



The piracatinga, *Calophysus macropterus*, production chain in the Middle Solimões River, Amazonas, Brazil

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Abstract Piracatinga, *Calophysus macropterus* Lichtenstein, was not exploited in Brazil until the early 2000s, when fish pressure increased markedly due to growing demands. The methods for capturing piracatinga involve the use of caiman and dolphin carcasses as bait; and the growing organization of the hunting and marketing of these animals raises concern. This study describes the production chain of piracatinga fishing in the region of the middle Solimões River, in Brazilian Amazonia. It was conducted in 19 local communities of the Mamirauá Reserve; data were collected from 50 individuals involved in the activity, divided into eight categories within the production chain. The production of piracatinga reaches its peak in the first months of the closed season for other fishes. The average profit margins of the activity between 2011 and 2013 were higher than those of other artisanal fishing activities, but they varied from 38% of losses by event to profits of 90%. The use of corrals and baits from aquatic vertebrates in piracatinga fishing are exclusive to this activity. It is important to develop participatory and sustainable options, such as the use of commercial fishes as bait or the engagement of the people involved in legal activities.

KEY WORDS: Amazonia, artisanal fishing, caimans, local populations, marketing, river dolphins.

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Introduction

Artisanal fishing can be defined as autonomous or family-based fishing activities with a commercial goal, using the fisher's own productive means or through partnership contracts, either disembarked or with the aid of small watercraft. This activity is responsible for around 45% of fish production in Brazil (MPA 2014). In Amazonia, this modality of fishing has socio-economic importance as one of the main sources of animal protein, employment and income for local populations (Santos 2005; Almeida 2006; Cavalcante 2011). In the middle Solimões region, an area corresponding to 300 km of this river located between the municipalities of Tefé and Fonte Boa (Viana 2004), fishing accounts for 70% of annual household income within the communities (SCM 1996) and the consumption of fish per capita can reach 130 kg yr⁻¹ (Queiroz 1999), much higher than the world average of 19.2 kg yr⁻¹ (FAO 2014). Most communities that depend on the production and marketing of the products of this activity as a fundamental source of income and food, however, face socio-economic, structural and environmental problems such as conflicts with commercial fishing, overfishing and excess of middlemen (Santos 2005; Silva *et al.* 2007; Cavalcante 2011; FAO 2014). These problems, associated with the difficulties found in other segments of the fishing industry (Almeida 2006), tend to compromise the performance of the fishing production chain in the long term. In this context, it is important these political instruments and public and private actions are formulated and implemented with a broad understanding of the reality of the agribusiness of artisanal fishing (Santos 2005).

Analyses of production activities associated with primary sectors of economy, such as artisanal fishing, demand a holistic and systemic understanding of the structures of production and marketing and the multiplicity of relations among economic agents that are part of this chain (Castro *et al.* 1998; SEBRAE 2000). The analysis of agribusiness as a system may provide the formulation of macro policies with relevant data; however, production chain analyses present greater applicability, due to their greater specificity and possible depth, mainly through the acknowledgement of the main bottlenecks of the activity (Castro *et al.* 1998; SEBRAE 2000). This application allows derivation of possible solutions for the particular problem in the production chain under discussion, enabling an increase in economic viability and the adoption of socially and environmentally sustainable practices (Euclides Filho *et al.* 2002).

The production chain is the set of interactive components, including the production systems directly influenced by local legal and organisational aspects, which

aims to supply the end user with certain products or sub-products; it can be divided into three segments: production, marketing and consumption. The first segment involves supplying necessary goods and inputs to the development of the activity (Santos 2005; SEBRAE 2000), including the production of watercraft and fishing gear and inputs such as ice and fuel, in addition to the fish production itself. The second segment is the process of marketing developed by people who perform value-adding functions, including storage, processing, transporting and distribution (SEBRAE 2000; Santos 2005). The final link of the production chain is the consumer market, which is the target of the whole process.

