Insights on the use of dolphins (boto, *Inia geoffrensis* and tucuxi, *Sotalia fluviatilis*) for bait in the piracatinga (*Calophysus macropterus*) fishery in the western Brazilian Amazon

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ABSTRACT

In the Amazon Basin, the use of the pink dolphin or boto (*Inia geoffrensis*) for bait in the piracatinga (*Calophysus macropterus*) fishery was first detected in the year 2000. Since then, this artisanal fishery has become more prevalent as it requires only a few hours of work per night and provides immediate cash earnings. It is thus an attractive addition to (or replacement for) traditional fishing. Previous reports have noted the use of botos as bait, but stated that the most common bait used are caimans (*Melanosuchus niger*, *Caiman crocodilus*). Estimates of the number of dolphins killed based on fish landings have been proposed and an apparent decrease in sighting/survival of an artificially-marked boto population was observed. Although stocks/population estimates, trends and actual numbers of hunted dolphins are unknown, the conservation impacts of this activity are of concern. Between October 2010 and November 2011, research was conducted within an area with serious conflicts between dolphins and fishermen as well as intense fishing for piracatinga, i.e. in the lower Japurá River, on the border with the Mamirauá and Amanã Sustainable Development Reserves, where both boto and tucuxi (*Sotalia fluviatilis*) are used for bait. One-hundred and fifty-seven monitoring surveys were carried out in eight key communities, confirming 114 piracatinga fishing events through direct monitoring and incognito surveys of fishing gear (*gaiolas)*. Empirical evidence of the activity in *gaiolas* comprised pieces of bait, carcass remains, piracatinga provoked vomits and dolphin fished carcasses. Of those, 31.2% (n = 35) involved cetacean bait (91.4% *I. geoffrensis*, 8.58% *S. fluviatilis*), 68.7% (n = 77) caiman bait (96% *M. niger,* 4% *C. crocodilus*), and two fishing events used both types. These percentages may be higher/lower in other areas within and outside the Reserves. Given the increasing trend of the piracatinga fishery, the authors believe that precautionary measures for the conservation of Amazonian dolphins are urgently needed. Development of practical short-term solutions (e.g. offal-baited fish traps) and multispecies management together with law enforcement, incentives and educational programmes could allow the future transition of riverine communities from the piracatinga fishery to sustainable, higher income activities.

KEYWORDS: BOTO; TUCUXI; DIRECT CAPTURE; FISHERIES; CONSERVATION; MANAGEMENT; SUSTAINABILITY; REGULATIONS

INTRODUCTION

In Latin America and the Caribbean (LAC), small-scale fisheries (SSF) constitute an important resource as the main supply of protein and income (Begossi, 2010; Castello *et al.*, 2009; Defeo and Castilla, 2005; Salas *et al.*, 2007). Following a worldwide trend, over the last fifty years, SSF in LAC have intensified in both marine and freshwater environments (Arellano and Swartzman, 2010; Barletta *et al.*, 2010; Barthem *et al.*, 1997; Salas *et al.*, 2011). Recently some have been linked to high bycatch rates of megafauna and the overexploitation of fish stocks (e.g. Alfaro-Shigueto *et al.*, 2010; Crespo *et al.*, 2009; Isaac and Ruffino, 2007; Jaramillo-Legorreta *et al.*, 2007; Peckham *et al.*, 2008; Secchi, 2010). The opportunistic use of bycaught or directly killed dolphins and porpoises for bait in some SSF (e.g. shark-longlining/gillneting, crab-fishing with traps) has been reported for several countries in LAC, involving both coastal and offshore species: Argentina (Goodall *et al.*, 1994); Brazil (Crespo *et al.*, 2010b; Di Beneditto *et al.*, 1998; Leatherwood and Reeves, 1994b; Secchi *et al.*, 2003a); Chile (Lescrauwaet and Gibbons, 1994); Colombia (Avila *et al.*, 2008; Mora-Pinto *et al.*, 1995); Mexico, Central America and the wider Caribbean (Vidal *et al.*, 1994); Peru (García-Godos and Cardich, 2011; Mangel *et al.*, 2010; Read *et al.*, 1988; Van Waerebeek *et al.*, 1997). The current, non-traditional use of small cetaceans for bait in SSF in developing countries is a complex issue involving small coastal or riverine cetacean species that are under threat combined with difficult socio-economic problems in fragile human communities. These communities often have high levels of illiteracy, considerable poverty and a lack of alternative sources of food and income (e.g. Avila *et al.*, 2008; Mangel *et al.*, 2010; Read *et al.*, 1988; Secchi, 2010; Sinha *et al.*, 2010).

The Amazon Basin comprises many different ecosystems with a large diversity of fish species (Barletta *et al.*, 2010; Saint-Paul *et al.*, 2000; Silvano *et al.*, 2009). The flooded forest or *várzea* comprises a productive white-water system that supports both industrial and small-scale fisheries (Almeida and Lorenzen, 2003; Barthem *et al.*, 1997; Crampton, 1999; McGrath *et al.*, 1998), the latter being the main economic activity of communities in the area (Batista *et al.*, 1998; Isaac and Ruffino, 2007; McGrath *et al.*, 1993). *Várzea* has also been defined as the key critical habitat for two 'Almost Threatened' dolphin species in Brazil (Silva Barreto *et al.*, 2010): the boto, *Inia geoffrensis* and the tucuxi, *Sotalia fluviatilis* (Faustino and da Silva, 2006; Martin and da Silva, 2004). Since they follow the flood pulses, *várzea* fisheries are highly seasonal. In the western Brazilian Amazon, the most common fish species traditionally exploited by local artisanal fishermen (see Castello, 2004; Garcez Costa Sousa and de Carvalho Freitas, 2011; Isaac and Ruffino, 2007; Silvano *et al.*, 2009) are: the

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pirarucu (*Arapaima gigas*); the tambaqui (*Colossoma macropomum*); and large migratory catfishes (Pimelodidae). However, the scavenger catfish piracatinga (*Calophysus macropterus*) fishery has recently grown, being at present an important supplement/fast-income alternative resource in *várzea* communities to the traditional species (Brum, 2011). Records indicate that the fishery started in the western Brazilian Amazon in the year 2000 (Brum, 2011; Estupiñán *et al.*, 2003; Gómez *et al.*, 2008), apparently as a substitute for the over-exploited capaz fish (*Pimelodus grosskopfil*) in the high-demand Colombian market (Gómez *et al*., 2008). As there is a constant demand for piracatinga and fishing generally only takes a few hours per night, this fishery is considered an optimum activity for people in need of immediate cash (Brum, 2011; Gómez *et al*., 2008).

