed in degrees and betweenness values

Institution	betweenness	degree
A&M	0	6
AQUASIS	113.1221654	16
AVN	0	3
BioPesca	130.1570978	25
Brock	0	10
CetAsia	0	5
CIEMAT	0.2222222	13
Columbia	0	4
Cornell	0	5
Dundee	1.3443182	3
ECOMAMA	0	1
EHIME	0	6
EMBRAPA	0	4
Everest	0	2
FIOCRUZ	225.4661369	18
FMA	87.3938823	12
FURG	427.4717971	31
Humboldt	0	8
IAL	0	4
Iassy	0	5
IBAMA	0	5
IBJ	30.4994621	9
ICMBIO	34.9080110	11
ICRA	1.4838097	12
IDAEA	28.7774078	19
IDSM	35.9381364	14
IEPA	0	8
INPA	308.2936035	14
INT	0	4
IPeC	32.5157007	12
IRD	0	5
MD	0	2
ME-CAN	0	12
MPEG	0	2
NEMA	0	4
Newfoundland	0	3
OMACHA	0	10
ORCA	8.9109065	15
PBF	75.6400488	8
PGR	0	3
Piagacu	0	4
Plymouth	0	4
PUC	58.4731093	13
RWTH	0	4
St Andrews	0	3
TAMAR	4.9008866	4
UA	45.3234775	11
UACH	0	1
UEMA	0	10
UENF	448.6591569	28
UERJ	540.4076494	39
UERN	0.6186869	5
UESC	0	2
UF	33.7990496	6
UFBA	5.2435481	8
UFC	0	5
UFES	20.1331789	11
UFF	2341544039	18
UFG	0	5
UFJF	387.5498518	17
UFPA	28.8500412	11
UFPB	0	4
UFPE	100.9312467	13
UFPR	8.9024598	12
UFRGS	0	4
UFRJ	657.9570871	41
UFRN	14.6688766	7
UFRPE	0	4
UFRRJ	78.0000000	5
UFSC	51.9961601	9
ULG	35.6037138	17
UNESP	18.8298463	7
UNICAMP	0	3

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Institution	betweenness	degree
UNIR	12.7462662	8
UNIRIO	2.8133700	5
UNIVILLE	2.9492691	13
USP	219.8557787	21
UW	0	1
Virginia Tech	0	2
WLU	0	2
WWF	0	8
ZMT	27.4881791	10

Appendix E. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2019.103738.

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