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River Dolphin (*Inia geoffrensis*, *Sotalia fluviatilis*) Mortality Events Attributed to Artisanal Fisheries in the Western Brazilian Amazon

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Abstract

In the Western Brazilian Amazon, interactions of boto (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) dolphins with fishing activities are common, but the prevalence of incidental/intentional catches is not known. This article describes incidental mortality events and intentional killing of *I. geoffrensis* and *S. fluviatilis* entangled in artisanal fishing gear and the opportunistic use of carcasses as bait. Between October 2010 and November 2011, surveys were conducted in waters of the lower Japurá River, between the Mamirauá and Amanã sustainable development reserves. In order to obtain information on interactions and to try to establish a stranding/entanglement response program (SERP), informal conversations were exchanged with local inhabitants (n = 174). Intense carcass-search surveys (n = 171) along the river in the four hydrological seasons (e.g., low, rising, high, and falling waters) were conducted, comprising a total of 1,197 h of sampling effort. Twenty-five dolphin–fishing interaction events were recorded (11 *I. geoffrensis* and 14 *S. fluviatilis*), 19 in 2011 and six in 2012 (through SERP). A total of 11 necropsies (three *I. geoffrensis* and eight *S. fluviatilis*) were performed. Four individuals (two *I. geoffrensis* and two *S. fluviatilis*) exhibited evidence of physical violence before death, and two (one *I. geoffrensis* and one *S. fluviatilis*) died in abandoned gillnets. Two intentional killing events of *I. geoffrensis* incidentally entangled for bait use in the piracatinga (*Calophysus macropterus*) fishery were reported by fishermen, while three carcasses (two *I. geoffrensis* and one *S. fluviatilis*) with gillnet marks were also used in that activity. At least six of the *S. fluviatilis* entanglement events occurred in fishing gear used for tambaqui (*Colossoma macropomum*) and pirapitinga (*Piaractus brachypomus*) (90/100-mm mesh-size gillnet), two of the most important commercial fish species in the Amazon Basin. As seasonal fishing constitutes the main income for riverine human populations, the negative reactions that cetacean presence causes to people could have a catalyst effect for the transition from "incidental capture" to "intentional capture and competitor removal." Law enforcement and precautionary measures through good fishing practices inside dolphin critical foraging areas should be taken together with fisheries' managers and fishermen to start to develop multiple-species management and ensure sustainable fishing practices.

Key Words: boto, *Inia geoffrensis*, tucuxi, *Sotalia fluviatilis*, incidental capture, gillnet, intentional killing, piracatinga, *Calophysus macropterus*

Introduction

Incidental captures of megafauna in fishing activities are common and represent a major source of mortality for long-lived organisms (Crespo & Hall, 2002; Lewison et al., 2004; Heppell et al., 2005). However, little research on bycatch and/or interactions of large vertebrates with fishing gear has been conducted in the freshwater environment (Reeves et al., 2003; Raby et al., 2011). These ecosystems have little resiliency and are far more vulnerable when facing uncontrolled development and anthropogenic stress (Allan et al., 2005; Dudgeon et al., 2006). Moreover, as a result of a globalized economy, human pressures on inland waters are increasing (Reeves et al., 2003; Neiland & Bené, 2008; Barletta et al., 2010). All estuarine and freshwater cetaceans are currently threatened by a combination of environmental degradation, overfishing, and bycatch (e.g., the vaquita [*Phocoena sinus*], Rojas-Bracho et al., 2006; the Ganges River dolphin [*Platanista gangetica gangetica*], Mansur et al., 2008; the franciscana [*Pontoporia blainvillei*], Crespo et al., 2010a; the finless porpoise [*Neophocaena phocaenoides asiaeorientalis*], Wang & Zhao, 2010). The first human-caused cetacean extinction involved the

baiji or Yangtze River dolphin (*Lipotes vexillifer*) (Turvey, 2010).