Although the fishery is not illegal *per se*, its bait usually is i.e. mostly caimans and dolphins (Brum, 2011; Gómez *et al*., 2008). As a result, estimates of numbers of killed dolphins based on fish landings have been proposed (e.g. Gómez *et al*., 2008; da Silva *et al*., 2011) and an apparent decrease in the sighting/survival of artificially-marked botos within a *várzea* lake has been reported (Mintzer *et al.*, 2013). Although there is no reliable information on stocks, population abundance and trends or even actual numbers of dolphins killed, the potential impact of this activity on dolphin populations is of concern. The present study was established to try to obtain reliable information on: the percentage of dolphin bait used in the fishery; the species and sustainability of the dolphin species concerned; the number of communities involved; and the social issues related to the fishery. Research was conducted within an area that has both major conflicts between dolphins and fishermen and an intense piracatinga fishery; the lower Japurá River, along the border of two Protected Areas in Amazonas State, Brazil.

Fishery characteristics

The piracatinga fishery is generally driven by the demand from middlemen who visit the communities while travelling upriver, request fish and sometimes leave ice boxes for storage (Brum, 2011). Some communities also have a local fish buyer (or buyers) who drives production when middlemen are not around. The fish is ultimately sold at freezing plants in nearby cities and commercialised under other names (*mota*, *pirosca*, *douradinha*) throughout Brazil and abroad (Brum, 2011; Gómez *et al*., 2008; Mintzer *et al*., 2013).

Fishing is mainly carried out at night by groups of 3 or 4 teenage males or young adults between 10–35 years old (Brum, 2011; Estupiñán *et al*., 2003). The only gear required is a *gaiola*, a wooden box/cage of variable dimensions but usually around 300 × 150 × 130cm (Brum, 2011; Estupiñán *et al*., 2003; Gómez *et al.*, 2008). The *gaiola* is used to keep the catch alive until evisceration and immediate freezing, because piracatinga meat decays rapidly (Brum, 2011). One or more *gaiolas* are commonly left in front of communities or hidden in nearby areas and are often shared by fishermen from neighbouring settlements (Brum, 2011).

The most common bait species used in the study area are black caimans *Melanosuchus niger* (Estupiñán *et al*., 2003; Gómez *et al*., 2008; although jacaretingas *Caiman crocodilus* are also used), followed by botos, tucuxis and fish offal. The present study also found occasional use of liver from rays (*Myliobatis* sp.) and meat of giant ant-eaters (*Myrmecophaga tridactyla*), jaguars (*Panthera onca*) and pigs (*Sus scrofa*). The bait items can be from incidental entanglements/bycatch (Brum, 2011; Iriarte and Marmontel, 2013) or directed hunts (Brum, 2011; Estupiñán *et al*., 2003; Gómez *et al*., 2008). Depending on bait availability, more than one caiman/dolphin may be used during one fishing event. Fishing techniques vary amongst communities (for details regarding fishing types see Brum, 2011) but the most popular method involves a fisherman being partially submerged by the river bank whilst holding a piece of decomposing meat between his legs and catching the fish by hand (Fig. 1).

Fig. 1. Fishing piracatinga with caiman (*M. niger*) bait. Note the *gaiola* in the background. Photo: V. Iriarte

MATERIALS AND METHODS

Study area

The Mamirauá (MSDR) and Amanã (ASDR) Sustainable Development Reserves are located at the confluence of the Solimões (Amazon) and Japurá Rivers (Fig. 2). They represent a high diversity forest area of 3,474,000 hectares in which natural resources are protected, but can be exploited by local human populations for both subsistence and commercial gain (Barthem, 1999; Queiroz, 1999). Both reserves contain *várzea* habitat. The rural human settlements are small, inhabited mostly by kin members and heavily dependent on fishing for protein and income (Castello *et al.*, 2009; Koziell and Inoue, 2006; Queiroz and Crampton, 1999). Conflicts regarding cetaceans and fishing activities (other than the piracatinga fishery) have been previously reported both within the Reserves and within adjacent areas (Brum, 2011; Iriarte and Marmontel, 2011; 2013; Loch *et al.*, 2009).

Fieldwork

Between October 2010 and November 2011, the first author (VI) and a local assistant conducted consecutive two/three-week field surveys (except in July and December 2011, when very difficult working conditions arose) within the study area. The four 'hydrologic seasons' were covered: low water (LW, September–November), rising water (RW, December–April), high water (HW, May–June) and falling water (FW, July–August). A Mamirauá Institute for Sustainable