Piracatinga *Calophysus macropterus* Lichtenstein, also known as mota, water vulture, pintadinha and capaz, is a middle-sized catfish (around 30 cm) that has long barbels and black spots on the dorsal area and below the lateral line; its body can vary from grey to dark brown, and some spotless variants are found as well. The most typical feature of this species is the flat teeth layered in one or two lines, unlike other catfishes from the Pimelodidae family. It is mainly necrophagous, although it may also feed on live fish, invertebrates and plant material. The piracatinga is a migratory species that inhabits mostly rivers and floodplains (Galvis *et al.* 2006; Pérez & Fabre 2009). It shows two peaks of annual growth, associated with the dry and wet seasons (Pérez & Fabre 2009). Piracatinga was neither of significant economic importance nor important for exploitation in Brazil (Santos *et al.* 2006) until the beginning of the 21st century, when its production increased considerably in the middle Solimões river region (Estupiñán *et al.* 2003). This increase is mainly due to the growing demands from Colombia (Santos *et al.* 2006), where it commercially replaces capaz, *Pimelodus grosskopfii* Steindachner, a much appreciated catfish the presence of which has been dramatically reduced by overfishing.

Fishing techniques for piracatinga involve the use of animal carcasses as bait, usually caiman and river dolphins, which threatens the conservation of these species (Estupiñán *et al.* 2003; Botero-Arias *et al.* 2008; Loch *et al.* 2009; Brum 2011; Iriarte & Marmontel 2013). Growing organisation of the hunting and marketing system of these animals, which can be attested by the existence of hunters who specialise in obtaining and providing baits (Brum 2011; Botero-Arias *et al.* 2014; Franco *et al.* 2014), is of concern. To reduce illegal hunting of caiman and river dolphins, an Interministerial Normative Instruction no. 6 was issued on 17 July 2014, to prohibit fishing, on-board retention, transshipment, storage, transportation, processing and marketing of the piracatinga under Brazilian jurisdictional on waters and in national territory for 5 years, beginning in 1 January

2015. Within the current context, the description of the piracatinga production chain is fundamental to provide hard data concerning economic and production aspects of the activity (Castro *et al.* 1998; Euclides Filho *et al.* 2002), and to estimate environmental damage caused by the killing of caiman and river dolphins and advance ecologically and economically sustainable options (Botero-Arias *et al.* 2014).

Materials and methods

Study area

The research was conducted in areas belonging to the Mamirauá Sustainable Development Reserve (MSDR) and municipalities of the reserve's area of influence. The MSDR is situated in the triangle formed by the Auati-Paraná, Solimões and Japurá rivers, encompassing the municipalities of Alvarães, Uarini, Fonte Boa, Maraã, Japurá and Tonantins. The reserve is the largest protected area in flooded areas in Brazil, including an area of 1 124 00 ha of floodplain, subdivided into political sectors, the latter constituted by riverine communities. The area defined by the Solimões, Japurá and Paraná of Aranapu rivers, known as the MDSR focal area, constitutes one of the main fishing areas in the region of the middle Solimões (Viana 2004).

Methodology

Semi-structured interviews were conducted between 2011 and 2013 to collect data according to snowball sampling (Bailey 1994), where the original interviewees indicate new interviewees, creating a network of stakeholders involved in the activity. The targets of the research were piracatinga fishers, bait hunters, middlemen and freezing plant and boat workers, from whom social and production data related to the activity were collected. The production segment was analysed by obtaining data such as costs by hunting or fishing event, baits used, volume of hunted/fished baits and harvest in kilograms of piracatinga. The activities of the interviewees were followed, whenever possible, to collect information on input costs, equipment and workforce, from the capturing of the baits and the fishing of the piracatinga to the delivery of the product to the buyers. Analysis of the marketing segment was performed by examining personnel, technology and necessary inputs to pre-processing, storage, transportation, sale and resale of the fishes. Interviews were conducted with fishers, boat and freezing plant owners, middlemen and those involved in pre-processing. Due to the absence of a local culture of piracatinga consumption identified during the

first expeditions, the consumption segment was not analysed. As an indicator of economic viability, the profit margins (Carvalho *et al.* 2004; Coelho 2005; Silva *et al.* 2013) of the activities developed within the production chain were calculated through analysis of all production costs obtained with the activity-based costing methodology (Nakagawa 2001), considering the activities developed and the products generated in the different stages of the piracatinga production chain.

