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Use of dolphins and caimans as bait for *Calophysus macropterus* (Lichtenstein, 1819) (Siluriforme: Pimelodidae) in the Amazon

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Summary

A new fishery has been developing in the Amazon that uses dolphin and caiman species as bait to catch piracatinga (*Calophysus macropterus*), having thus the potential to cause adverse food-web impacts; however a lack of basic understanding of this fishery is a limitation to the necessary management action. Interviews with fishers and analyses of fishing records in Brazil were used for the study, including harvest methods, types of baits used, commercialization chains, and the rate of increase of piracatinga yields in recent years. Piracatinga fishers are subsistence fishers who harvest piracatinga as a means to alleviate economic constraints when the catch of other species is not profitable or banned due to (reproductive) closed seasons. Harvesting is done with wooden and nylon crates and cages in which whole or pieces of caimans and dolphins are placed to attract the piracatinga, entrapping them. The piracatinga are then sold to intermediate sellers for resale to a few large fish freezing and processing plants for export to Colombia. Annual piracatinga yields in the study area increased at an average rate of 446.5% per year, from 865 kg in 2003 to 23 176 kg in 2009. Because dolphins and caimans comprise various endangered species, the Brazilian government has recently implemented a ban on this fishery, which can be enforced at fish freezing and processing plants. However, there is a danger that such enforcement will lead to the development of a geographically dispersed chain of commercialization and export, such as currently exists for other species including caimans, which would be impossible to control.

Introduction

There are increasing concerns on the impacts of fishing activities regarding aquatic ecosystems worldwide (Pikitch et al., 2004). In tropical multispecies fisheries, the large number of species involved makes them susceptible to the 'fishing-down' process, where historical increases in the fishing effort reduce the mean body size of harvested species through the depletion of large-bodied species and the gradual replacement with small-bodied ones (Welcomme, 1999). In the Amazon River in South America, for example, 'fishing-down' shrank the mean maximum length of harvested species from 206 cm in the early 1900s to 79 cm today (Castello et al., 2013a). The depletion of aquatic species changes the structure and function of aquatic ecosystems, increases social dependency on only a few species, and threatens food security.

Fisheries that require bait typically rely on the use of small-body, generally abundant species (e.g. sardines – Clupeidae) to catch larger-body, high values species (e.g. tunas – Scombridae). However, a new but poorly documented form of fishing has been developing in the Amazon to catch piracatinga (*Calophysus macropterus* Lichtenstein, 1819, Siluriformes: Pimelodidae), a necrophagous species that grows up to 40 cm in length and 1 kg in weight (Santos et al., 2006). The readily available dolphin and caiman species are used as bait for their capture. Dolphins (*Inia* spp. and *Sotalia fluviatilis* Gervais & Deville, 1853) and caimans (*Melanosuchus niger* Spix, 1825, *Caiman crocodilus* Linnaeus, 1758 and *Paleosuchus* spp.) are 'K-strategist' species vulnerable to human impact, and hence highly susceptible to population decline and extinction (Da Silva, 2008; Thorbjarnarson, 2010; Velasco and Ayarzagüena, 2010). Such use of dolphins and caimans is not only to their detriment but will also downgrade the Amazonian trophic food webs.

Although piracatinga fishery in the upper Solimões River began possibly as early as the mid-1990s, the first record of this fishery in Brazil was in 2000, when researchers became concerned about the impact on dolphin and caiman populations and called attention to the potential ecological problems (Da Silveira and Viana, 2003; Da Silva et al., 2011; Alves et al., 2012; Iriarte and Marmontel, 2013, 2014; Mintzer et al., 2013). By 2007, piracatinga yields in Brazil were around 1 600 000 kg, ranking 29th among the Amazon's largest commercial fisheries (Barthem and Goulding, 2007). Although fisheries statistics in the Amazon are almost non-existent (Bayley and Petrere, 1989; Castello et al., 2013a), such data on piracatinga yields is roughly reliable because it comes from the few large fish freezing and processing plants exporting to Colombia, where it is a substitute for *Pimelodus grosskopfii* (Steindachner, 1879 – Siluriforme: Pimelodidae), a highly sought-after but overexploited species of the Colombian Amazon (Trujillo et al., 2010b; Mojica et al., 2012). By 2011, piracatinga yields in in State of Amazonas, Brazil, the main center of piracatinga fishing, were around 4 400 000 kg (Amazonas

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Secretary of Production, unpublished data). The impact of piracatinga fishing is now evident. Survival rates of the boto (*Inia geoffrensis* Blainville, 1917) in the Middle Solimões region have declined after the rise of piracatinga fishing (Mintzer et al., 2013). Consequently, the piracatinga fishery has recently been banned by the Brazilian government for a period of 5 years (Instrução Normativa N° 6, 17 July 2014) to enable the development of alternative baits and techniques and the recovery of the caiman and dolphin populations.

