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Comparison of local knowledge about the bottlenose dolphin (*Tursiops truncatus* Montagu, 1821) in the Southwest Atlantic Ocean: New research needed to develop conservation management strategies

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ABSTRACT

The aim of this study was to compare the local knowledge of artisanal fishermen about interactions between the bottlenose dolphin (*Tursiops truncatus*) and fisheries in Brazil and Uruguay. Between 2008 and 2011, we performed 88 interviews in Brazil ($N = 66$) and Uruguay ($N = 22$). *Fuzzy* logic was used to identify fishermen who could recognize the bottlenose dolphin. Seventy-nine fishermen (89.8%) identified the bottlenose dolphin, with 40 (50.6%) describing positive interactions, and 21 (34.4%) reporting negative interactions. In Brazil, the local ecological knowledge about the bottlenose dolphin was considered partial but more elaborate, as such knowledge was still incipient in Uruguay. Decreasing the impact of artisanal fishing on coastal populations of bottlenose dolphins in the southwest Atlantic Ocean (SAO) will require the regular monitoring of their areas of use and the locations where gillnets are arranged; consideration the size of the dolphins' populations and the fishing effort in each region; and the participation of social actors through educational activities, particularly in Brazilian areas, and the participation of social actors through educational activities (particularly in Brazilian areas, where the fishermen evinced feelings of competition in relation to the bottlenose dolphin) and improvements in the living and income conditions of these communities. From these results we propose measures for reducing anthropic impacts on bottlenose dolphin populations, including monitoring areas of use and the locations of fishing along the SAO as well as integrated management between social actors – government – research institutes for decisions about fishery management.

1. Introduction

The species *Tursiops truncatus* (Montagu 1821), known as the bottlenose dolphin, has a wide distribution, ranging from tropical to temperate areas around the world (Jefferson et al., 1993; Culik, 2010). In the southwest Atlantic Ocean (SAO), the bottlenose dolphin occurs from the mouth of the Amazon River in northern Brazil

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(0°40′S; 49°55′W) (Siciliano et al., 2008) to Tierra del Fuego, southern Argentina (54°55′S; 67°34′W) (Goodall et al., 2011). Resident and seasonal resident coastal populations have been recorded along the Brazilian coast (Castello and Pinedo, 1977; Simões-Lopes, 1991; Flores and Fontoura, 2006; Lodi et al., 2008; Caon et al., 2009). In Uruguay, records of the bottlenose dolphin in estuarine areas of the Rio de la Plata have been made since the 1960s (Lázaro and Praderi, 2000). However, the occurrence of the bottlenose dolphin is only frequent on the Atlantic coast (Laporta, 2009).

Interactions between artisanal fisheries and bottlenose dolphins in the SAO have been reported. On the Brazilian coast, positive interactions are characterized mainly as those in which the fishermen understand that bottlenose dolphins assist fishing activities (e.g., Pryor et al., 1990; Simões-Lopes, 1991; Simões-Lopes et al., 1998; Przbylski and Monteiro-Filho, 2001; Peterson et al., 2008; Zappes et al., 2011a). The main negative interaction with fishing refers to mortality due to accidental involvement with gillnets in some areas of the SAO (Fruet et al., 2011). In Brazil, bycatch of the bottlenose dolphin has been described in the northeast (Siciliano, 1994), southeast (Siciliano, 1994; Zerbini and Kotas, 1998) and south (e.g., Simões-Lopes and Paula, 1997; Zerbini and Kotas, 1998; Fruet et al., 2010). For artisanal fishermen, negative interactions between fisheries and bottlenose dolphins generally relate to accidental catches that cause damage to the fishing gear and/or the death of the dolphins, collisions with boats or when these populations move the target fishery schools during the execution of their feeding behaviors (Przbylski and Monteiro-Filho, 2001; Zappes et al., 2011b, 2013a). In Uruguay, studies of interactions between small cetaceans and artisanal fisheries began to be conducted in the 1970s (Brownell and Praderi, 1974). Studies of the bottlenose dolphin have reported that bycatches in fisheries are fairly rare (Praderi, 1985, 1990), but these captures do occur and are caused by gillnets (Praderi, 1985; Franco-Trecu et al., 2009).

Traditional fishing communities can provide practical and theoretical information based on their observations of the biology and ecology of animals distributed in their region (Costa-Neto, 2000; Zappes et al., 2013b). This information represents the accumulation of years of experience in activities related to the use of marine resources in the environment in which they live, allowing the construction of a culture integrated with nature as well as appropriate forms of management. This knowledge is called ‘local ecological knowledge’ (LEK) and is passed on from generation to generation within the community (Begossi, 1995; Diegues, 2001).

In Brazil, the ethnobiological studies dealing with the local perceptions of fishing communities about the bottlenose dolphin only include works carried out by Peterson et al. (2008), Zappes et al. (2010, 2011a), Zappes et al. (2011b, 2013a). To date, no studies on the bottlenose dolphin have taken this approach in Uruguay. Thus, due to the scarcity of information about the LEK related to bottlenose dolphins in the SAO, this study aimed to describe and compare the state of artisanal fishermen's knowledge of this dolphin and its interaction with artisanal fisheries along the coasts of Brazil and Uruguay. Our results suggest potential effective measures based on this LEK for the reduction of anthropic impacts on coastal natural populations of the bottlenose dolphin.

Bycatch of bottlenose dolphins by gillnets used in artisanal fisheries is considered the main anthropic impact on coastal populations of this dolphin (Siciliano, 1994; Simões-Lopes and Paula, 1997; Zerbini and Kotas, 1998; Fruet et al., 2010). In this sense, local knowledge is important for scientific studies focused on marine organisms, such as cetaceans, because fishing activities directly influence the way of life of these species (Castro, 2000; Zappes et al., 2010). Although several studies on the local knowledge of artisanal fishermen about the bottlenose dolphin have been conducted in Brazil (e.g., Peterson et al., 2008; Zappes et al., 2010, 2011b, 2013a, 2011a, 2011b, 2013a), these studies did not compare the state of this knowledge among fishermen of different regions of the SAO and did not provide specific management proposals to contribute to the conservation of this dolphin in our study areas. Finally, no studies have adopted this approach for examining the LEK about the bottlenose dolphin in Uruguay.