Results

After initial exploratory expeditions to 60 communities, 40% (24/60) were found to engage in piracatinga fishing activities. Among these, 19 communities, located in seven sectors throughout the Solimões and Aranapu rivers, were selected as research locations due to the greater concentration of people involved in the activity, higher numbers of events of bait hunting and piracatinga fishing and greater receptivity of the inhabitants. In addition, technical visits to freezing plants and trading posts were made in the municipalities of Uarini, Alvarães and Fonte Boa. Fifty persons involved in the production and marketing segments of the piracatinga production chain were interviewed and grouped in eight main categories (Fig. 1).

The input suppliers are sellers within the communities or municipalities responsible for providing the other agents of the production chain with assorted inputs, such as flashlights, fishing gear, fuel and ice. Among the interviewees, only one (2%) had input supplying, mainly gasoline and batteries, as the main professional activity within the piracatinga production chain. Three others (6%) performed it as a secondary activity. Three of the four of these workers were men; the mean age of the interviewees was 37 years. Bait suppliers specialised in hunting and selling the main baits used in piracatinga fishing. They generally work jointly with the fishers, not performing any other activity within the chain. Institutional influence is more directly suffered by these workers, as hunting wild animals, such as caiman and dolphins, is illegal. Among the interviewees, 12% (6/50) had hunting for supplying baits as their main activity, while 2% (1/50) had it as a secondary activity. All hunters were males with mean age of 48 years and started their commercial activities around 2006. Piracatinga fishers were at the end of the production sector of the production chain. They are the ones who usually accumulate other functions, mainly those of bait hunter, eviscerator and middleman. They constituted most of the interviewees, accounting for 46% (23/50). Among these, 21 (91.3%) hunted their own baits, buying or selling only in specific events and opportunistically. Only one woman (2.5%) performed this activity among the fishers.

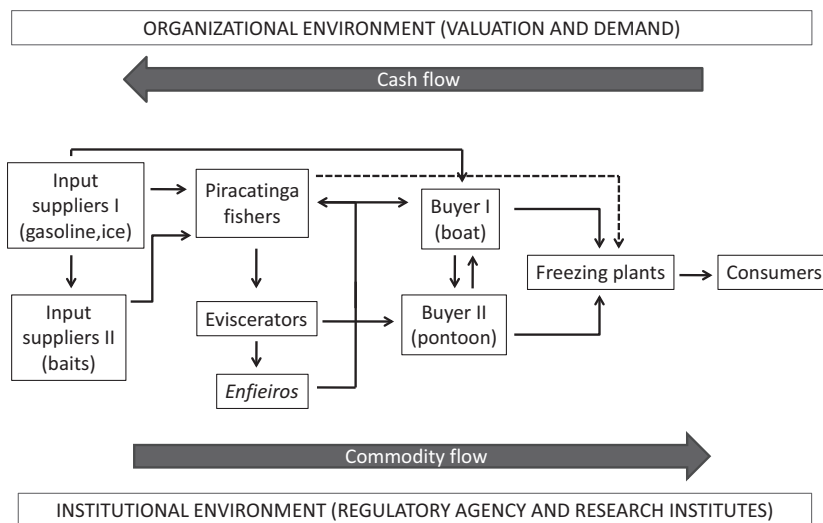


Figure 1. Flowchart of the piracatinga production chain.

The mean age of fishers was 35 years, and the onset in the activity happened around 2002.

The eviscerators were mostly children, adolescents and women who did not play a direct role in fishing and were paid to eviscerate the fishes when their quantity was very large. They may also be relatives or friends of the fishers; in this case, they received no payment for their work. Only 4% (2/50) of the interviewees performed this task as their main activity commercially, although 16% of the others (8/50) performed it for their own fishing activities or due to friendship or family relationship. Among eviscerators, only women of mean age of 19 performed it as their main activity, having started in it around 2009. In some localities, mainly where fishing occurs on a larger scale, there are *enfieiros*. They are generally part of the crew of buyer boats, or workers who work for the pontoon middlemen, and paid to arrange the eviscerated piracatingas on a line by passing a wooden needle through them. The *enfieiras* are used to facilitate weighting.