The Brazilian Amazon covers an area of 5 million km^2, comprising different key ecosystems (Silvano et al., 2009; Barletta et al., 2010). Of those, the floodplain or *várzea* constitutes a highly productive murky-water area and the main source of animal protein for traditional human communities. It is also the principal economic income through intense seasonal fish exploitation (Isaac & Ruffino, 2007; Neiland & Bené, 2008; Silvano et al., 2009). This biome is regulated by flood pulses with extreme annual oscillations (SCM, 1995; Barletta et al., 2010) and has been described as the critical habitat for the two endemic and sympatric freshwater South American cetaceans: the pink dolphin or boto (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*) (Martin & da Silva, 2004; Faustino & da Silva, 2006).

In the Amazon, interactions of both dolphin species with fishing activities are common but difficult to detect. Thus, numbers on incidental catches are poorly known (Martin et al., 2004; Crespo et al., 2010b). Reported interactions showed that animals may be disentangled and let free or killed for bait use (see Aliaga-Rossel, 2002; da Silva & Martin, 2010). *I. geoffrensis* usually take fish from nets and long-lines, causing gear and/or capture damage (Reeves et al., 2003; Silvano et al., 2009; Beltrán-Pedreros & Filgueiras-Henriques, 2010). As a result, local fishermen consider dolphins to be competitors, especially *I. geoffrensis*, and usually react negatively towards them (e.g., Loch et al., 2009; Iriarte & Marmontel, 2011).

The first record on the use of *I. geoffrensis* as bait for the scavenger catfish piracatinga (*Calophysus macropterus*) dates from 2000 (Estupiñán et al., 2003). Later work speculated on the number of killed dolphins based on fish landing data and claimed that activity could represent an immediate threat for the species (da Silva & Martin, 2007; Serrano et al., 2007).

According to the few available data, the international conservation status of *I. geoffrensis* and *S. fluviatilis* is of "Data Deficient" (Secchi, 2010; Reeves et al., 2011), although in Brazil, both species are categorized as "Almost Threatened" (Silva Barreto et al., 2010). Despite Brazilian Federal Law protecting cetaceans against intentional harassment, takes, and kills (Lodi & Barreto, 1998), the lack of enforcement and education in remote areas where *I. geoffrensis* and *S. fluviatilis* occur leave these dolphins vulnerable. This article describes incidental mortality events and intentional killing of *I. geoffrensis* and *S. fluviatilis* entangled in artisanal fishing gear. In addition, the opportunistic use of dolphin carcasses as bait for the piracatinga fishery in two Protected Areas in Brazil is documented.

Methods

Study Area

Mamirauá and Amanã sustainable development reserves (MSDR and ASDR) are located at the confluence of the Solimões (Amazon) and Japurá Rivers (Figure 1). They represent a high diversity forest area of 3,474,000 ha and are protected from industrial exploitation. Both reserves contain the *várzea* habitat, which remains flooded for 6 mo of the year, and have one of the highest water-level fluctuations in the Amazon, up to 11 m (SCM, 1995). Human settlements are small and strictly depend on fishing for protein intake and economic income (Koziell & Inoue, 2006; Silvano et al., 2009).

Fieldwork

Fieldwork was focused in an area previously described as conflictive in terms of caiman (*Melanosuchus niger*, *Caiman crocodilus*) and dolphin-killing for bait (Estupiñán et al., 2003) (Figure 1). Three-week field trips on the Japurá River were conducted monthly between October 2010 and November 2011 (except in July 2011), covering the four hydrological seasons: (1) low water (LW, September-November), (2) rising water (RW, December-April), (3) high water (HW, May-June), and (4) falling water (FW, July-August). A Mamirauá Institute for Sustainable Development (MISD) floating base was used as the main research platform. Radio contact with another MISD base located 23 km downriver allowed an exchange of information with traditional communities that intensively fish inside an area frequently used by foraging dolphins. A 15-Hp outboard motor metal skiff was employed to conduct community visits and field surveys.

Community Visits—Multiple visits were made to 22 communities, covering almost all human settlements in the study area. Informal conversations with fishermen and local inhabitants were exchanged with the aim of presenting the research proposal, establishing key contacts, gathering information on dolphins and their interaction with fishing activities, and establishing a stranding/entanglement response program (SERP) which encouraged people to send a radio message from the closest MISD floating base or report new entanglement events directly to researchers.