2. Material and methods

2.1. Area of study

This study was carried out in artisanal fishing communities of the Brazilian (Arquipélago das Cagarras – AC, Barra de Imbé/Tramandaí – BIT, and Lagoa dos Patos – LP) and Uruguayan coasts (Punta del Diablo – PD, Cabo Polonio – CP, and La Paloma – LPA) (Fig. 1). Populations of bottlenose dolphin in these locations have coastal habit, which enables contact with the artisanal fishermen during fishing activities.

The Arquipélago das Cagarras (AC) (23°01′S; 43°12′W) is located off the coast of the city of Rio de Janeiro, State of Rio de Janeiro, southeastern Brazil, approximately 3 km from the coastline. Bottlenose dolphins are primarily distributed in the inner area of this archipelago, near the coast, increasing the susceptibility of these dolphins to impacts caused by anthropic activities such as artisanal, sport and recreational fisheries (Barbosa et al., 2008; Lodi and Monteiro-Neto, 2012). According to these studies, there are no current population estimates for the bottlenose dolphin in the AC, which features seasonal resident population occurring mainly between August and November. The information available for the region between 2004 and 2010 reports the occurrence of 4–11 groups/year composed of 3–30 individuals (Lodi and Monteiro-Neto, 2012). In this study, we interviewed artisanal fishermen associated with the Z-13 Fishermen Association of the municipality of Rio de Janeiro, which has 80 members, and the Z-08 Fishermen Association of the municipality of Niterói, with 40 members who work in the AC (Fundação FUNDAÇÃO PROZEE, 2005).

The lagoon-estuarine system of Barra de Imbé/Tramandaí (BIT) (29°57′S; 050°11′W) is located to the north of the State of Rio Grande do Sul, southern Brazil. Bottlenose dolphins are primarily distributed at the mouth of the BIT estuary. This area features a cooperative fishery with strong positive interactions between fishermen and dolphins (Simões-Lopes, 1991; Simões-Lopes et al., 1998; Zappes et al., 2011a). The resident population of bottlenose dolphins in the region was estimated at nine individuals sighted throughout the year; this population size has been maintained for more than a decade (Simões-Lopes et al., 1998; Simões-Lopes and Fabián, 1999). In this region, there are 40 artisanal fishermen registered in the Fishermen's Union of Tramandaí.

Lagoa dos Patos (LP) (32°09′S; 52°05′W), also located in the State of Rio Grande do Sul, has a total area of 9 270 km^2 and an estuarine area of 870 km^2. The estuary is linked to the Atlantic Ocean through a narrow channel (0.5–3 km wide) formed by two stone piers with an approximate extension of 4 km towards the sea (Vooren et al., 2005). Bottlenose dolphins are distributed within this channel and adjacent coastal areas throughout the year, and the population is estimated at 70 to 90 individuals (Fruet et al., 2011). There are 100 artisanal fishermen who are registered in the Z-01 Fishermen Association in the municipality of Rio Grande and work in the southern area of Lagoa dos Patos.

Relative to other areas in Uruguay, the Atlantic coast has the highest occurrence of bottlenose dolphins. The most important traditional artisanal fishing ports in this region are Punta del Diablo (PD) (34°22′S; 53°46′W), Cabo Polonio (CP) (34°23′S; 53°46′W) and La Paloma (LPA) (34°39′S; 54°10′W) (Franco-Trecu et al., 2009).