The buyers (12/50) are refrigerator boats and middlemen known as *patrões* (which could be loosely translated as 'bosses'), who are fundamental for the maintaining the production chain in communities far away from marketing freezing plants. Among the interviewees, 8% (4/50) performed this task by buying the fishes received on their pontoons and delivering them to boats or freezing plants. All were men with a mean age of 39 and who started in the activity around 2008. Transportation, buying and reselling with boats were performed by 16% (8/50) of the interviewees. All were men of mean age of 40 years, and they started in this activity in 2008. Freezing plants represent the final link of the marketing segment. Six (12%) workers in this category were interviewed, four in the municipality of Fonte Boa and two

in the municipalities of Alvarães and Uarini, even though the Uarini freezing plant stopped marketing piracatinga 3 years ago because of economic reasons.

Consumers have a fundamental influence in the whole chain, as they generate the demand, regulating the volume produced and even the viability of the activity. The low acceptance of the piracatinga among the inhabitants of the MSDR resulted in the scarcity of consumers; therefore, this segment was not described. Among the interviewees, 60% (30/50) performed more than one task within the production chain, mainly fishing and bait supplying (70%) and fishing and evisceration (30%).

The piracatinga production chain is directly influenced by factors such as the hydrological cycle, market values, transportation and demand and environmental law. Environmental laws protecting local fauna and actions by research institutes concerned with environmental issues impact on bait hunting, having caused the cessation of the activity in six (42.8%) of the 14 communities where piracatinga fishing has stopped. Communities in the Ingá, Liberdade and Horizonte sectors, where baits are sold, have reduced or ceased the supply of river dolphin due to surveillance and research actions. The marketing of caiman, however, still occurs, according to the inhabitants, and is seen as a 'lighter' crime by them.

Supplying basic inputs, mainly ice and gasoline, plays a crucial role in the piracatinga production chain. Supplying may occur through the direct purchasing of the items in the market in municipalities closer to the communities or through middlemen. The most frequently purchased items in the municipalities are harpoons, harpoon rope, axe blades, flashlights and nails. Among the 40 interviewees in the production segment, 80% purchased these items in the municipality of Tefé, even when there were

nearer municipalities, due to the lower prices offered. Uarini, on the other hand, was frequently avoided due to the high prices (up to 100% higher for items such as harpoons). Only 5% (2/40) of the fishers, both from the Aranapu sector, referred to Maraã as a source of basic inputs. Fuel and ice are the inputs of greater economic importance within the production chain, as they are needed in almost all activities. They are obtained in the communities through middlemen who buy them in municipalities and resell them for prices that are 10–20% higher than the original – ice can cost as much as $\$0.28 \text{ kg}^{-1}$; and fuel $\$1.84 \text{ L}^{-1}$. The most distant sectors from the main urban centres, and those that are more dependent on middlemen for the acquisition of basic inputs, showed the highest prices (up to 60% higher than other sectors). Inputs may also be supplied by boat or freezing plant owners, aiming at exclusively supplying fishers and other fishing activities (Almeida 2006). The supplying of inputs is not dependent upon the piracatinga production chain, as these inputs are used in an array of other production activities. Even though bait hunting and supplying based on personal relationships has appeared along with piracatinga fishing, the marketing of this input is more recent, having started around 2006.

Bait hunting is very homogenous in the area. Caiman hunting is generally performed by two men – a boatman (using a rabeta, an outboard motor canoe of potency lower than 15 HP) and the one responsible for capturing the animals. A flashlight is used for locating caiman at night through the reflection of the light in the eyes. The animals are harpooned and struck with an axe or a club, then lifted into the canoe. Two or three animals are killed each night, although in some communities this number may reach as many as nine.