However, the piracatinga fishery is still not well studied, in part because dolphins and caimans are protected under Federal Law in Brazil, thus the piracatinga fishers typically do not share this information; however, further information is needed if these effects on dolphin and caiman populations are to be better assessed and additional management action is to be taken. This study documents key characteristics of the piracatinga fishery, including: (i) the fishers, (ii) the rate of increase of piracatinga yields, (iii) harvesting of piracatinga, (iv) main sources of bait used, and (v) commercialization of the fish.

Methodology

Study area and sampling

This study was conducted between February 2010 and February 2013, before the current ban on piracatinga fishing, in two areas of Amazonas State, Brazil: (i) the Middle Solimões River region, comprising the cities of Tefé, Alvarães, and Uarini, as well as the surroundings of the Mamirauá Sustainable Development Reserve, and (ii) the Lower Purus River region, comprising the cities of Beruri, Anori, and Tapauá, inside the Piagaçu-Purus Sustainable Development Reserve (Fig. 1).

Several data sources were used. An initial survey of the five associations of fishers in the two study areas indicated that only the Tefé Fishers' Association possessed historical records of piracatinga yields per fishers, together with information on each fisher's gender, age, and place of residency. This information was used to characterize the fishers and estimate the rate of increase of piracatinga yields. In order to describe how piracatinga is harvested, the main sources of bait, and how the fish is commercialized, 57 fishers were interviewed via a snowball system (Bailey, 1982) in which an expert is identified, interviewed, and asked to suggest another expert. This method usually produces satisfactory samplings in a region based on key informants for specific activities. Standard questionnaires were used in which fishers were free to describe their fishing practices and given multiple-choice questions aimed at understanding and quantifying the types of bait used and the methods of piracatinga commercialization. In the Middle Solimões area, 17 piracatinga fishers from four communities were interviewed; in the Lower Purus, 40 fishers from 24 communities in the Piagaçu-Purus Reserve were interviewed. For a better understanding of the commercialization and export, the managers at freezing and processing plants were also interviewed (seven in the city of Tefé and two in the city of Manacapuru).

Results

Fishers

A total of 413 piracatinga fishers between 21 and 64 years of age (average 41.4 years, SD ±9.9 years, 81% males) are registered with the Tefé Fishers' Association. Interview data showed that both the Solimões and Purus regions have predominantly subsistence fishers who live in floodplain communities and for whom piracatinga is not their main target species. Piracatinga fishing is an occasional activity to complement earnings, mainly during high river water levels when fishing for commercially valuable target species such as *Colossoma macropomum* Cuvier, 1816 and Pimelodidae is banned due to (reproductive) closed seasons, or are not profitable.

Harvesting

In the Middle Solimões area, all fishers reported using wooden crates approximately 1.2 m high, 2.5 m long, and 1.2 m wide,

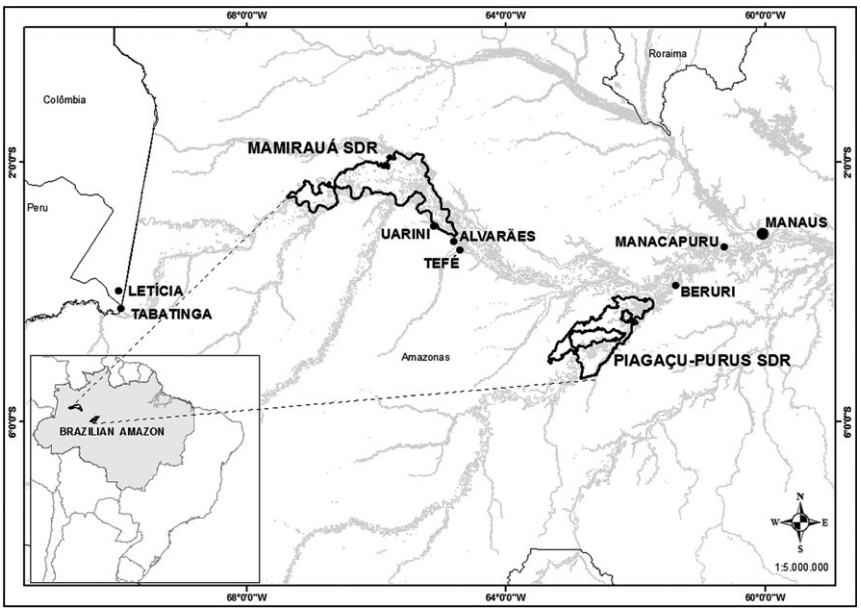

Fig. 1. Study area, Central Amazon, Brazil, indicating the sustainable development reserves (SDRs Mamirauá and Piagaçu-Purus), as well the nearby cities (small dots) with freezer facilities and for piracatinga, *Calophysus macropterus*, commercialization