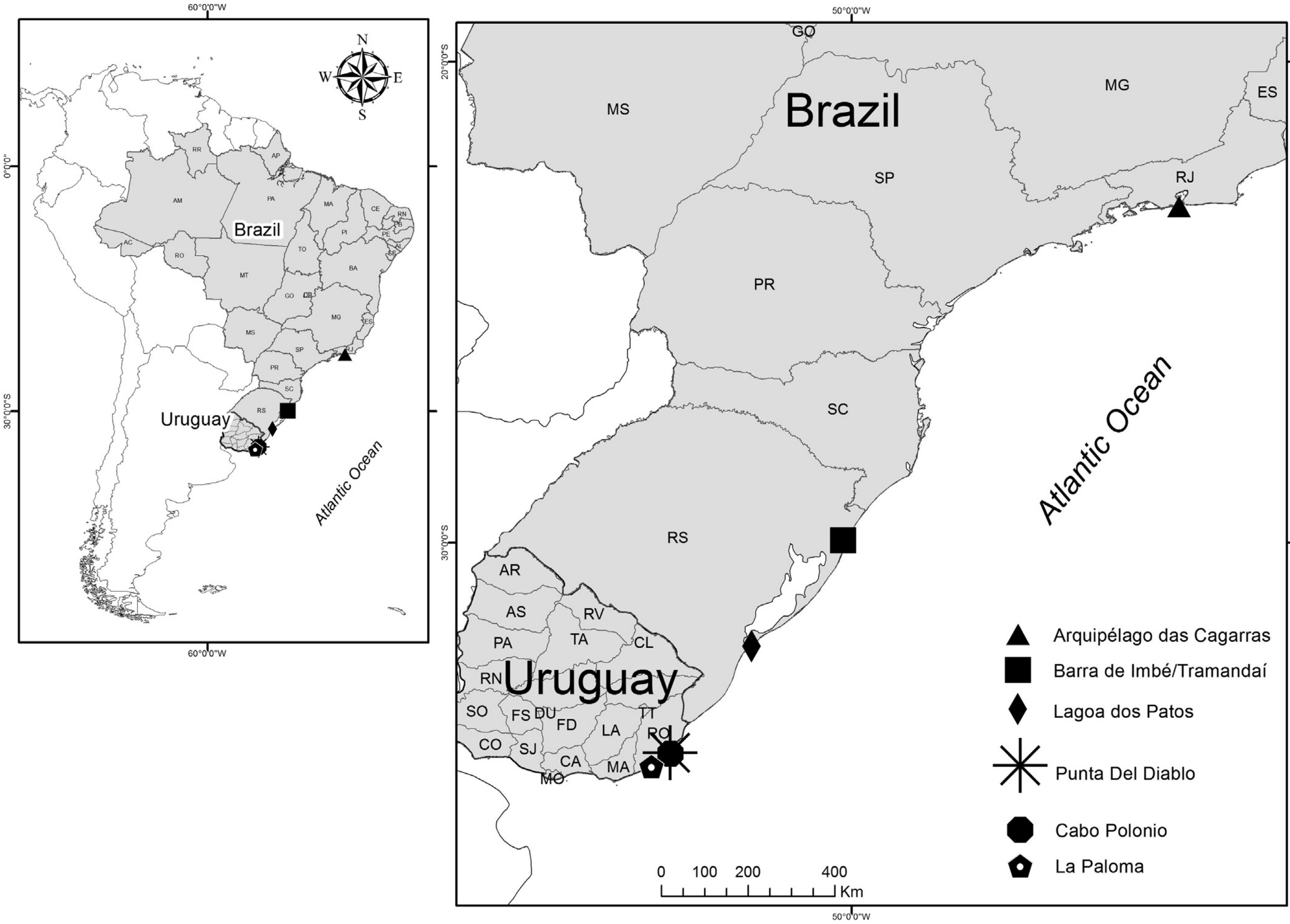

Fig. 1. Areas of study regarding the interaction between bottlenose dolphins (*Tursiops truncatus*) and artisanal fishing in the Southwest Atlantic Ocean: Brazil and Uruguay.

The fishermen involved in artisanal coastal fishing work throughout the year in the same locality, though they shift to estuarine areas during the austral autumn (March to May) and winter (June to August). Information on bottlenose dolphins indicates their occurrence throughout the year and mainly in marine coastal areas (Laporta, 2009). The first estimate of population abundance of the bottlenose dolphin in Uruguay indicated a population size of 55 individuals (Laporta, 2009). Unlike Brazil, Uruguayan fishermen are not registered in institutions organized by the community as fishing associations but rather in the *Dirección Nacional de Recursos Acuáticos* (DINARA), which is a state entity responsible for regulating and controlling the fishing activity in the country.

2.2. Procedures

Between 2008 and 2011, we performed 88 ethnographic interviews with artisanal fishermen distributed in Brazil (AC: $N = 22$; BIT: $N = 22$; LP: $N = 22$ and Uruguay (PD/CP/LPA: $N = 22$). The three areas studied in Uruguay were considered a single fishing area due to the short distance between them.

In qualitative studies, frequencies are rarely important because when a sample size is large and numerous reports are collected, additional data do not necessarily present new information related to the objectives of the research, which can become repetitive (Crouch and McKenzie, 2006; Mason, 2010). In qualitative research related to human ecology, the culture and symbolism of a community are related, such that the level of reality cannot be quantified. Therefore, the research should consider the real meanings of the reports, which cannot be reduced to variables (Kendall, 2008). In this sense, studies related to local ecological knowledge are subjective and complex because they are based on the beliefs and symbols of a community (Begossi, 1992).

Ethnoscience studies describe an ideal sample size between 30 and 60 interviews (Morse, 1994; Bernard, 2000; Mason, 2010). As in this study, other ethnobiological studies of fishermen's perception of marine mammals in southeastern and southern Brazil also used sampling rates equivalent to less than 50% of the fishermen registered in local fishing institutions: Souza and Begossi (2007) reported an average of five respondents in each community in São Sebastião, state of São Paulo; Peterson et al. (2008) had 51 interviews in Laguna, state of Santa Catarina; Zappes et al. (2011a) reported 22 interviews in the Bar Imbé/Tramandaí, state of Rio Grande do Sul; Alves et al. (2012) had 16 respondents in Central Amazon; Zappes et al. (2013a) described between 16 and 44 interviewees in the Central Amazon and along the Brazilian coast; and Zappes et al. (2013b) reported 33 interviews in the Southern Right Whale Environmental Preservation Area (EPA) in the state of Santa Catarina. Based on these studies of similar communities, our sample size of 88 respondents is sufficient for obtaining ethnobiological information.

The method of participant observation was applied as the first step of this study (Malinowski, 1978; Schensul et al., 1999). The selection of fishermen for interviews was carried out in three steps:

1) assistance provided by the presidents of the fishing associations or by fishermen who represented the groups in each area studied (Sanches, 2004); 2) snowball sampling technique; and 3) randomization of the sample. The selection of the first interviewee involved the collaboration of the president of the fishermen's association, while the second respondent was identified using the snowball sampling technique (Goodman, 1961; Biernacki and Waldorf, 1981; Bailey, 1982; Patton, 1990). The snowball method could be stopped, and the approach to the next fisherman occurred at random through opportunistic encounters. Three criteria were established for the application of these methods (Peterson et al., 2008): 1) all respondents should be artisanal fishermen; 2) fishing should be their main professional activity; and 3) artisanal fishery activities should be practiced in areas with bottlenose dolphin occurrence.

In the interviews, we applied a pre-established questionnaire containing semi-structured open-ended ($N = 40$) and closed ($N = 17$) questions that allowed the incorporation of new information during the dialogs (Schensul et al., 1999; Kendall, 2008). This questionnaire was divided into four categories: 1) description of artisanal fisheries; 2) characteristics of the bottlenose dolphin; 3) interactions between bottlenose dolphins and artisanal fisheries; and 4) solutions to possible conflicts between bottlenose dolphins and artisanal fisheries.

An illustrative chart containing photographs of five odontocete species present in each area of study was presented at the end of the interview as a visual ethnography tool to assess the recognition and differentiation of the bottlenose dolphin by the fishermen (Miranda et al., 2007). One photograph of a bottlenose dolphin was present among these images. The size of the cetaceans in the photographs was not proportional to their actual size; this was explained to the respondents.