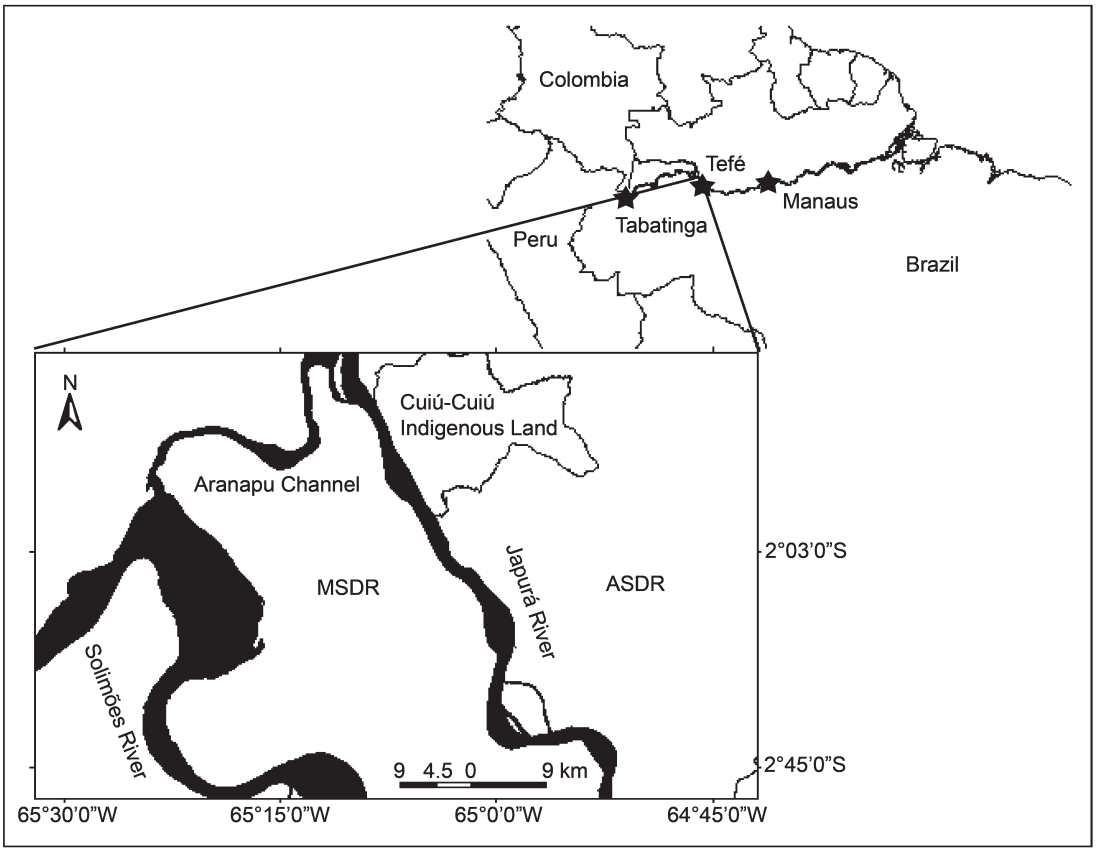

Fig. 2. Study area in the Japurá River, border of Mamirauá (MSDR) and Amanã (ASDR) Sustainable Development Reserves.

Development (MISD) floating base was used as the main research platform. A metal skiff (with a 15hp outboard motor) was employed to conduct monitoring surveys of communities and piracatinga fishing events.

Community surveys

Multiple *ad libitum* visits were made to 22 communities. Three of these were fishing piracatinga annually, 17 intermittently and two were not fishing at all. A total of 174 informal conversations with fishermen and local inhabitants (mixed gender/age) were made with the aim of explaining the research project, generating key contacts and obtaining specific information on the frequency of the piracatinga fishery, the type of bait used and its 'productivity' (i.e. target fish yield per bait of one animal).

Piracatinga fishing event surveys

Eight communities were selected to examine fishery events; 157 visits to these communities and/or their piracatinga wooden boxes were carried out in order to obtain empirical information on the use of cetaceans for bait.

Working conditions were considered good when it was quiet around a *gaiola* with no fisherman close enough to detect activity. Bad conditions were when the fisherman became angry/dangerous. Three different monitoring strategies were applied, depending on the working conditions:

(i) direct observation of bait before the fishing event (fresh carcass);

(ii) observation of a fishing event; and

(iii) post-fishing event wooden cage 'incognito' survey.

The last type was conducted only if the *gaiola* was available away from human settlements. Visits occurred immediately after sunrise, and an actual fishing event was considered to have occurred only if at least one of the following conditions existed:

(i) a hidden fresh carcass awaiting processing was observed (with posterior confirmation of the event);

(ii) a fish catch was available in the cage;

(iii) no catch was found but bait remains were observed;

(iv) new fished carcass or remains were observed in the surroundings;

(v) observation of a vulture (*Coragyps atratus*) aggregation on a *gaiola* in front of a community with fished dolphin carcass/remains or discarded dead fish subsequently retrieved downstream of that settlement.

Fresh dolphin carcasses tied to *gaiolas* were measured and skin samples were taken when working conditions permitted. After a post-fishing event, as many small floating pieces of bait as possible were collected, and if the catch was inside the *gaiola,* 1–3 piracatingas were ventrally massaged to provoke a 'last meal' vomit. Fished cetacean carcasses were always brought aboard and taken to the MISD floating base for skeleton processing. All samples collected were preserved in 92.8% ethanol for genetic analyses.

Although the study area includes bays and beaches, the river currents are strong and complex such that finding biological evidence of fished cetaceans represented a major challenge – each time a fishing event including dolphin bait

was detected, an intense search was carried out all over the wooden box and surrounding floating vegetation. However, this was often without success. The dataset presented here includes only confirmed fishing events with at least a tentative identification of the type of bait. Despite caiman/dolphin meat and blubber having different appearance and smell, sometimes it was quite difficult to make the distinction, perhaps because both caiman and dolphin were mixed. Genetic analyses will provide more detailed information on the actual number, species, and sex of dolphins used for bait in the searched communities during the study period. Those results will be presented elsewhere.

RESULTS

Community surveys

Informal conversations provided information on how local people perceived dolphins as well as characteristics of the fishery and which of the fishermen engaged in the practice. Locals are aware of the prohibitions on killing dolphins and caimans, but as the latter are dangerous and may attack people, the people believe their activity of killing caimans is more than justified. Therefore, although the use of dolphins for bait is clandestine, it is not difficult to obtain information on caiman catches.