made of boards spaced so as to allow smaller fish to escape (Fig. 2a). The crates are used in two ways for piracatinga fishing and always at night. The 'box fishing' method is used by 52.9% of the interviewed fishers, generally using spoiled bait attached to fishing poles to attract the fish. When the fish bite and grab the bait, they are dragged into the wooden crate through an open door and trapped. The bait is removed from the top of the wooden crate and used repeatedly until completely consumed. The 'hand fishing' method is used by 47.1% of the fishers and requires standing in the water and positioning the bait between their legs; when the fishes approach, they manually grab the larger ones and throw them into the semi-submerged wooden crate. With this method, the crate serves as a storage place and does not always have a door. Fish are kept alive inside the submerged crate until the next morning, when they are eviscerated and preserved in ice.

In the Lower Purus area, fishing for piracatinga uses four main types of gear: nylon cage (used by 65% of those interviewed); longline (19%); hand line (10%); and seine net (6%). Although longline, hand line, and seine net fishing are common methods, the nylon cage is a method developed specifically for piracatinga. Nylon cages are usually about 1.5 m high and 6 m wide and long (Fig. 2b). Fishers dive during the day to attach the bottom corners of the nylon cage to anchorage stakes close to the riverbank. They then use canoes to drag bait and attract fish towards the trap door. The door is closed when fish enter the cage, and the process is repeated until the bait is completely consumed. This occurs at night and the bait is handled manually or using a hook. Fish are kept alive inside the nylon cage until the next morning. Fishers from this area stated that fishing boats from Manacapuru were the main piracatinga fishers in the Purus River, but none could be contacted.

Bait

All interviewed fishers in the Middle Solimões used botos (*Inia geoffrensis*) and caimans (black caiman *Melanosuchus niger* and common caiman *Caiman crocodilus*) meat as bait for piracatinga. Catfish viscera (Pimelodidae, mainly *Brachyplatystoma rousseauxii* Castelnau, 1855) were also described as bait for 29.4% of fishermen. Use of tucuxi dolphin (*Sotalia fluviatilis*) meat was not reported. All persons interviewed stated that they caught their own bait, but there were reports of fishers who specialized in capturing dolphins and caimans to sell as bait. Botos were unanimously cited as the best bait for piracatinga.

In the Lower Purus, 70% of the fishers used botos as bait, and 52% also used caimans. A higher bait diversity was registered in comparison to the Middle Solimões, including cattle fat, catfish viscera (Pimelodidae), stingrays (Potamotrygonidae), tucuxis, and piranhas (*Serrasalmus* sp.).

Yield increase

Fishers' Association historical records of piracatinga yields in the Middle Solimões region indicated that the yields varied relatively little over the course of a year. However, annual piracatinga yields increased by 2679% during the study period (at an average increase rate of 446.5% per year), from 865 kg in 2003 to 23 176 kg in 2009 (Fig. 3).

Commercialization

Fishers in Middle Solimões did not themselves consume piracatinga; all yields were sold to freezing and processing plants, either directly or through intermediate sellers or middlemen,

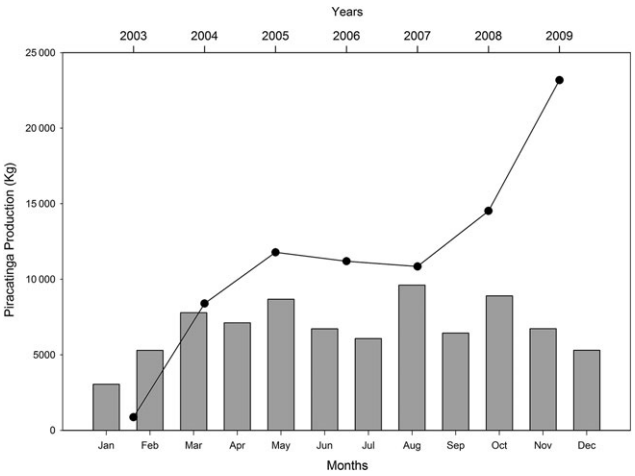

Fig. 3. Piracatinga production registered in Medium Solimões, Central Amazon, 2003–2009. Bars = monthly production per year; connected line = registered total annual production