Amazon river dolphin hunting was described, but not witnessed, in only four communities in the sectors of Ingá, Horizonte and Aranapu. Two hunting methods were mentioned. In the first, 5–10 people use fishing nets to cover entrances of bays where dolphins are found and, after the animals are isolated, they are harpooned and killed. The second method can be characterised as opportunistic hunt-

ing, in which fishers, alone or in pairs, capture smaller dolphins with the same technique described for caiman or kill entangled animals. Hunters who performed this activity were cited in the sectors of Ingá, Liberdade and Horizonte. The captured and marketed baits were the black caiman (*Melanosuchus niger*), the spectacled caiman (*Caiman crocodilus*) and the Amazon river dolphin (*Inia geoffrensis*), even though dolphin marketing has suffered a decrease in the last five years, been extinguished or became restricted to the selling of accidentally entangled animals or those found dead, since the demand decreased in the communities due to fear of greater surveillance. Another possible activity is the supply of fish by-products (bowels, heads and fishes that cannot be marketed); these are not sold but supplied by friends or relatives.

Bait-buying communities were found in the sectors of Ingá, Liberdade and Guedes. There are fixed prices for bait selling in Horizonte and Ingá. Prices are calculated according to the length of the baits, regardless of the species in the case of caiman, with prices ranging from $\$3.65$ for 1.5-m-long caiman to $\$29.30$ for 4-m-long caiman in Horizonte; from $\$36.60$ to $\$73.25$ for caiman over 3 m long and from $\$73.25$ to $\$109.90$ for dolphins in the Ingá sector. The prices increase by up to 50% during flooding and flood periods, when capturing the animals becomes more difficult. Hunters work on demand, capturing and killing animals only after bait is requested. The number of requests may vary between six and 20 caiman per week. In the Liberdade sector, dolphin hunting was found in one community, but the activity now no longer exists. The prices varied from $\$36.60$ to $\$54.95$ per specimen; over 9 years, six dolphins were used in fishing activities within the community. The profit margins for bait hunters were the highest and most stable (Table 1).

Piracatinga fishing in the sectors researched started around 2002. Fishers from the Ingá sector started earlier, around 1997. This activity is performed by one of three methods: using a corral (also called ‘box’ or ‘pan’) with a door; using a simple corral, without a door; and using a canoe. Only 8.7% (2/23) of the fishers fished with a canoe, placing it a few metres from the shore, where the

Table 1. Costs, revenues and average profit margin of production and marketing activities

Activity (average production)	Origin of costs	Total Cost (\$)	Total Revenue (\$)	Profit Margin (%)
Commercial hunting (5 caiman per hunting event)	Gear, gasoline and workforce	21.70 ± 2.38	109.90	80 ± 2.0
Fishing (560 kg per fishing event)	Gear, ice and workforce	58.60 ± 48.28	206.96 ± 123.07	66 ± 24.3
Evisceration (102 kg day ⁻¹)	Workforce	2.25 ± 0.84	5.50 ± 1.97	58 ± 4.5
Reception in Pontoon (700 kg week ⁻¹)	Purchasing and Ice	285.70 ± 127.47	313.18 ± 169.60	5.75 ± 9.0
Boat transportation (1900 kg trip ⁻¹)	Fuel, workforce and ice	913.55	1043.95	12.5
Freezing plant (up to 5 t month ⁻¹)	Purchasing, workforce and energy	610.07 ± 69.67	695.97 ± 51.80	12.5 ± 3.5
Freezing plant (up to 25 t month ⁻¹)	Purchasing, workforce and energy	10508.80 ± 5129.76	12339.82 ± 6833.70	12.9 ± 10.0

fishers stand with the bait between their legs, with water up to their knees. The fishers catch the fish with their hands and throw it into the canoe. Fishers who use this technique work alone, using few baits, as the profit is lower than that provided by other techniques as the capacity of a canoe is lower than that of a corral system. The most common technique employed was the corral without doors (60%), used mainly in the Ingá, Liberdade and Horizonte sectors. The technique is identical to that of the canoe, but the fishes are thrown into corrals that can hold as much as 3 t. A corral equipped with a door was used by 34.7% of the fishers (8/23), its use being restricted to the Aranapu and Guedes sectors. It is the safest technique for the fishers, as he does not need to get into the water; he stands on wooden boards on the corral and, with the door open, he moves the baits, directing the fishes inside the corral. A large piece of the bait is placed at the opposite side of the door to keep the fishes away from the exit; however, the capacity of these corrals is lower than that of corrals without doors of the same size; this is because some fish escape from corrals holding lots of fish each time the door is opened. The cost for building such a corral ranged from \$25.64 to \$183.15; those with capacity over 2 t are built with more resistant woods and thus are more expensive. The corral's service life also varied from 3 months to more than 3 years.