Attitudes to dolphins

Local people generally have a negative view of dolphins, especially the boto, which often 'steals' their catch and damages fishing gear. Few people believe folklore legends and taboos related to dolphins (e.g. see Leatherwood and Reeves, 1997) but two middle-aged men (>50 years-old) expressed the belief that *resident* botos in lakes (which remain isolated from the main river during the dry season) are evil, breathe every two hours and turn into bad people. These characteristics are used to justify killing botos, regardless of sex, age class or size, and without an immediate reason. Although the tucuxi has a better reputation and its meat and blubber are not considered good piracatinga bait, this does not stop fishermen from taking advantage of entangled individuals or intentionally hunting them (see Iriarte and Marmontel, 2013).

Dolphins for bait

Dolphins are killed by experienced hunters who also catch Amazonian manatees (*Trichechus inunguis*). Most hunters do not fish for piracatinga, but are often fathers, uncles, or elder brothers of the fishermen. Direct killing usually occurs in dolphin foraging/resting areas near beaches and in lakes, where the animals are more vulnerable. A common strategy is to close the small channels that connect the main river to lakes during the night; in the morning the dolphins are harpooned in any portion of the body and then killed – often by striking them on the head with an axe or machete or, because botos are reported to fight ferociously for their lives, by shooting in the head. Another strategy involves: (i) harpooning the dolphin; (ii) tying a rope to its caudal peduncle; (iii) fixing its maxilla with a rope; (iv) harpooning it again; and (v) keeping the animal alive for days before being used for bait (Figs 3–5). During the receding water season in 2011, an entire feeding group was witnessed (between 5–8 dolphins, including a calf) in a drying lake (approx. 2m depth) after they had been encircled with a cotton gillnet by a young man in a canoe with three very

Fig. 3. Caudal peduncle of an *I. geoffrensis* female killed for bait. The arrow indicates a deep cut made by fishermen to pass rope through. Photo: V. Iriarte.

Fig. 4. Right flank of an *I. geoffrensis* female killed for bait. The arrow indicates a deep cut below the dorsal fin made by fishermen to pass rope through. Photo: V. Iriarte.

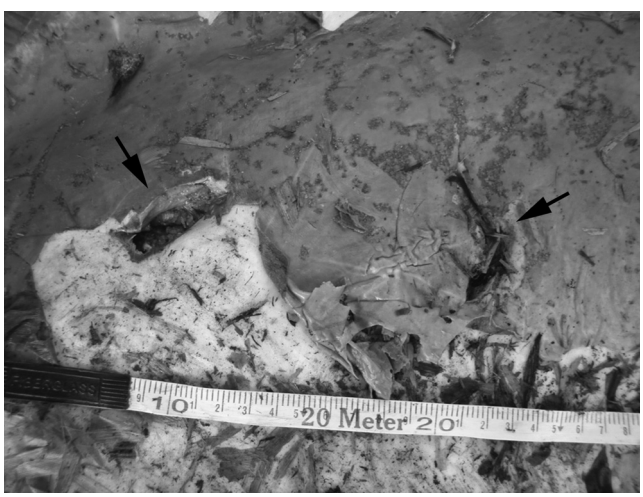

Fig. 5. Left flank of an *I. geoffrensis* female killed for bait. The arrows indicate two harpoon wounds made by fishermen to submit the dolphin. Photo: V. Iriarte.

Table 1

Number of monitoring surveys (in brackets) and confirmed fishing events per month and per community. UN = unknown (floating carcass/remains not directly linked to a specific community).

	2010	2011											
	Oct. (9)	Jan. (10)	Feb. (8)	Mar. (13)	Apr. (19)	May (17)	Jun. (13)	Jul. (5)	Aug. (19)	Sep. (11)	Oct. (17)	Nov. (16)	
Community ID	Number of confirmed fishing events												Total
1	2	4	2	5	1	1	–	1	2	–	–	1	19
2	1	1	1	2	2	1	–	–	–	–	2	4	14
3	1	–	–	–	–	–	–	–	–	–	–	–	1
4	–	–	2	13	8	3	3	1	10	1	9	9	59
5	–	–	–	2	–	–	–	–	–	–	–	–	2
6	–	–	–	2	1	–	–	–	–	–	–	8	11
7	–	–	–	–	1	–	–	–	–	–	–	–	1
8	–	–	–	–	–	–	–	–	2	–	–	2	4
UN	–	–	–	–	–	–	–	–	1	–	–	2	3
Total	**4**	**5**	**5**	**24**	**13**	**5**	**3**	**2**	**15**	**1**	**11**	**26**	**114**

young male children. The kill was not observed but the following morning, dolphin bait was found in three different *gaiolas*.

Piracatinga fishing event surveys

Fishing events

In the 157 monitoring surveys in the eight selected communities, a minimum of 114 piracatinga fishing events were confirmed (Table 1 and Appendix 1). Fishing activity was recorded throughout the year, but there were two clear peaks in fishing effort, in March and November (Table 1, Fig. 6).

Type of bait and variation by community

From the *in situ* evidence collected (Fig. 9), 31.2% ($n = 35$) of the piracatinga fishing events involved cetacean bait, 68.7% ($n = 77$) caiman bait, and two fishing events used both types (Fig. 8 and Appendix 1).

In three communities, piracatinga fishing activity was constant throughout the year whereas activity was more sporadic in the other five (Table 1). The communities mostly fished with black caiman bait although three (ID 1, 4, 6) also used dolphin bait. One community (ID 4) was very constant both in piracatinga fishing activity and in the use of dolphin bait (Fig. 8). Two communities (ID 4, 6) had used mixed bait at least once (Fig. 8).

Cetacean bait

Fig. 9 summarises the empirical evidence of the cetacean type of bait used in fishing events ($n = 37$); details can be found in Appendix 1. Evidence comprised one or more of the following: fresh dolphin carcasses ($n = 6$); pieces of bait sampled from *gaiolas* ($n = 19$); intentionally-provoked vomits from the available piracatinga catch in *gaiolas* or catch remains (1–3 individuals accidentally left in the cage after catch retrieval) ($n = 4$); stomach contents of dead discarded piracatinga ($n = 1$); fished dolphin carcasses (already used as bait) ($n = 8$) (Fig. 7) and dolphin carcass remains ($n = 4$). Both botos and tucuxis were recorded as being used for bait.