In the final step of the interview, we asked every fisherman to provide a description of the main target fish species in the region. The fish indicated was photographed and later identified at the lowest taxonomic level possible by specialists from the area through specific identification guides.

2.3. Data analysis

The answers were grouped into themes as a means of interpreting the reports, and discourse analysis was applied for the assessment of the LEK of the bottlenose dolphin and interactions with the artisanal fisheries (van Dijk, 1993; Bogdan and Biklen, 1994).

The selection of fishermen who correctly identified the bottlenose dolphin was performed through an inference system based on *fuzzy* logic rules using MATLAB (version 7.6) software (see Zappes et al., 2010, 2011b). Fishermen who accurately identified bottlenose dolphin individuals based on this *fuzzy* logic were those whose responses included the following characteristics: body size between 1.70 and 4.0 m (see Jefferson et al., 1993; Bastida et al., 2007; Fruet et al., 2010); gray color (see Jefferson et al., 1993; Bastida et al., 2007); and the appropriate area of occurrence within the study area ('beach/mouth', 'coast', 'open sea', 'Arquipélago das Cagarras and surrounding areas') (see Castello and Pinedo, 1977; Simões-Lopes, 1991; Simões-Lopes et al., 1998; Bastida et al., 2007; Barbosa et al., 2008; Laporta, 2009; Lodi, 2009). We only analyzed reports from those fishermen selected through *fuzzy* logic who described the aforementioned characteristics correctly.

In our analysis of the reports, we also used the method of triangulation, with the objective of crossing and filtering information collected with the various methods applied (participant observations and interviews (questionnaires, recordings, and use of charts) (Jick, 1979). To that end, we applied the same questionnaire to different subjects in the same period and in each area studied (Opdenakker, 2006).

An analysis of variance using the Kruskal–Wallis test (BioEstat 5.0) was applied to verify the significance of differences in the identification of the bottlenose dolphin as well as to analyze differences between proportions (STATISTICA 8.0) to compare the types of interactions between the bottlenose dolphin and the studied areas.

3. Results

From a total of 88 fishermen interviewed, 79 (89.8%) were able to correctly identify the bottlenose dolphin: Brazil – AC ($N = 17$; 21.5%), BIT ($N = 22$; 27.9%), and LP ($N = 22$; 27.9%); Uruguay ($N = 18$; 22.7%). A significant difference in the accurate identification of the bottlenose dolphin was found between fishermen of different study areas ($H = 5.3976$; g.l. = 1; $p = 0.0202$). Based on this result, subsequent analyses were based on these 79 interviews. In the areas studied, fishermen called the bottlenose dolphin by different names: AC – *boto* or dolphin; BIT and LP – *boto*; and Uruguay – *tonina*.

3.1. Characteristics of artisanal fishing activities in the study areas

In Brazil, the preferred period for the practice of artisanal fisheries is at dawn/morning, whereas no such preference exists in Uruguay. The main gear include gillnets and longlines, which can be used both on the high seas and coastlines. Fishermen in BIT use the smallest boats with low engine power because fishing is mainly practiced on the beach of the Tramandaí River mouth using cast nets, and it is not necessary to use large boats. In the Brazilian areas of AC and LP and the Uruguayan areas of PD/CP/LPA, boats have greater autonomy, which allows for the exploration of other fishing areas. Table 1 provides information on artisanal fishing practices in the study areas.

3.2. Interactions between the bottlenose dolphin and artisanal fisheries

Among the 79 fishermen interviewed, 50.6% ($N = 40$) described the occurrence of positive interactions. All of the fishermen from BIT ($N = 22$) and 18 fishermen from LP reported this type of interaction. Positive interactions are related to aid provided by the bottlenose dolphin during fishing activities, as the dolphins indicate the location of the school. This aid refers to the fact that dolphins: 1) corner the school towards the mouth of the estuary; 2) drive the fish to the beach; and 3) help when fishermen fish with a cast net. Among the fishermen of BIT, 31.8% ($N = 7$) reported that the aid from the dolphins is unintentional because it is related to their feeding behavior. In LP, 11.1% ($N = 2$) of the fishermen also reported that the dolphins' aid is not intentional because the dolphins only display fishery behavior, and fishermen enjoy this opportunity to capture more fish.

Negative interactions were described by 26.6% ($N = 21$) of the fishermen. All fishermen from AC ($N = 17$) reported such interactions, distributed as follows: 15 reported that the bottlenose dolphin frightens the school away, one commented that the dolphins rip the net, and one reported that they get trapped in the net. In BIT, even though all fishermen reported positive interactions, four also mentioned negative interactions. These were related to the bottlenose dolphins because they: 1) removing and stealing fish from the cast nets by raising the lead weights; 2) ripping the mesh if their calves get stuck in the cast net; and 3) deceiving the fisherman by not correctly revealing the location of the school.

Table 1
Description of artisanal fishing practices in Arquipélago das Cagarras (AC) and surrounding areas, Barra de Imbé/Tramandaí (BIT) and Lagoa dos Patos (LP) along the Brazilian coast, and in Punta del Diablo (PD), Cabo Polonio (CP) and La Paloma (LPA) along the Uruguayan coast, according to the reports of the fishermen interviewed.