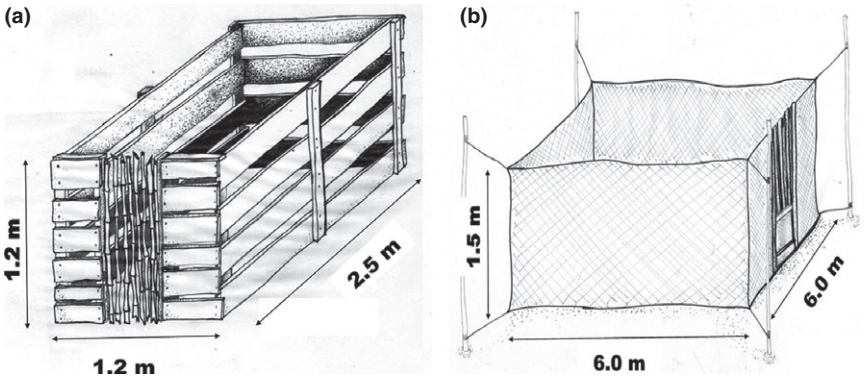

Fig. 2. Drawings of main types of gear used to fish for piracatinga in the Central Amazon. (a) Wooden crate used in the Medium Solimões region; (b) Nylon cage used in the Lower Purus region

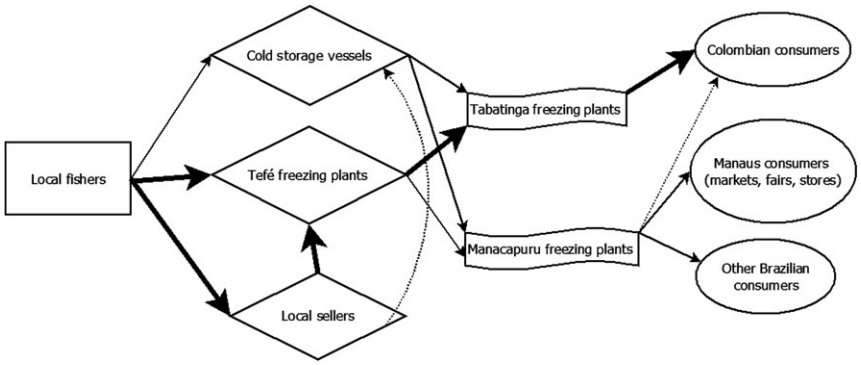

Fig. 4. Piracatinga supply chain diagram, Middle Solimões region. Rectangles = producers; rhombus and flags = intermediate sellers; ovals = consumers. Thick arrows = most common pathway registered; thin arrows = registered paths but rarely in use; dotted arrows = likely but unregistered paths

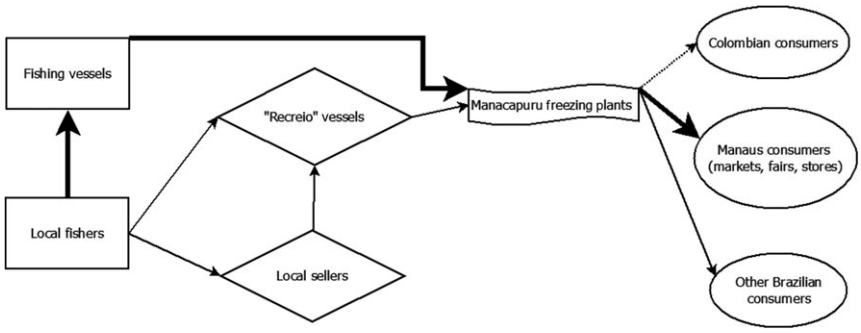

Fig. 5. Piracatinga supply chain diagram, Lower Purus Solimões region. Rectangles = producers; rhombus and flags = intermediate sellers; ovals = consumers. Thick arrows = most common pathway registered; thin arrows = registered paths but rarely in use; dotted arrows = likely but unregistered paths

for an average price of US$ 0.42. The fish were passed on to other facilities in the cities of Tabatinga, Manacapuru, or Manaus (Fig. 4).

Piracatinga was also not consumed in the Lower Purus region. Fishers sold eviscerated piracatinga for an average price of US$ 0.35 per kg directly to fishing boats or intermediate sellers. There were no freezing facilities in the area and fishing boats transported all yields to Manacapuru for storage (Fig. 5).

Discussion

Fisheries statistics are lacking for most of the Amazon (Bayley and Petrere, 1989; Castello et al., 2013a) and there is no monitoring or control of the freezing facilities, leading to uncertainties as to production levels and the exact starting date of the piracatinga fishery. Nevertheless, our estimate of the annual rate of increase of piracatinga yields is around 446.5% in the Middle Solimões region (Fig. 4), indicating the importance of this recent banned fishery.