Monitoring Surveys—One-hundred and seventy-one skiff surveys were conducted, covering approximately 70 km per transect (35 km upriver, right river bank; 35 km downriver, left river bank). Two observers constantly searched for dolphin carcasses and/or indirect clues (e.g., presence of vultures [*Coragyps atratus*]), giving priority to river banks, beaches, bays, and enclosed areas with floating vegetation. If found, carcasses were retrieved and taken to the floating base for necropsy, following

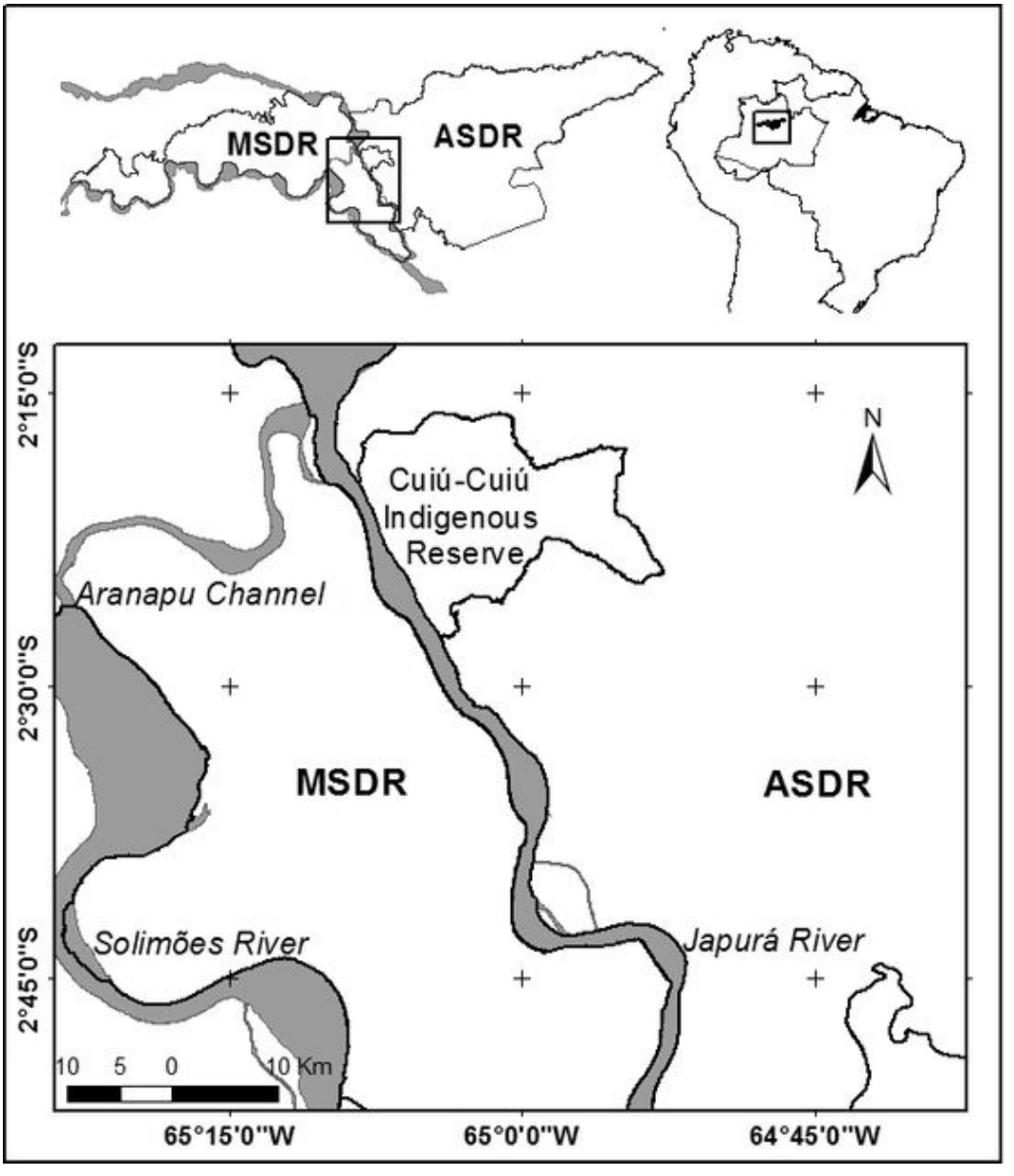

Figure 1. Lower Japurá River, border of Mamirauá and Amanã Sustainable Development Reserves, Western Brazilian Amazon

standard protocols (e.g., Dierauf & Gulland, 2001). Age classes (calf, juvenile, and adult) based on dolphin size were defined following da Silva (1993).