The main baits used are the black caiman (preferred by 100% of the fishers), the spectacled caiman (26.1%), the Amazon River dolphin (47.8%) and fishes (26.1%), mainly the pellona (*Pellona* spp.), bacus (*Doradidae*) and the viscera of commercial fishes such as pirarucu (*Arapaima gigas*), redbtail catfish (*Phractocephalus hemiliopterus*) and sorubim (*Pseudoplatystoma* spp.). The opportunistic use of rays (*Potamotrygon* spp.), jaguars (*Panthera onca*) and domestic dogs (*Canis lupus familiaris*) was mentioned (4.34% of the fishers) in the Liberdade, Horizonte and Barroso sectors, respectively, as well as the use of cooking oil in low-fat baits to increase the catch rate of piracatinga in the Guedes sector. The only bait used in all the sectors was the black caiman, due to its abundance, high availability and yield. The use of dolphins was not witnessed during the research periods, although some reports were received between 2011 and 2012. Fishes are used occasionally but the use is increasing, mainly in the Aranapu and Guedes sectors, where species of low commercial value are used.

The average cost of each fishing event (Table 1) comprises mainly obtaining baits, costs of evisceration and ice for preservation of the fishes. Cost of baits ranged from \$0.00 (in the case of viscera of commercial fishes or entangled caiman and dolphins that were not charged for) to \$109.90 (the highest price for the Amazon river dolphin). Cost of ice, which is not necessary for fishers in

communities with middlemen who provide it but indispensable for those who sell the product to freezing plants, may be as high as \$131.86 per fishing event. Evisceration costs varied little and were around \$12.82 per fishing event. Other costs per fishing event were workforce (around \$9.78) and the depreciation of corrals (\$1.28). As many as 26% of fishing events failed and accounted for considerable financial losses of as much as 225%. Approximately 20% of communities stopped piracatinga fishing between 2001 and 2013 because of the perceived high costs, risks involved and greater engagement of fishers in other production activities, especially pirarucu management and agriculture. There was also a decrease in the number of piracatinga fishers in four (57%) of the seven sectors monitored, and up to 60% in the Aranapu sector, where legal pirarucu management started in the past few years and is becoming a strong economic activity. After fishing, the piracatingas undergo two pre-processing stages. The evisceration starts with a horizontal incision in the ventral region, just below the gills, followed by a vertical incision traversing medially the first incision. The second incision allows access into the fish's viscera, which are then removed. The operation ends with the eviscerated piracatinga being washed in the nearest source of water. Agents specialising in this activity eviscerate from 43 to 60 kg h⁻¹, whereas others who only occasionally perform this activity eviscerate from 30 to 40 kg h⁻¹.

After pre-processing, the piracatingas may be sold directly to freezing plants or through middlemen on buyer boats or pontoons. The buyers working on pontoons in the communities receive the produce of around 13% of the fishers (3/23) and in general (75%) are informally associated with boat owners who deliver the fish to freezing plants, which enable them to sell to more than one boat, according to their needs. These pontoons are reception points with low capacity, buying, storing and reselling around 600 kg per week, at the height of the production, between August and November. Among the interviewees, these provided the lowest profit margins (Table 1) of all activities in the production chain. One of the middlemen with a pontoon in the municipality of Alvarães had the capacity of 1 tonne per week and received the production of many communities; he also owned his boat, and sold his products to the nearest freezing plants in Tefé, thus obtaining a profit margin as much as 18%.