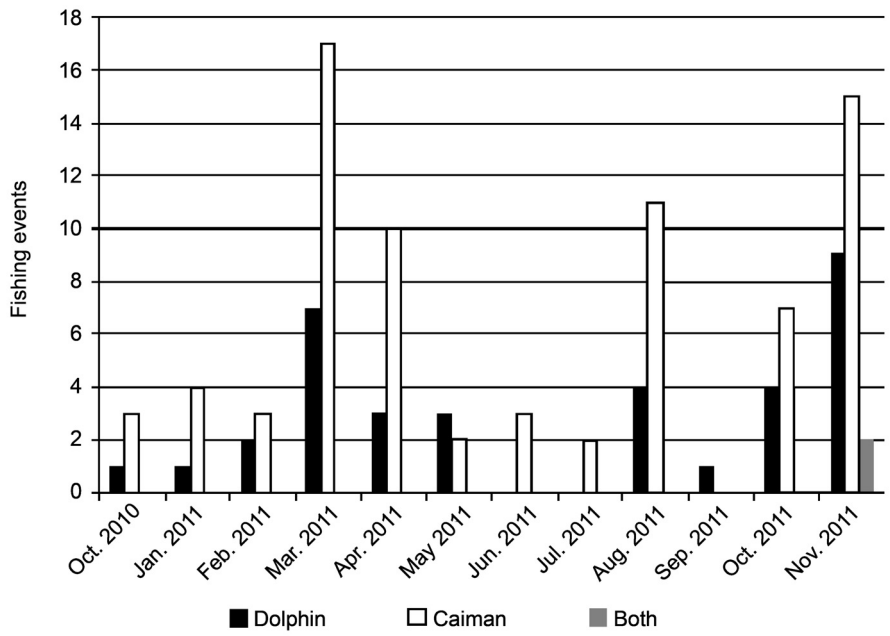

Fig. 6. Number of confirmed fishing events per month and type of bait.

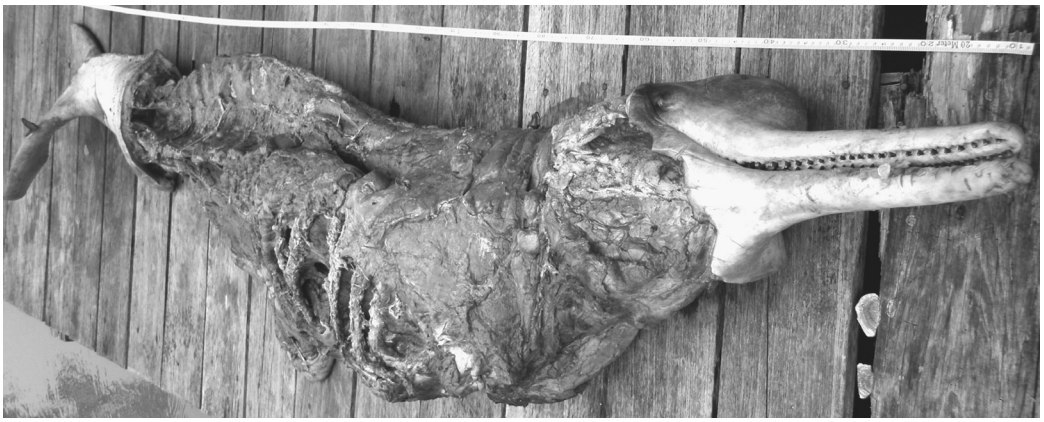

Fig. 7. *Inia geoffrensis* fished carcass. Photo: V. Iriarte.

Dolphin carcass productivity

From direct observation of the fish caught in *gaiolas* or information provided by fishermen, it was possible to estimate/obtain the 'productivity' of dolphin bait in nine different fishing events (Table 2), i.e. the profit made from selling the fish obtained 'per cm of cetacean' bait. Although the information is far from complete, it provides an insight on profitability and an understanding of why the piracatinga fishery has become so popular. As it is a highly seasonal activity, market price varies depending on demand/availability of the fish. During the months of greatest activity (the RW season), fishermen earn about 0.5USD per piracatinga kilogram. Given that the observed yield of a fished boto (i.e. average piracatinga catch in a fishing event with dolphin bait) is about 300kg, the profit would be 150USD which divided among the fishing event participants (generally three) would represent 50USD of individual earnings. In the HW season, when other fishing resources are scarce, the price of piracatinga per kg can reach up to 1USD, thereby doubling the income. The Brazilian Minimum Salary equivalent is 310USD (Decree Nº7.655), therefore the potential amount of immediate cash obtained from using one dolphin as bait for a few working hours is significant.

DISCUSSION

In the Amazon, both botos and tucuxis were directly exploited for human consumption and handicrafts by the Mura, Cocama, and Ticuna people until the first half of the last century (Leatherwood and Reeves, 1997). However, the current use for bait in the area studied is non-traditional and may be related to general cultural and social changes being experienced in developing countries. Loss of traditional knowledge, changing values and changed perspectives on life through globalisation have been responsible for both increased consumerism (Arnett Jensen, 2003; Firouzeh, 2004; Freitas *et al.*, 2004; Sirén, 2006) and unsustainable fishing practices elsewhere (Crowder *et al.*, 2008).