The rapid expansion of the piracatinga fishery is probably due mainly to its complementary role in the livelihoods of subsistence fishers, the decline in other commercially valuable fish species, and the poor enforcement of regulations. The marked seasonality of Amazon fisheries, caused by the seasonality in river water levels, results in significantly lower fishery productivity (i.e. catch per unit effort) during the high water levels, and impacting the fishers' livelihoods (McGrath et al., 1993, 2008) which are also affected by closed (reproductive) season regulations for most commercial fish species. The piracatinga fishery is new, thus it is not included in management regulations and therefore offers an additional source of income for subsistence fishers. At the same time, the fishers face seasonal economic difficulties, with the additional economic challenges caused by the decline of some of the most important commercial fish species. Of the 18 most important taxa in Amazon fisheries, *Arapaima* spp. is considered endangered, with four more species overexploited in at least one region of the basin (*Brachyplatystoma filamentosum* Lichtenstein, 1819; *C. macropomum; Brachyplatystoma vaillantii* Valenciennes, 1840; *Pseudoplatystoma* spp.; Castello et al., 2013a). In the Lower Amazon region, strong indications show that five of the nine most important species harvested by subsistence fisheries are overexploited (Castello et al., 2011). This increasing degradation of fish stocks forces fishers to identify new profitable fisheries, such as the piracatinga.

Finally, caimans and dolphins as principal bait items for piracatinga fishing is illegal: dolphins and caimans are protected in Brazil by Federal Law N° 5.197 of 3 January 1967. However, due to scarce human and financial resources this is not enforced because of the paucity of enforcement in Brazil for environmental management (Oliveira, 2002), combined with Brazil's historical focus on natural resource exploitation rather than sustainability (Chapman, 1989; Crampton et al., 2004; Castello et al., 2007).

The impact of the piracatinga fishery on regional dolphin and caiman populations has yet to be properly assessed, however, the impacts are expected to be severe. The IUCN has always considered caiman species in the Amazon to be endangered because of the history of harvesting for skins and more recently for human consumption (Da Silveira and Thorbjarnarson, 1999). *M. niger* and *C. crocodilus* are no longer endangered in the Amazon (IUCN, 2013), but addi-

tional mortality by the piracatinga fishery could cause adverse effects (Da Silveira and Viana, 2003). *I. geoffrensis* in the Amazon faces a somewhat similar threat; although it is considered as data-deficient by the IUCN, entangling in fishing nets and habitat destruction are important threats (Trujillo et al., 2010a). Additional mortality is of concern: in the Middle Solimões, 35 piracatinga fishery events are documented using dolphin bait over 1 year (Iriarte and Marmontel, 2014). Long-term *I. geoffrensis* monitoring showed a recent population decline attributed to the piracatinga fishery (Mintzer et al., 2013). A decline of caimans and dolphins in the Amazon has a multiple adverse impact potential, whereby the loss of these apex predators could alter the food web structure, water quality, and nutrient cycles, as is documented elsewhere in the world for various top-of-the-food-web species (Estes et al., 2011).

These previous studies have called for urgent management actions for effective protection of caimans and dolphins from piracatinga fishing; the Brazilian government responded by declaring a 5-year ban. Although most fishery regulations in the Amazon are ineffective because of poor enforcement and the difficulties of monitoring geographically dispersed subsistence fisheries (Castello et al., 2013a), the results of this study indicate that such ban has the potential to be effective. All commercialization of piracatinga is via large freezing and processing plants (Fig. 5) that are relatively easy to monitor. However, enforcement of such a ban may lead to the development of a geographically dispersed commercial and export chains, which would be impossible to control. It is well known that, given the paltry governmental budget allocations for fisheries management and the high degree of geographic dispersion of subsistence fisheries in the Amazon, it is impossible to ensure regulation compliance via conventional top-down management approaches (Isaac et al., 2008; Castello et al., 2013b). Widespread lack of compliance with regulations has already caused local extinctions of the giant fish *Arapaima* spp. in the Lower Amazon region (Castello et al., 2014), thus uncontrolled fishing for piracatinga might continue to threaten dolphins and caimans in the Amazon. There is therefore a need to monitor the effects of the ban at freezing and processing facilities as well as a direct monitoring of subsistence fishers. This ban should also be useful for the proper monitoring of recovering populations and threats to bait-used taxa, the proper assessment of the *C. macropterus* biological and conservational status, and for the development of alternative baits.

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