Most fishers (65.2%) sell their produce to boats owned by middlemen (62.5%) or by freezing plants in Tefé, Fonte Boa or Alvarães (37.5%). The boats had a crew of around four and 10-t capacity. These boats carry piracatingas in their holds on 35% of trips and account for 21% of the total load. Middlemen usually consider piracatinga difficult to preserve, as they are packaged in many layers and over 3 days and this may result in big

losses due to poor freezing. Tefé receives around 39.3% of these boats, and 35.7% are destined for freezing plants in Fonte Boa and 25% operate in both municipalities; but 61.5% of the piracatinga harvest is unloaded in the municipality of Fonte Boa, accounting for 52.7 t of fish unloaded each year in the two municipalities. Of the six freezing plants studied, 83% process piracatinga, which consists in making filets or simply removing the head of eviscerated fish. They can process 3–30 t of fish per month, of which piracatinga contributes 25% (8–50%) in the peak season, between August and November. Around 75% of the production of four freezing plants in Fonte Boa is sent to Tabatinga, from where it enters the Colombian market in the cities of Leticia and Bogota; the rest is sent to Manaus and finally reaches the Brazilian internal market, mainly the south-east of the country. More than 80% of the produce obtained in Alvarães is sent to Fonte Boa, following the same route to Colombia afterwards. The remainder goes from Tefé to Manaus, from where it is sent to other Brazilian states.

Considering that the black caiman is the only species used as bait in all the communities visited, the mean number of hunting and fishing events per sector and the average quantity of animals killed per event was estimated; however, due to the complexity of the piracatinga fishing activity, the precise number of vertebrates killed per year for this goal has not been found. The estimate of dead caiman in 2013 for the sectors researched was 2300 animals, of which around 18.5% were sold as bait. Caiman are the preferred bait due to their high productivity, easy access and capture and also due to cultural reasons, as they are treated as hostile by most fishers, who see them as harmful to the fish stocks and the safety of the local populations and their animals.

Discussion

The basic structure of the piracatinga production chain is similar to other fishing production chains in the Amazon region (Batista *et al.* 2004; Viana 2004), including the prevalence of men older than 30 years old (Silva *et al.* 2007; Cavalcante 2011), the boats used, and the commercial relationships between fishers and middlemen (Batista *et al.* 2004). However, it also presents some unique characteristics: the different functions are strictly linked to specific workers and there is a specialised workforce for each segment in communities where this activity is one of the primary sources of income, while in communities where piracatinga fishing is occasional, the agents perform their tasks opportunistically. The piracatinga production chain is becoming more complex and organised with the inclusion of new techniques and

division of labour over the years (Botero-Arias *et al.* 2014; Brum *et al.* 2015). This allows greater flexibility in the processes, as well as adaptability to different organisational models practiced by fishers (Botero-Arias *et al.* 2014) which considerably increases the productivity of fishing, but also the pressure on the vertebrates used as baits. The same technique for hunting caiman was observed in other studies (Da Silveira & Thorbjarnarson 1999; Estupiñán *et al.* 2003), and, although the black caiman is still the most frequently hunted animal, pressure on illegal Amazon river dolphin hunting is felt more intensely by stakeholders, possibly due to greater media exposure. The techniques and gear used in piracatinga fishing are exclusive and cannot be found in any other fishing modalities in the region (Viana 2004; Silva *et al.* 2007; Cavalcante 2011; Ferraz *et al.* 2012).

The commercial value of the piracatinga is influenced by the hydrological cycle similar to other fisheries (Ferraz *et al.* 2012). The greatest values are observed between May and July, and October and January (Fig. 2) – that is, the months that correspond to flood and flooding periods, respectively. The distance from buying centres also impacts on the value, as fishers from neighbouring areas may sell directly to freezing plants, avoiding middlemen and maintaining a more stable price throughout the year. The greatest production of piracatinga occurs between August and November, which is probably due to the beginning of the closed season of species of greater economic importance, such as the tambaqui, *Colossoma macropomum* (Cuvier) and the arowana, *Osteoglossum bicirrhosum* Spix & Agassiz.