The development of commercial fisheries in Amazonia in the last century resulted in a shift from harsh agricultural work to fishing, allowing higher wages and an increase in the number of commercial fishermen in *várzea* communities (Batista *et al.*, 1998; McGrath *et al.*, 1993; McGrath *et al.*, 1998). The

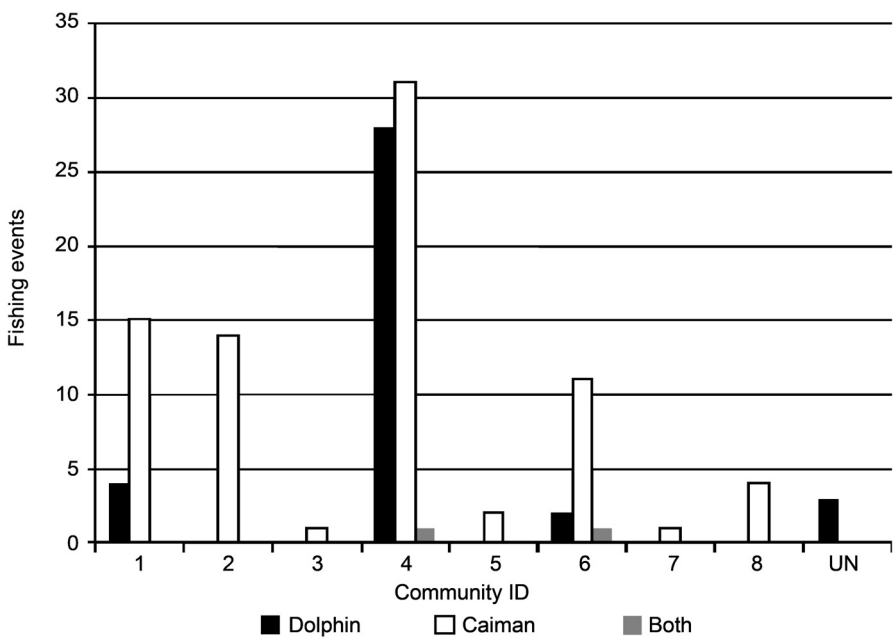

Fig. 8. Number of confirmed fishing events per community, with a distinctive type of bait. UN = unknown (floating carcass/remains not directly linked to a specific community).

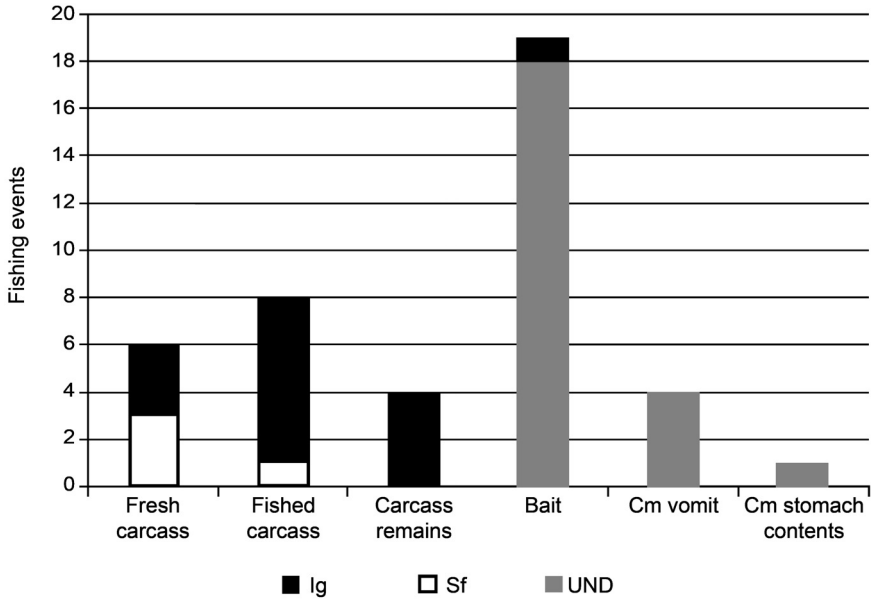

Fig. 9. Evidence recorded in the piracatinga confirmed fishing events with cetacean bait (n = 37). Ig = *Inia geoffrensis*; Sf = *Sotalia fluviatilis*; Cm = *Calophysus macropterus*; UND = unidentified dolphin.

intensification of fishing reduced catches for each fishermen and in the area as a whole (Castello, 2004; McGrath *et al.*, 1993; Silvano *et al.*, 2009). As a consequence, co-management fishing agreements began to be implemented for the most commercially important species (Almeida and Lorenzen, 2003; Almeida *et al.*, 2009; Begossi, 2010; Silvano *et al.*, 2009). As a part of those single species management strategies, an economic incentive ('*seguro defeso*') equivalent to a minimum national salary per month was implemented for professional fishermen during periods of a fishing ban (Decree Nº 6.514/2008). However, delays and irregularities in its availability have led fishermen to target other low value species (Brum, 2011), with piracatinga being an excellent option not only for community fishermen, but also for itinerant unemployed city labourers (this study). The combination of ignorance of the potential consequences, antipathy towards top predators and the need for a financial supplement to their household income, have all contributed to the development of the piracatinga fishery. In the study area, this fishery constitutes an important and relatively constant source of income for communities in which traditional commercial species are the main targets. Piracatinga fishing is pursued with some regularity in some communities, or in certain periods when it may be the only or main source of income for some families.

Community surveys

The information obtained here from informal conversations within communities is consistent with previous work done in adjacent regions in which interactions of botos with fishing gear have given them a negative reputation (Brum, 2011, Iriarte and Marmontel 2011, 2013; Loch *et al*., 2009). Although in the surveyed communities fishermen obtained the bait within their community and family, in nearby places inside and outside the Reserves, commercialisation of dolphin/caiman carcasses may occur (Brum, 2011; Iriarte and Marmontel, unpublished data).

The piracatinga fishermen in the *várzea* describe boto meat as an excellent bait because of its smell and blubber strength, which allows a higher productivity than caiman/fish-offal bait (the latter may last less time and break into pieces). This is a similar situation to that reported for Peruvian fishermen who use cetacean bait (see Mangel *et al*., 2010). However, many piracatinga fishermen prefer caiman as it is less smelly and because its consistency makes grabbing the fish easier. Nevertheless, bait availability is the major determining factor and caimans are more abundant and require less hunting effort than dolphins. In most cases, direct killing of the latter occurs mainly when caimans are difficult to catch (i.e. in the extreme HW and LW seasons). Bait

Table 2

Piracatinga fishing events with confirmed dolphin bait: characteristics, approximate productivity, and profit. Ig = *Inia geoffrensis*; Sf = *Sotalia fluviatilis*; Cm = *Calophysus macropterus*; M = male; F = female; UN = unknown; UND = unidentified dolphin.