Location	Fishing period	Fishing area	Gear	Boat	Target species
AC	Dawn/Morning	Area adjacent to AC Area adjacent to AC Inner area of AC Inner area of AC	Gillnet – positioned next to the bottom or on the surface (length: 200 to 3 000 m). Installation in the water – 06:00 PM; withdrawal of water – 05:00 AM. Longline (Length: 600 m). Installation in the water – 06:00 PM; withdrawal of water – 05:00 AM. Fishing line or bait (length varies according to depth; it can have 1 or more hooks). Installation in the water – 06:00 PM; withdrawal each hour until to 08:00 AM. Harpoon (used in underwater fishing during morning).	Trawler (length: 8–14 m/engine power: 18 to 210 HP) Boat (length: 10 m/engine power: 210 HP) Boat (length: 85 m/engine power: 5 HP) Whaling boat (length: 4–7 m/engine power: 7 to 18 HP)	Anchovy (*Pomatomus saltator*) Blue runner (*Caranx crysos*) Mahi–mahi (*Coryphaena hippurus*), Sardine (*Brevoortia aurea*) Croaker (*Micropogonias furnieri*) Mullet (*Mugil* spp) Little tunny (*Euthynnus alletteratus*) Sole (Order Pleuronectiformes) Hake (*Cynoscion microlepidotus*) Black grouper (*Mycteroperca bonaci*) Dusky grouper (*Epinephelus marginatus*) Bigeye (*Priacanthus arenatus*) Angel shark (*Squatina squatina*) Sand shark (*Rhinobatus* spp)
BIT*	Dawn/Morning	Mouth of Tramandaí River and, in lower scale, in the inner area of the lagoon and the beach	Cast net (Circumference: 31–37 m - this net is launched all the time in the water); gillnet (length: 50 to 1 200 m). Installation in the water – 06:00 PM; withdrawal of water – 05:00 AM. Longline (length: 100 m). Installation in the water – 06:00 PM; withdrawal of water – 04:00 AM. Fishing line (length varies according to depth; it can have 1 or more hooks). Installation in the water – 06:00 PM; withdrawal each hour until – 05:00 AM. Codend net (length: 18 m). Installation in the water – 06:00 PM; withdrawal of water – 05:00 AM.	Fiberglass kayak (length: 6 m/engine power: 3.5 HP) Paddle canoe (length: 5–7 m)	Mullet (Mugil spp) Catfish (*Genidens genidens*) Croaker (*M. furnieri*) Silverside (*Atherinella brasiliensis*) Southern kingfish (*Menticirrhus americanus*) Sea bass (Centropomus spp.) Anchovy (*P. saltator*) Wolf fish (*Hoplias malabaricus*) Pompano (*Trachinotus marginatus*) Sardine (*B. aurea*) Sand shark (Rhinobatus spp.) Atlantic seabob (*Xiphopenaeus kroyeri*)
LP	Dawn/Morning	Estuarine area of the lagoon (south portion)	Gillnet – positioned next to the bottom or on the surface (length: 50 to 5 000 m). Installation in the water – 06:00 PM; withdrawal of water – 05:00 AM. Codend net (length: 18 m). Installation in the water – 06:00 PM; withdrawal of water – 05:00 AM. Cast net (circumference: 20 to 37 – this net is launched all the time in the water); Beach netting (length: 18 m) – installation in the water – 06:00 PM; withdrawal of water – 05:00 AM.	Boat (length: 5–12 m/engine power: 10 to 60 HP) Canoe (length: 8 m/engine power: 18 HP) Trawler (length: 18–20 m/engine power: 280 HP)	Mullet (Mugil spp.) Catfish (*Genidens genidens*) Croaker (*M. furnieri*) Flounder (*Paralichthys orbignyanus*) Silverside (*Atherinella brasiliensis*) Southern kingfish (*Menticirrhus americanus*) Anchovy (*P. saltator*) Wolf fish (*Hoplias malabaricus*) Sand shark (Rhinobatus spp.) Atlantic seabob (*Xiphopenaeus kroyeri*)
PD/CP/LPA	During all day and night	Coastline with depth between 13 and 50 m	Gillnet (length: 1 800 to 7 200 m). There is no preference for time of installation and removal, but the gillnet may stay in the water during 06 h. Longline (length up to 7 000 m). There is no preference for time of installation and removal, but the longline may stay in the water during 04 h. Demersal trawl (horizontal opening: 9 m). This trawl is dragged in water for 1 h – is hoisted and clean and again dragged in water. This procedure can last up to 6 h.	Vessel with housing facility and internal- or external-type engine (length: 5–10 m/engine power: 15 to 180 HP)	Brótola (*Urophycis* spp.) Mero (*Epinephelus* spp.) Merluza (*Merluccius* spp.) Corvina (*M. furnieri*) Pescadilla (Family Sciaenidae) Pargo (*Pagrus pagrus*) Gatuzo (*Mustelus* spp.) Angelito (*Squatia* spp.) Camarón-rojo (Família Penaeidae)

* In the area of BIT, the fishermen do not use boats much, since fishing with cast nets is prevalent and performed from the beach.

Respondents from Uruguay (PD/CP/LPA) did not describe any type of interaction between fisheries and the bottlenose dolphin. A significant difference was found between the reports about the types of interactions that occur between the bottlenose dolphin and artisanal fisheries in the studied areas ($p = 0.0385$).

Only six (7.6%) fishermen reported accidents involving the bottlenose dolphin and fishery activity. A fisherman from BIT reported never having witnessed accidents with dolphins, but he knew that such events occurred because bottlenose dolphins had appeared dead on the beach with net marks. A fisherman from LP reported a collision with a canoe, and another fisherman from the same area reported that a dolphin being caught in a fishing net was considered an accident. Although the Uruguayan fishermen did not report any interactions between fishing activities and the bottlenose dolphin, three related accidents involving the dolphins as accidental catches in fishing nets.

With respect to dolphins appearing as bycatch, 58.2% ($N = 46$) of fishermen reported such events: 34.8% ($N = 16$) in BIT; 32.6% ($N = 15$) in AC; and 28.3% ($N = 13$) in LP, Brazil, and 4.3% ($N = 2$) in Uruguay (PD, CP and LPA). Forty-five fishermen (97.8%) cited gillnets as the gear responsible for enmeshing; only one from BIT reported the appearance of a dolphin in a cast net.

Among the fishermen who reported enmeshing, 45.6% ($N = 21$) indicated estimates for these catches in their respective fishing areas: 10 dolphins/year ($N = 1$; 4.8%); 5 dolphins/year ($N = 1$; 4.8%); 1-2 dolphins/year ($N = 10$; 47.6%); 1 dolphin every 4 years ($N = 2$; 9.5%); and 1 dolphin every 10 years ($N = 7$; 33.3%). Twenty-three fishermen mentioned that enmeshing occurs because the dolphins do not see the nets in the water.