Stability in earnings from hunting may be explained by the rise in the prices of baits during times of flood (when costs rise) and the constant demand for piracatinga from fishing communities. The average profit margins from fishing activities were far greater than those found in other artisanal fishing activities (Almeida *et al.* 2001; Coelho 2005; Silva *et al.* 2013), but they were much more variable (Table 1) – from losses of

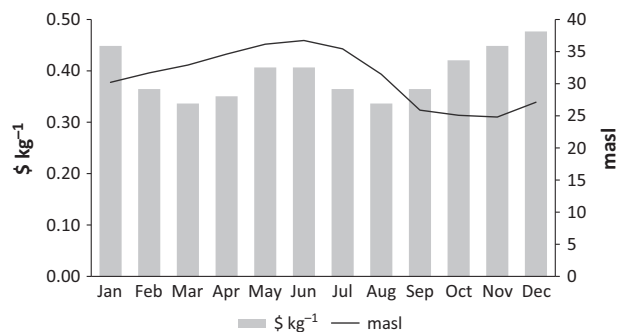


Figure 2. Annual variation in the value of piracatinga in relation to water level between 2011 and 2013.

38% per fishing event to profits of 90%. The great variability in the success of fishing is explained by the large number of factors influencing it, such as individual features of the baits used (species, size and fat contents), preparation of baits, time of the year, demand, differences in fishing techniques and fisher's ability. Although black caiman and the Amazon river dolphin secure the greatest productivity, difficulty obtaining them increases the total cost per fishing event. Fish gives slightly higher profit margins than other baits because non-commercial species accidentally caught in nets or the viscera of commercial species, which must be eviscerated for marketing, are generally used. A near-zero value is attributed to obtain these baits. The reduced use of the spectacled caiman as bait is explained by the fishers by its lower fat contents and, accordingly, lower productivity, in addition to the aggressive behaviour of the animal, which increases the risks of capturing it. Fishers tend to think in terms of the great volume of fishes obtained without assessing their real profit, which hinders the use of legal alternative baits, such as fishes, which could result in greater profit margins. The average high and stable profit margins of eviscerators (Table 1) is because this task requires no expenses with equipment and the short time needed to perform it. The average profit margin of the boats (considering the piracatinga load only) was lower than the average for boats of similar size found in other studies (Almeida *et al.* 2001; Almeida 2006). The lower profit margins of the middlemen on pontoons and boats are due mainly to the cost of ice, since twice as much ice as fish is used to transport piracatingas. Profits from freezing plants were greater by as much as 50% compared with information provided by Almeida (2006) in an analysis of the total produce of freezing plants in Amazonia. However, it is worth highlighting that none of the interviewees limited their activity to the piracatinga production chain, most of them worked with other species, and the high variability in contribution of piracatinga through freezing plants and middlemen may conceal the real profit margins of this activity.

The number of caiman illegally killed in 2013 was lower than those estimated by Da Silveira and Thorbjarnarson (1999) as annually killed in the MSDR during the 1990s for supplying meat and hides. This value may be, however, underestimated, given the great variability in hunting and piracatinga fishing events per year, the baits used, the amount of baits per event and the communities that could not be studied. Although illegal killings are now rarer than in previous decades, the impact of hunting on caiman and dolphins is still unknown due to the absence of data on the population dynamics of these species (Botero-Arias *et al.* 2014) and it could pose a future threat if the events increase in numbers or

fishing areas increase in extension. A community-based caiman management initiative is being implemented in the Mamirauá Reserve (Botero-Arias *et al.* 2009) and may represent a way to engage hunters and fishers in a legal and sustainable activity, therefore reducing illegal fishing practices. The engagement of persons involved with the piracatinga fishery in community-based tourism, agriculture and fisheries management (Botero-Arias *et al.* 2014) may also contribute towards reducing problems associated with the piracatinga fishery. Considering the territorial extension of Amazonia and the lack of qualified workforce for the enforcement of environmental law, the slow pace of legal proceedings and weaknesses in the collection of fees (Silva & Bernard 2014), prohibition of piracatinga fishing and other associated activities may not have the expected effect. In addition, lack of engagement of civil society, especially of those directly involved in the activity, to resolve the problems of illegal activities increases the probability that the Interministerial NI n. 6 may become another of many laws that are not realistic (Surgik 2006), thus hindering the action of the authorities (Ávila 2001). Further research is needed to enable the use of other species of bait and the engagement of stakeholders in legal activities, ensuring both an income source for the fishers and conservation of species, as well as avoiding criminalisation of local populations and developing participatory and sustainable options.

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