Data	Field ID	No. confirmed individuals	Sp	Sex	Length (cm)	Cm productivity (kg)	Profit (USD)
25 Mar. 2011	209	1	Ig	M	210	90*	45
28 Mar. 2011	218	1	Sf	F	153	0*	0
29 Mar. 2011	000	1	Ig	M	256	50*	25
31 Mar. 2011	221	UN	UND	UN	UN	300	117
11 May 2011	266	UN	UND	UN	UN	300	234
06 Sep. 2011	389	1	Ig	M	120	40	20
09 Oct. 2011	411	UN	UND	UN	UN	200	100
21 Nov. 2011	464	1*	Ig*	M*	150*	171*	85
21 Nov. 2011	467	1	Ig	M	135	100	50

*Fishermen's data.

productivity apparently depends on water characteristics, the piracatinga life cycle and the skill of the fishermen (da Silva *et al*., 2011; this study). Fishermen generally believe that black waters negatively affect the fishery, with catch success being higher during the rising water season. Although the fishermen stated that the total piracatinga catches are becoming smaller, they confirmed that the bait from an adult boto can actually provide a piracatinga catch of 600kg and that in the past, this could reach up to 1 tonne. Brum (2011) reported an average fish yield of 450kg from a boto but we were unable to document that level of yield (Table 2).

Fishing events surveys

Fishing activity (Table 1, Fig. 6) was recorded throughout the study period, with two clear peaks in fishing effort in March and November, which corresponds to the late RW and LW seasons respectively, when the yield of piracatinga is higher and other commercial fish species emigrate or are legally protected (Brum, 2011; Gómez *et al*., 2008). Biological evidence from this study confirmed what has been stated by others (Estupiñán *et al*., 2003; Gómez *et al*., 2008), i.e. that caimans are the most common bait (Fig. 6) and that some communities alternate between types of bait depending on availability/hunting success. However, compared with previous estimates of the percentage of dolphin bait used (Brum, 2011; Estupiñán *et al*., 2003; Gómez *et al*., 2008), our data are higher showing more than 30%. This, along with the expectation that piracatinga fishing will continue to grow (see Brum, 2011) leads to further concern for the cetaceans. This proportion may be higher/lower in other areas within and outside the Reserves. Odontocetes may be particularly susceptible to removals (Wade *et al*., 2012) and botos specifically have a complex population structure with high female philopatry, making local populations more vulnerable to extirpation (Hollatz *et al*., 2011). As both boto and tucuxi were recorded as being used for bait in the piracatinga fishery, it is essential that reliable estimates of their abundance in areas where the piracatinga fishery is known to take place are obtained, along with proper monitoring of fishing activities in order to evaluate the impacts on the dolphin populations/stocks and develop appropriate conservation strategies.

CONCLUSIONS

The increasing piracatinga fishery is part of a complex social problem that is linked to a failure to pursue ecosystem-based management and sustainable fishing practices. It also reflects the difficulties experienced by riverine communities in trying to cope with changes in lifestyle and pulses of unemployment. Although there is insufficient information to quantify fully impacts of the fishery on cetacean populations/stocks, it is clear that precautionary measures are urgently needed given the vulnerability of river dolphins. Previous authors have suggested possible solutions including the use of alternative bait (Gómez *et al*., 2008; Mintzer *et al*., 2013). Given that potentially effective mitigation measures to impacts on megafauna often prove impractical to implement (e.g. Cox *et al*., 2007; Sinha, 2002;) and/or have unforeseen consequences on other components of the ecosystem, especially in huge areas such as the Amazon with poor communities, we believe that it is critical to develop a multidisciplinary and inter-institutional strategy. Ensuring compliance with introduced conservation measures is essential and this often requires a combination of law enforcement and incentives (e.g. Cox *et al*., 2007). For the piracatinga fishery, a practical short-term solution could be to develop simple *gaiola* traps baited with fish offal, accompanied by enforcement efforts to prevent the use of protected species as bait along with an educational and outreach programme. For the long term, as suggested by Estupiñán *et al.* (2003), encouraging the development of other activities during the HW season, including the management of other fish species and caimans (see Botero-Arias *et al*., 2009; Marioni *et al*., 2013) could allow the transition of riverine communities from the piracatinga fishery to a higher income and co-managed activities.

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Appendix 1

DETAILED INFORMATION ON PIRACATINGA CONFIRMED FISHING EVENTS

A total of 114 fishing events on piracatinga were confirmed and recorded. Key: Ig = *Inia geoffrensis*; Sf = *Sotalia fluviatilis*; Mn = *Melanosuchus niger*; Cc = *Caiman crocodilus*; UN = unknown; UNC = unidentified caiman; UND = unidentified dolphin; B = bait; C = fresh carcass; CR = carcass remains; FC = fished carcass; PV = piracatinga vomit; SC = piracatinga stomach contents.