Results

Community Surveys

Information on 15 entanglement events in the study area described above were provided by members of the community—nine during the research period (October 2010 through November 2011) and six in 2012 through SERP, when fieldwork was being carried out in a different area. Of the total number of entanglements, six were *I. geoffrensis* and nine were *S. fluviatilis* (Table 1). Fishermen were present during four of the 15 entanglements, and two dolphins were released alive (ID-C3 *I. geoffrensis* & ID-C2 *S. fluviatilis*), while one of each species was

Table 1. Mortality events recorded (Ig = *Inia geoffrensis*, Sf = *Sotalia fluviatilis*; A = adult, J = juvenile, C = calf, F = female, M = male, UN = unknown; LW = low water, RW = rising water, HW = high water, FW = falling water; + = biological sample taken, – = biological sample not taken, N = necropsied)

Date information was recorded	Field ID	Hydrologic season	Species	Sex	Age class	Carcass stage	Biological sampling	Comments
12 Jan 2011*	C1	RW	Sf	UN	UN	C1	_	Entangled and killed for bait.
12 Jan 2011*	C2	RW	Sf	UN	C	C1	_	Disentangled and released alive.
12 Jan 2011*	C3	RW	Ig	F	UN	C1	_	Disentangled and released alive.
23 Jan 2011*	C4	RW	Ig	UN	UN	C2	_	Entangled and sold for bait ($25.00 USD).
23 Jan 2011*	C5	RW	Ig	UN	UN	C2	_	Entangled; left on a beach and consumed by a jaguar.
9 Feb 2011*	C6	RW	Ig	F	UN	C1	_	Exhausted individual with rope tied around flukes by fishermen; killed for bait.
28 March 2011	218	RW	Sf	F	A	C2	+	Lactating; gillnet marks on the head, flanks, and flukes. Possibly killed by fishermen. Carcass was prepared for use as bait by fishermen. Carcass recovered on 31 March 2011 (Figure 3).
5 Aug 2011	327	FW	Sf	F	A	C3	N	Subtle gillnet marks on right flank; possibly hit by fishermen on right side of the head. Full stomach; in floating vegetation.
24 Aug 2011	343	FW	Ig	UN	J	C4	+	Gillnet marks around rostrum; used for bait (Figure 4). On a beach.
25 Aug 2011	351	FW	Ig	M	J	C4	N	Entangled on the caudal peduncle (cut-off flukes); full stomach. Floating downriver.
28 Aug 2011	001	FW	Sf	M	A	C2	N	Gillnet marks around rostrum; full stomach. SERP reported.
5 Sept 2011	386	FW	Ig	M	J	C2	+	Gillnet marks around rostrum, left pectoral fin, and flank. Carcass was prepared for use as bait by fishermen.
6 Sept 2011	391	FW	Sf	M	A	C2	N	Gillnet marks on the head, flanks, and caudal peduncle; full stomach. SERP reported.
11 Sept 2011	401	LW	Sf	M	C	C3	N	Gillnet marks on anterior body portion and left pectoral fin; possibly killed by fishermen. Empty stomach; floating downriver.
12 Sept 2011	404	LW	Sf	F	A	C2	N	Lactating; gillnet marks on head, back, and flanks (Figure 2). Full stomach; in floating vegetation.
15 Sept 2011	405	LW	Ig	M	J	C4	N	Without apparent gillnet marks; possibly killed by fishermen. Broken rostrum; cuts and stab wounds all over the body. On a beach.
1 Oct 2011	004	LW	Ig	F	A	C4	N	Possibly entangled; suspected blow to the head by fishermen. Floating downriver.
20 Oct 2011*	C7	LW	Sf	UN	UN	C2	_	Entangled; carcass discarded by fisherman.
1 Nov 2011*	005	LW	Ig	UN	J	C5	+	Entangled in fixed abandoned gillnet; totally decomposed.
17 April 2012	C8	RW	Ig	F	A	C2	_	Entangled and discarded; SERP reported.
17 May 2012	C9	HW	Sf	UN	UN	C4	_	Entangled in an abandoned gillnet; advanced decomposition state. SERP reported.
19 May 2012	025	HW	Sf	M	J	C2	N	Entangled in fixed gillnet; full stomach. SERP reported.
20 May 2012	026	HW	Sf	M	J	C2	N	Entangled in fixed gillnet; full stomach. SERP reported.
5 June 2012	027	HW	Sf	F	C	C2	N	Entangled in fixed gillnet; full stomach. SERP reported.
26 June 2012	C10	HW	Sf	UN	UN	C2	_	Entangled in fixed gillnet and discarded; SERP reported.