Among the 46 fishermen who reported enmeshing, 30 (65.2%) stated that there was no solution to avoid this problem. The three solutions reported suggested not using gillnets, leaving spaces between long gillnets and changing the position of gillnets in the water. All respondents from BIT and LP who reported the occurrence of accidental catches stated that they did not want to change the position of the nets in the water because this would cause them to be excluded from the best fishing areas. The fishermen did not answer this question in AC and Uruguay.

The areas of described bycatch occurrences were the coast, AC and surrounding areas, the inner area of LP, and mouth/breakwaters. The fishermen reported that carcasses of bottlenose dolphins enmeshed in fishing nets were treated as follows: disposal at sea ($N = 36$; 78.3%); sale ($N = 4$; 8.7%); family consumption ($N = 3$; 6.5%); or as bait for catching cartilaginous fish in longline fisheries ($N = 3$; 6.5%).

4. Discussion

In BIT and LP in southern Brazil, respondents were able to recognize the bottlenose dolphin due to the close contact of these fishermen with the dolphins. The total overlap in their use of these areas allows daily encounters between fishermen and dolphins, the development of cooperative fishing and extended periods of time for the fishermen to observe the dolphins (Simões-Lopes, 1991; Zappes et al., 2011a, 2013a). This contact allows the fishermen to establish empirical knowledge of the dolphins with which they coexist (Mourão et al., 2006; Zappes et al., 2009, 2013b). In the AC area of southeastern Brazil, the interviewees do not encounter the bottlenose dolphin throughout the full year due to the seasonal occurrence of the population in this region (Barbosa et al., 2008; Lodi, 2009). The population of bottlenose dolphins near the Uruguayan fishing areas has been sighted throughout the year in an area located between 500 and 1 000 m from the coastline (with a preference for the wave-breaking line), where fishing is not usually practiced (Laporta, 2009). The main fishing areas of the Uruguayan communities examined are located beyond 9 000 m from the coastline (Franco-Trecu et al., 2009). Most likely, the more limited contact of AC and Uruguayan fishermen with the bottlenose dolphin reduces the possibility of regular observations as compared with fishermen from BIT and LP.

Cooperative fisheries were initially reported in Brazil in BIT (Simões-Lopes, 1991) and Laguna (28°29′S; 48°45′W) in the State of Santa Catarina (Pryor et al., 1990; Simões-Lopes, 1991). The fishermen from BIT and Laguna described in detail the importance of this practice for their family income (Simões-Lopes, 1991; Peterson et al., 2008; Zappes et al., 2011a). In LP, in southern Brazil, there was no description of this type of cooperative fishing in the literature. The fishermen from BIT and LP note that although the dolphins help with fishing, it is not intentional because it is part of their feeding behavior. This type of interaction likely occurs in estuarine areas due to the local geography that makes it easier for bottlenose dolphins to fish and feed, as they can round up and encircle the school and push it to a barrier, such as the relief in the mouth of BIT or the breakwaters of LP. This same strategy was reported for the *boto-cinza* (*Sotalia guianensis*) (estuarine dolphin), which is another species of coastal dolphin in the Iguape-Cananéia Estuarine Lagoon Complex (25°00′S; 47°55′W) in the State of São Paulo, southeastern Brazil (Monteiro-Filho, 1995).

In other parts of the world, human-dolphin cooperative fisheries and human-dolphin interactions in the catching of mullet have been reported in Narbonne, Australia (Busnel, 1973), with aboriginal Australians (Neil, 2002) and fishermen in Myanmar (Smith et al., 2009) and Chilica Lagoon, India (D'Lima et al., 2013). These interactions occur in areas where the dolphins approach the beach to use the sand as a barrier to corral the schools. The fishermen have come to value this technique because it can facilitate the capture of fish while reducing the amount of effort invested due to improved accessibility of the schools (Pryor et al., 1990; Simões-Lopes, 1991; Zappes et al., 2011a). These interactions have developed over a period of decades, and the dolphins do not identify man as a threat because fishermen do not catch dolphins in these regions.

For the fishermen of AC, negative interactions with dolphins 'frightening the schools away' directly affect fishing by preventing fish catches. In these situations, the dolphins approach the boat and frighten the fishery targets away (Zappes et al., 2011b). This generates a feeling of 'anger' towards the dolphins and causes financial loss because the fishermen sometimes give up fishing and return to port. The loss is related to spending on fuel, the purchase of ice for fish conservation and feeding the crew on board. Zappes et al. (2009) report that the *boto-cinza* causes this same type of interaction and losses for artisanal fisheries in the State of Bahia, northeastern Brazil, and in the states of Espírito Santo and Rio de Janeiro, southeastern Brazil.

The removal of fish caught in cast nets by bottlenose dolphins, described by fishermen from BIT, is not an interaction that affects fishing. According to the fishermen, the amount of fish 'stolen' is small compared with that revealed by the dolphins for catching. Other studies have described the feeding of bottlenose dolphins from nets in North America, Sardinia and the Mediterranean Sea (Lauriano et al., 2004; Zollet and Read, 2006; Brotons et al., 2008a; Rocklin et al., 2009). Another interaction, described as 'cheating the fisherman', was related to the bottlenose dolphin indicating the wrong location of the school during cooperative fishing in the same region. When working in conjunction with this type of dolphin, the amount of fish caught by the fishermen is low. The fishing community from BIT has previously demonstrated knowledge of the behavioral ecology of the bottlenose dolphin in this region (Zappes et al., 2011a).

Fishermen described bycatch separately from other negative interactions. Gillnets are the main gear responsible for bottlenose dolphin enmeshing in the SAO. On the coasts of Brazil and Uruguay, this gear is primarily responsible for accidental catches of small costal and oceanic cetaceans (e.g., Praderi, 1985; Siciliano, 1994; Di Beneditto, 2003; Franco-Trecu et al., 2009; Fruet et al., 2010). In this study, we attempted to estimate the annual amount of accidental catches of bottlenose dolphin from the fishermen's knowledge, but they did not feel comfortable quantifying the total volume of bycatches. This may be related to the fact that fishermen are aware that harassing and catching cetaceans is prohibited in the SAO (in Brazil by Federal Law N^o. 7 643/87 and in Uruguay by the Decree-Law N^o. 238/98, Art. 1, 2 and 3).