Fishing event	Date	Field ID	Community	Cage ID	Type of bait (sp.)	Evidence	Biol. samples	Fishing event	Date	Field ID	Community	Cage ID	Type of bait (sp.)	Evidence	Biol. samples
1	19/10/10	–	1	1a	Sf	C	–	35	28/03/11	218	4	4c	Sf	C	+
2	26/10/10	–	1	1a	Mn/Cc	C	–	36	29/03/11	000	4	4h	Ig	FC	+
3	28/10/10	–	2	2a	Mn	C	–	37	31/03/11	221	4	4d	UND	B/PV	+
4	29/10/10	–	3	3a	Mn	C	–	38	31/03/11	224	4	4e	Mn	C	–
5	12/01/11	–	1	1a	Mn/Cc	C	–	39	02/04/11	226	6	6b	UNC	B	+
6	12/01/11	–	1	1b	Sf	C	–	40	02/04/11	227	4	4c	UNC	B	+
7	20/01/11	–	2	2b	Mn	C	–	41	02/04/11	228	7	7a	Mn	FC	–
8	21/01/11	–	1	1a	Mn	C	–	42	13/04/11	232	4	4f	Ig	FC/B	+
9	23/01/11	–	1	1b	Cc	C	–	43	13/04/11	234	4	4g	Mn	C	–
10	09/02/11	–	1	1a	Ig	C	–	44	14/04/11	238	4	4b	Mn	C	–
11	24/02/11	160	4	4a	Mn	FC	–	45	18/04/11	–	1	1a	Mn	C	–
12	24 /02/11	161	4	4c	Ig	CR	+	46	21/04/11	–	2	2b	Mn	C	–
13	25/02/11	–	2	2a	Mn	C	–	47	23/04/11	253	4	4c	Mn	FC	–
14	25/02/11	169	1	1a	Mn	C	–	48	23/04/11	256	4	4d	UND	B	+
15	01/03/11	177	4	4c	Mn	B	+	49	24/04/11	257	4	4f	Mn	FC	+
16	01/03/11	178	4	4d	UNC	B	+	50	28/04/11	–	2	2a	Mn	FC	–
17	04/03/11	182	4	4d	Mn	CR	–	51	28/04/11	259	4	4b	UND	B	+
18	04/03/11	184	4	4c	Mn	FC	–	52	11/05/11	266	4	4c	UND	PV	+
19	04/03/11	185	4	4f	Mn	FC	–	53	16/05/11	–	2	2a	Mn	FC	–
20	07/03/11	–	1	1a	Mn	C	+	54	20/05/11	275	4	–	Ig	CR	+
21	23/03/11	196	2	2a	Mn	B	+	55	23/05/11	–	1	1a	Mn	C	–
22	23/03/11	198	4	4c	UNC	CR	+	56	27/05/11	279	4	–	UND	SC	+
23	23/03/11	–	5	5a	UNC	B	–	57	23/06/11	297	4	4g	Mn	FC	–
24	24/03/11	–	1	1a,1b	Mn	FC	–	58	26/06/11	301	4	4c	Mn	FC	–
25	24/03/11	–	1	1c	Mn	C		59	28/06/11	304	4	4g	UNC	B/PV	+
26	25/03/11	–	1	1a	Mn	C	–	60	21/07/11	312	4	4a	Mn	CR	–
27	25/03/11	–	1	1c	Ig	C	–	61	23/07/11	–	1	1b	Mn	C	–
28	25/03/11	203	5	5a	Cc	FC/B	+	62	03/08/11	–	1	1a	Mn	C	–
29	25/03/11	205	6	6a	Ig	B	+	63	04/08/11	326	4	4b	Mn	FC	–
30	25/03/11	209	4	4c	Ig	FC	+	64	06/08/11	–	1	1b	Mn	C	–
31	25/03/11	211	4	4g	UND	B	+	65	06/08/11	329	4	4g	UND	B	+
32	26/03/11	213	4	4f	Mn	C	–	66	08/08/11	331	4	4g	UND	B	+
33	26/03/11	–	2	2a	Mn	FC	–	67	24/08/11	343a	4	4a	Ig	FC	+
34	28/03/11	214	6	6a	UNC	CR	–	68	24/08/11	343b	4	4a	Mn	CR	–

Fishing event	Date	Field ID	Community	Cage ID	Type of bait (sp.)	Evidence	Biol. samples
69	24/08/11	344	4	4c	UNC	B/PV	+
70	24/08/11	344	4	4d	Mn	C	–
71	24/08/11	345	4	4g	UNC	B	+
72	25/08/11	349/350	4	4c/4d	UNC	B/PV	+
73	26/08/11	353	8	8a	Mn	B/SC	+
74	29/08/11	356	UN	–	Ig	CR	+
75	29/08/11	359	4	4c	UNC	B	+
76	29/08/11	360	8	8a	Mn	CR	–
77	05/09/11	386	4	4c	Ig	C	+
78	07/10/11	406	4	4a	UNC	PV	+
79	07/10/11	407	4	4c	UNC	PV	+
80	07/10/11	408	4	4d	UNC	B	+
81	09/10/11	411	4	4a	UND	B	+
82	09/10/11	412	4	4c	UND	B	+
83	09/10/11	414	4	4d	Mn	FC	–
84	12/10/12	417	4	4c	UNC	B	+
85	12/10/12	–	2	2a	Mn	FC	–
86	20/10/12	422	4	4c	UND	B	+
87	22/10/12	425	4	4c	UND	B	+
88	23/10/11	–	2	2b	Mn	FC	–
89	12/11/11	426	2	2a	Mn	PV	+
90	12/11/11	427	2	2b	Mn	FC	–
91	12/11/11	428	1	1a	Mn	FC	–
92	12/11/11	434	6	6c	Mn	C	+
93	14/11/11	440	4	4c	UND	B/PV	+
94	15/11/11	442	6	6c	Mn	B	+
95	15/11/11	443	8	8a	Mn	CR	–
96	16/11/11	445	4	4c	UNC/D	B	+
97	17/11/11	447	4	4d	UNC	B/PV	+
98	17/11/11	450	8	8c	Mn	C	–
99	18/11/11	452	6	6a	Mn	C	–
100	18/11/11	453	6	6b	UNC/D	B	+
101	18/11/11	455	4	4c	UND	B	+
102	18/11/11	458	4	4h	Ig	CR	+
103	19/11/11	459	6	6c	UNC	B	+
104	20/11/11	460	6	6b	UNC	B	+
105	21/11/11	463	4	4c	UND	B	+
106	21/11/11	464	4	4d	UND	B/PV	+
107	22/11/11	467	4	4c	Ig	FC	+
108	25/11/11	468	4	4c	UND	B	+
109	26/11/11	469	2	2a	Mn/Cc	B	+
110	26/11/11	471	6	6b	UNC	B	+
111	26/11/11	474	6	6c	UNC	B	+
112	27/11/11	–	2	2a	Mn/Cc	C	+
113	30/11/11	006	UN	–	Ig	FC	+
114	01/12/11	007	UN	–	Ig	FC	+