*Data from community surveys

killed for bait (ID-C1 *S. fluviatilis* & ID-C6 *I. geoffrensis*). During five of the 15 entanglement events, dolphins were found dead: one *I. geoffrensis* (ID-C4) was sold for bait, one (ID-C5) was left on a beach and consumed by a jaguar (*Panthera onca*), one *S. fluviatilis* (ID-391) was radio reported and the carcass recovered while another (ID-C7) was discarded, and one *I. geoffrensis* (ID-005) skull was found by a fisherman in an abandoned gillnet. Of the six entanglements reported through SERP in 2012, one of each species were discarded (ID-C8 *I. geoffrensis* & ID-C10 *S. fluviatilis*), three *S. fluviatilis* (ID-025, ID-026 & ID-027) were recovered for necropsy, while another one (ID-C9) was in an advanced state of decomposition on a fixed abandoned gillnet.

Monitoring Surveys

There were 1,197 h of carcass search effort. Remains of ten dolphins were found (five *I. geoffrensis* and five *S. fluviatilis*) (Table 1). Evidence of interaction with fishing gear consisted of gillnet square marks along the body, and scratch and/or abrasive marks around the peduncle area, head, or rostrum (Figure 2). Two *I. geoffrensis* (ID-405 & ID-004) and two *S. fluviatilis* (ID-321 & ID-327) that apparently did not suffer direct interaction with fishing gear exhibited evidence of physical violence before death, with either blows on the head, stab wounds, or knife-cuts in vital areas. Three other dolphins with gillnet marks around the rostrum and flanks, flippers, or flukes were used as bait (ID-343 & ID-386 *I. geoffrensis* and ID-218 *S. fluviatilis*) for the piracatinga fishery (Figures 3 & 4). Identification of gillnet type was possible in four *S. fluviatilis* carcasses: 100 mm-mesh size cotton gillnet (ID-404) and 90 mm-mesh size nylon gillnet (ID-025, ID-026 & ID-027), both used for fishing tambaqui (*Colossoma macropomum*) and pirapitinga (*Piaractus brachypomus*).

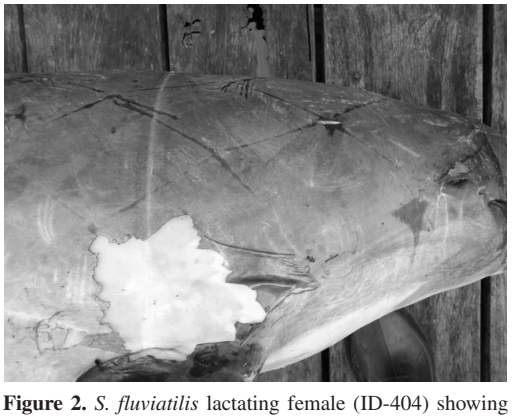

Figure 2. *S. fluviatilis* lactating female (ID-404) showing gillnet marks as a result of fishing gear entanglement (Photo by V. Iriarte)