Studies have described that bycatch of bottlenose dolphins by gillnets are considerably lower in Uruguay (Praderi, 1985, 1990). Nevertheless, there is a preoccupation related to dolphin bycatch in LP, Brazil. According to the analysis of Fruet et al. (2010) of the viability of the bottlenose dolphin population in LP, there is a 75.5% probability of population decline given the current levels of bycatch, even with a 50% reduction in the effort of the fishery. This projection is worrying because according to Laporta (2009), individual dolphins have been displaced between the Uruguayan coast and LP in Brazil. Despite the flow of dolphins between these two areas, it is believed that gillnet bycatch in LP can interfere with the size of the Uruguayan population (Laporta, 2009). In this sense, bycatch of bottlenose dolphins in southern Brazil must be minimized to decrease the negative influence on the populations of not only this country but also that of Uruguay.

Conflicts between fisheries and bottlenose dolphins have also been described in other parts of world, including the Mediterranean Sea (Bearzi et al., 2011), Asinara Island National Park, Sardinia (Lauriano et al., 2004; Díaz López and Shirai, 2007), South Australia (Kemper et al., 2005), the Balearic Islands (Brotons et al., 2008a), and the east coast of South Africa (Natoli et al., 2008). In all of these areas, these encounters injure both the fishermen, who may lose artifacts or fishing effort, and the dolphins, as they can be injured or killed.

The fishermen interviewed indicated that the main cause of enmeshing was that bottlenose dolphins do not see fishing nets under the water. To maximize the efficiency of fish catches, the nets are designed in such a way as to hamper being seen underwater (Dawson, 1991). For this reason, the failure to detect the net filaments is one of the factors that contribute to dolphin enmeshing (Tregenza et al., 1997). However, the problem of enmeshing may be more accurately attributable to the dolphins' failure to perceive the net as an obstacle because the dolphins may perceive the net as a penetrable object. There is also the possibility that the dolphins fail to distinguish the reflection of their sonar as belonging to their prey or to the nets (Au and Jones, 1991). During this study, it was made clear that some fishermen feel that the dolphin should detect the net in the water and divert from the obstacle. The fishermen described several solutions to avoid accidental catches of bottlenose dolphins, including not using gillnets, changing their position in the water and leaving spaces between extensive nets for the dolphins to pass by. Similar proposals were reported by Au and Jones (1991) and Valdemarsen and Suuronen (2001).

The installation of mechanical signs in the nets, such as rattles and bells, or electronic signs that emit sound pulses of high and low frequencies can make the gear acoustically apparent to cetaceans (Jefferson and Curry, 1996; Bordino et al., 2002; Brotons et al., 2008b). The emission of biological sounds (playback method) that simulate the vocalization of natural predators of cetaceans, such as the killer whale (*Orcinus orca*), may also prevent their approach into areas where the fishing nets are positioned (Jefferson and Curry, 1996). On the other hand, it is possible that the installation of such signs in fishing nets could train and acclimate the cetaceans to feed directly from the nets, acting as a 'bell calling for lunch' (Dawson, 1991). In this study, the fishermen reported that the installation of signs would make artisanal fishing impossible, particularly because of the costs. They also mentioned their concern that the signs could interfere with fish catchability.

Regarding the carcasses of bottlenose dolphins caught accidentally, disposal was the most frequently mentioned destination. The fishermen were afraid to keep the carcasses inside the boat and bring them to shore because the manipulation of the cetaceans without permission is forbidden in Brazil (Federal law N^o. 7 643/87) and Uruguay (Decree-Law N^o. 238/98, Art. 1, 2 and 3). The consumption of accidentally caught bottlenose dolphins for food purposes was reported in AC and LP by only a few fishermen, indicating that it is not a common practice. Other authors have already reported this type of consumption and use of carcasses for medicinal and religious purposes by fishing communities in Brazil (Siciliano, 1994; Przbylski and Monteiro-Filho, 2001; Ferreira et al., 2006; Alves and Rosa, 2008; Zappes et al., 2009). Along the Uruguayan coast, there are records of porpoise meat consumption (Laporta, P., *personal communication*). The justification given by fishermen for the limited consumption of accidentally caught dolphins relates to their unpleasant taste, which has also been recorded in other studies (e.g., Ferreira et al., 2006; Zappes et al., 2009). The use of the fat layer and muscle of carcasses as bait for elasmobranch fisheries was reported to occur in AC. According to the fishermen, the musculature releases a great deal of blood into the water and attracts sharks. This practice has been described in Brazil since the 1990s (Lodi and Capistrano, 1990; Zappes et al., 2009), but there is no record of this practice occurring in Uruguay. Within the reports of the fishermen, we did not identify any intention to catch bottlenose dolphins, but only the use of the carcasses when incidental catches occur.

In a genetic study, five distinct communities, or Management Units, of bottlenose dolphins were identified in southern Brazil and Uruguay (Fruet et al., 2014). In these areas, human activities can negatively impact these dolphins (Fruet et al., 2010, 2011). In AC, little is known about the real effects of artisanal fisheries on the bottlenose dolphin population. Nevertheless, Lodi and Monteiro-Neto (2012) suggested that measures limiting fishing activities in AC are essential for inclusion in the management plan for this marine protected area.

In this sense, understanding the impacts caused by artisanal fisheries on bottlenose dolphin populations in SAO involves working with fishery management and consequently acting with fishing communities. Ecological knowledge has contributed to the development of fishery research and can help in establishing guidelines for the development of educational programs related to the conservation of bottlenose dolphins and fishery management (Bandara and Tisdell, 2003; Aswani and Hamilton, 2004). Understanding the diversity of knowledge and values is crucial because the interaction between local communities and public managers can be complex (Reed, 2008). Ethnobiological studies of fishery communities are also important because they may justify the inclusion of local fishermen in management decisions in priority conservation areas, such as the Brazilian and Uruguayan coasts (Paz and Begossi, 1996).