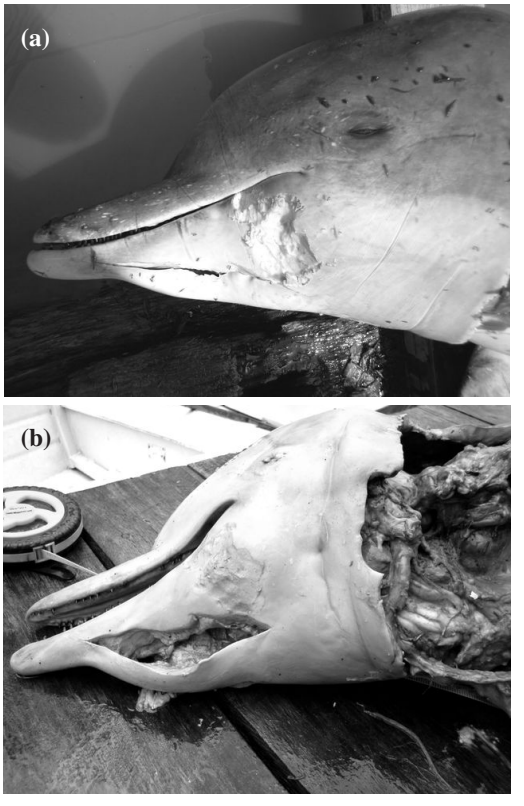

Figure 3. (a) *S. fluviatilis* lactating female (ID-218) on 28 March 2011 before being used as bait for the piracatinga fishery, and (b) fished carcass remains recovered on 31 March 2011 (Photos by V. Iriarte)

Biological Sampling

Biological material for genetic analysis only (i.e., skin/bone) were obtained from four individuals, three *I. geoffrensis* (ID-343, ID-386 & ID-C5) and one *S. fluviatilis* (ID-218) (Table 1 & Figure 3a). The latter was observed and sampled in a community where fishermen were preparing the carcass to be used as bait in the piracatinga fishery. Even though skeletal remains were requested by researchers for preservation, fishermen discarded them. However, recovery of the carcass, discovered on floating vegetation, occurred 3 d later, on 31 March 2011 (Figure 3b). Eleven complete necropsies were performed on three *I. geoffrensis* (ID-351, ID-405 & ID-004) and on eight *S. fluviatilis* (ID-327, ID-001, ID-391, ID-401, ID-404, ID-025, ID-026 & ID-027) (Table 1). Stomach contents were available from nine of the necropsied dolphins; all of them were full, except for the *S. fluviatilis* male calf (ID-401). Decomposition condition of the sampled carcasses was established following Pugliares & colleagues (2007), defined as Alive (C1), Fresh Carcass (C2),

Figure 4. *I. geoffrensis* (ID-343) after being used as bait (Photo by V. Iriarte)

Moderate (C3), Advanced (C4), and Skeletal Remains (C5) (Table 1). Pathological, genetic, and stomach content samples are currently being analyzed and will be presented elsewhere (Iriarte & Marmontel, unpub. data).

Sex and Age Classes—Of the 15 dolphins sampled (six *I. geoffrensis* and nine *S. fluviatilis*), five *I. geoffrensis* were juvenile (three males, ID-351, ID-386 & ID-405, and two unknown, ID-343 & ID-005) and one was an adult (female, ID-004). Five *S. fluviatilis* were adults (two males, ID-391 & ID-001, and three females, ID-327, ID-404 & ID-218), three juveniles (two males, ID-025 & ID-026, and one female, ID-027), and one calf (male ID-401) (Table 1).

Discussion

The limited number of entanglement events recorded during October 2010 and November 2011 (except July 2011), as well as the SERP reports in 2012, do not allow us to establish bycatch trends or their connection to hydrologic season and type of habitat. However, the high entanglement risk reported for *S. fluviatilis* (Crespo et al., 2010b) in combination with the observations from this study suggest that all *S. fluviatilis* age classes as well as *I. geoffrensis* calves and juveniles in the lower Japurá River are particularly vulnerable to entanglement. These differences in vulnerability to gillnet entanglement could be related to social ecology differences in both species (see Smith & Reeves, 2012), with *S. fluviatilis* being more gregarious and foraging on schooling fish primarily in open areas where fishing intensity is higher during the FW period and LW season. *I. geoffrensis*, on the other hand, form small ephemeral groups and primarily forage on bottom-dwelling fish in forest flooded areas (Martin et al., 2004; Gómez-Salazar et al., 2012). The possibility of fishing gear awareness/scavenging behaviour learning in *I. geoffrensis*, as described for other cetaceans (e.g., *Orcinus orca*, Visser, 2000; *Tursiops truncatus*, Cox et al., 2003), is not ruled out.

It is important to stress that the occurrence of entanglement events in the study area are likely under-represented. In the Amazon, cetacean interactions with fishing activities are extremely difficult to record, are not reported for taboo or fear of law enforcement actions, and complex river currents and a high abundance of scavengers affect the probability of finding biological material. Despite these obstacles, ten dolphin remains were found, and at least six of the *S. fluviatilis* entanglement events reported here could be traced to fishing gear (90/100-mm mesh-size gillnet) used for fishing two of the most important commercial species in the Amazon Basin: (1) the tambaqui and (2) the pirapitinga (Silvano et al., 2009; Garcez Costa Sousa & de Carvalho Freitas, 2011). These fish species are exploited year-round (with a fishing prohibition from 1 October to 31 March, Decree No. 6.514/2008) using monofilament gillnets, with the activity being more intense during the FW period and LW hydrological season when fish move from floodplain areas to deeper waters (Isaac & Ruffino, 2007; Silvano et al., 2009; Garcez Costa Sousa & de Carvalho Freitas, 2011). Fishermen usually leave gillnets fixed in low-current high-productivity areas, where dolphins concentrate foraging efforts (Martin et al., 2004; Faustino & da Silva, 2006). Natural/animal-damaged gear may be abandoned after the LW intense fishing season, with consequent "ghost-fishing" (mortality of fish and other species after all

control of the gear is lost by a fisherman) (Iriarte & Marmontel, unpub. data).

Eight of the 11 necropsied individuals had full stomachs, suggesting they were bycaught in foraging grounds. Whether dolphin carcasses (ID-343, ID-386 & ID-218) used for bait for the piracatinga fishery were incidentally or intentionally entangled is unknown. As mentioned earlier, in the lower Japurá River, fishing constitutes the main income for riverine human populations, and it is highly seasonal, so negative reactions towards cetaceans' presence are not uncommon (e.g., Loch et al., 2009; Iriarte & Marmontel, 2011). Fishermen usually express their disgust for *I. geoffrensis* (Iriarte & Marmontel, in prep.), and these conflicts could have a catalyzing effect on the transition from "incidental capture" to "intentional capture and competitor removal." The use of Amazonian river dolphin carcasses as bait, which might be regarded by local fishermen as a cost-effective means of sourcing bait for piracatinga fishing, is a matter of concern (Iriarte & Marmontel, in prep.).

Odontocete cetacean populations are highly susceptible to exploitation (Wade et al., 2012), and large vertebrate removal has been reported to create ecological imbalance for ecosystems (Jackson et al., 2001; Springer et al., 2003). In the Brazilian Amazonia, incidental and intentional catches of dolphins are known to occur even inside protected areas. Although the present research does not present comprehensive entanglement rates, it suggests incidental takes in fishing gear could be an important source of mortality for Amazonian dolphins as occurs with other aquatic mammal species elsewhere (e.g., Read, 2008). Critical areas for dolphin foraging should be identified, and the intensity of gillnet usage and incidental catches quantified. Bycatch research is urgently needed in order to evaluate this threat and develop precautionary measures against unsustainable take rates. Interdisciplinary work with fisheries' managers and fishermen is crucial for developing multiple-species management, to explore dolphin bycatch mitigation measures (e.g., deterrents, improved fishing gear, fishing exclusive areas, and/or the prohibition of fixed gillnets without fishermen monitoring), and to implement good fishing practices to ensure Amazonian artisanal fisheries are truly sustainable.

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