4.1. Comparison of the LEK about the bottlenose dolphin in the areas studied

In AC, despite the fact that the fishing area apparently does not overlap with the area described as having a higher occurrence of bottlenose dolphin (Barbosa et al., 2008; Lodi, 2009), the fishermen reported that dolphins disturb their fisheries (Table 2). In BIT and LP, the fishermen's contact with bottlenose dolphins occurs daily

Table 2
Comparison of local ecological knowledge (LEK) about the bottlenose dolphin (*Tursiops truncatus*) and immediate issues for environmental education activities in each study area.

Country	Area*	Identification of the species through *fuzzy* analysis	Interactions	Need for environmental education
Brazil	AC	Partial	Well described	High: seeking solutions to reduce bycatches of bottlenose dolphin together with the community.
	BIT	Complete	Well described	Medium: identifying the interference of bycatches on the viability of the local population of the bottlenose dolphin.
	LP	Complete	Partially described	High: seeking solutions to reduce bycatches of the bottlenose dolphin inside the estuary and surround coastal areas together with the community.
Uruguay	PD/CP/LPA	Partial	Not described	High: to understand the areas of occurrence and displacement of the local population and the increased risk of bycatches of bottlenose dolphin during these shifts.

* AC – Arquipélago das Cagarras; BIT – Barra de Imbé/Tramandaí; LP – Lagoa dos Patos; PD – Punta del Diablo; CP – Cabo Polonio; LPA – La Paloma.

because both use the same area. However, even though the fishermen from LP maintain this type of contact, they were unable to register the occurrence of accidental catches, already reported for the region in the literature (Castello and Pinedo, 1977; Fruet et al., 2010) (Table 2).

In Uruguay, some fishermen were able to identify the bottlenose dolphin; however, no interactions with fisheries were reported. Even so, fishermen described the occurrence of enmeshing and disposal of carcasses, indicating that they most likely do not regard accidental catches as negative interactions with dolphins (Table 2). The fishing area and the area of bottlenose dolphin occurrence do not overlap, so the fishermen tend to observe this dolphin from the coast, where some of them live, or in opportunistic occasions during the outward and return journeys between the fishing port and the fishing area.

5. Conclusions

Although there is limited contact between fishermen from AC and the population of bottlenose dolphins, considered seasonal residents, they do have partial knowledge of these dolphins. In BIT and LP, all fishermen identified the bottlenose dolphin correctly and demonstrated feelings of respect and gratitude because the dolphins assist with fisheries. In Uruguay, the fishermen showed incipient local knowledge of human interactions related to the bottlenose dolphin, most likely due to their limited contact with the dolphins and the reduced occurrence of accidental catches in fishing nets.

From this interpretation of the fishermen's knowledge about bottlenose dolphins along the coasts of Brazil and Uruguay, we can propose measures that will contribute to the conservation of this dolphin. To assess the interference of artisanal fishing on the bottlenose dolphin, it is necessary to regularly monitor their areas of use and the locations where gillnets are arranged along the SAO. Fisheries' impact assessments should consider the size of the dolphins' populations and the fishing effort in a given region. To lessen the impact of artisanal fishing on coastal populations of bottlenose dolphins in the SAO, the participation of social actors through educational activities must be incorporated. Efforts must be made to improve the living and income conditions of the communities because these measures could influence the socioeconomic situation of families that depend on artisanal fishing.

5.1. Research actions to close the data gaps

The following actions are recommended to minimize accidental catches and integrate local communities into conservation actions, particularly in localities where there are the interference of fisheries with bottlenose dolphin populations:

1) obtaining information about the physical characteristics of gillnets, ways of positioning them and areas where they are positioned;
2) limiting and restricting the fishing effort, the maximum length of gillnets and the number of boats that operate with gears in a given region;
3) performing systematic surveys of the number of catches of bottlenose dolphins by gillnets (catch per unit effort - CPUE) and comparing this information with population estimates to determine the viability of populations in regions of overlapping use;
4) determining whether there are traditional fishery management activities conducted by local communities in areas of bottlenose dolphin occurrence;
5) seeking alternatives for fishing techniques in conjunction with the fishermen, which may result in lower impacts on bottlenose dolphins while maintaining local practices and;
6) creating marine conservation units with the effective participation of fishermen, residents' associations, research institutes, educational institutions and local governments.

5.2. Proposals addressing fishing communities

The development of these strategies will require the constant and long-term participation of scientists in the areas of social and biological sciences. Concomitant to these activities, incentives related to social issues as well as understanding the behavior of fishing communities will be necessary; these include:

1) the development of individuals' abilities (human capital) to value social actors and what they can offer with their life experiences;
2) organizational strengthening, to create leadership and/or administrative groups;
3) the creation of networks and social alliances to identify local realities and the opinions of residents through the exchange of experiences between individuals of different subgroups (e.g., older adult fishermen who teach the practice of fishing to children);
4) deepening norms and values (e.g., solidarity, reciprocity and trust) that contribute to the achievement of the common good (social capital);
5) providing education related to interactions between artisanal fishing, fishermen and the bottlenose dolphin to contribute to the conservation of this dolphin with the participation of local members. Educational activities can involve training courses related to fisheries management (e.g., fishing gear innovations, changes in fishing areas to reduce accidental dolphin catches, and knowledge of legislation relating to fisheries) or education

(conservation of the bottlenose dolphin, its ecological and economic importance, and pollution of coastal marine ecosystems). Furthermore, research and educator groups can participate in children's education in conjunction with teachers, nurseries and school administrators. Finally, promoting public meetings between leaders and local actors, governments, educators and researchers can help to diagnose conflicts between artisanal fisheries and the bottlenose dolphin and organize solutions and;
6) allowing fishermen to participate in the decision-making process for changes related to fishing activities in areas of bottlenose dolphin occurrence.

From the moment that fishermen understand that accidental catches are attributable not to the dolphins themselves but rather to their ways of casting or positioning fishing gear, it will be possible to propose and implement effective measures for the conservation of these populations.

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