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SHORT COMMUNICATION

Predation on pirarucu larvae by opportunistic fish species

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ABSTRACT

One of the constraints in pirarucu, *Arapaima gigas* farming is the reproduction in captivity, due to inconsistent number of spawning events per reproductive cycle, thus, unreliable availability of juvenile fish. This is a first-hand report on predation of pirarucu larvae by opportunistic fish species in a breeding pond. Fish samples were collected for stomach content analysis from a pirarucu-breeding pond with reported predation on the larvae. We obtained 61 fish of different species (*Tetragonopterus* sp., *Astyanax bimaculatus, Moenkhausia intermedia*, *Hoplias malabaricus*, and *Apistogramma* sp.). *Tetragonopterus* sp. stomachs had the highest frequency of occurrence of pirarucu larvae (83.3%), followed by *A. bimaculatus* (7.4%). The relationship between the feeding behaviour of these species and their predation upon pirarucu offspring is discussed.

KEYWORDS: *Arapaima gigas,* feeding behaviour, fish stress, reproduction

Predação de larvas de pirarucu por espécies de peixes oportunistas

RESUMO

Um dos principais gargalos na produção do pirarucu, *Arapaima gigas* é a reprodução em cativeiro, devido à inconstância no número de desovas por ciclo reprodutivo, resultando em instabilidade na disponibilidade de juvenis. Este é o primeiro registro de predação de larvas de pirarucu por peixes oportunistas em um viveiro de reprodutores. Amostras de peixes foram coletadas para análise estomacal em um viveiro de reprodução. Coletamos 61 peixes de diferentes espécies (*Tetragonopterus* sp., *Astyanax bimaculatus*, *Moenkhausia intermedia*, *Hoplias malabaricus* e *Apistogramma* sp.). Os estômagos de *Tetragonopterus* sp. apresentaram a maior frequência de ocorrência de larvas de pirarucu (83,3%), seguida por *A. bimaculatus* (7,4%). Discutimos a relação dos hábitos alimentares destas espécies e sua predação sobre a prole de pirarucus.

PALAVRAS-CHAVE: *Arapaima gigas*, hábito alimentar, estresse, reprodução

Pirarucu, *Arapaima gigas* (Schinz, 1822) is a fish native to the Amazonas and Araguaia-Tocantins basins (Torati *et al.* 2019). It is threatened by overexploitation and is included in Appendix II of Cites (CITES 2022). In this scenario, aquaculture can be a sustainable alternative to supply the market demand for pirarucu.

Fast growth under farming conditions (Lima 2020), obligatory aerial breathing (Brauner *et al*. 2004) and tolerance to high concentrations of total ammonia nitrogen (Cavero *et al*. 2004) are features that make pirarucu farming attractive. In Brazil, 2,000 tonnes of pirarucu have been farmed in 2019 (IBGE 2020). The main bottleneck for production increase is the inconsistent number of spawning events per cycle, as reproduction in captivity is done naturally (Farias *et al*. 2015), and the consequent unreliable supply of juvenile fish to the market (Valenti *et al*. 2021).

Pirarucu is a partial spawner (Torati *et al*. 2019) and, although female fertility is between 27,000 and 65,000 mature oocytes per reproductive cycle (Fontenele 1948), not more than 20,000 spawned eggs and 12,000 swimming larvae have been observed in captivity (Fontenele 1948; Halverson 2013). The averages per broodstock pair are even lower, around 1,000 to 4,000 larvae per spawning event (Halverson 2013; Rebelatto *et al*. 2015).

Pirarucu reproduction is usually carried out in large excavated earthen ponds. In most cases, spawning is only noted by farmers when fish larvae are seen swimming in the pond and are already around 5-7 days old and 2 cm in length (De Alcântara *et al.* 2019). The larvae are harvested only when they reach 4-8 cm in length (Halverson 2013; Rebelatto *et al*. 2015). In general, the longer the larvae are kept under parental care inside the ponds, the lower is the recruitment,

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due to predation by other fishes or birds (Halverson 2013; Rebelatto *et al*. 2015). The local fish fauna enters the earthen ponds via the water inlet and thrives inside. One concern of farmers is to eliminate the carnivorous fish that may predate on the pirarucu larvae. However, predators of pirarucu larvae under parental care in breeding ponds have not been reported, therefore farmers tend not to worry about herbivore or omnivorous coinhabiting fish. Here we provide the first report on the predation on pirarucu larvae by opportunistic omnivorous fish in an outdoors earthen cultivation pond.

The pond (1,000 m² and 1.4 m average depth) is located in a commercial pirarucu farm in the city of Cana Brava, Mato Grosso state, Brazil (11°8'39"S, 51°56'9"W) and was sampled for predatory fishes in December 2020. The pond was stocked with one pair of broodstock pirarucu and predation on the larvae had been observed previously by the farmer. Fish were sampled in the pond using a 5-mm mesh trawling net dragged along the pond three times in a single day. Captured fish were kept intact and preserved in 70% ethanol until identification and analysis of the stomach content. The procedures were approved by the ethics committee on studies with animals of Embrapa Pesca e Aquicultura (protocol # 62/2020 CEUA/Embrapa).

In the laboratory, the fish were identified to genus or species level (Silva *et al*. 2016; van der Sleen *et al*. 2017; Urbanski *et al*. 2018), weighed with a semi-analytical balance (0.01g; Quimis, Diadema, SP) and measured for total length with a digital Vernier calliper (0.01 mm; Zaas, Piracicaba - SP). Fish stomachs were removed, and the content analysed for the presence of pirarucu larvae. The frequency of occurrence (FO) of pirarucu larvae in the stomachs was calculated for each sampled species as the percentage of stomachs containing pirarucu larvae relative to the total number of stomachs analyzed (Hyslop 1980). Fish specimens were deposited in Systematic Ichthyology Laboratory at Universidade Federal do Tocantins, Brazil.

A total of 64 fish were collected, of which 61 belonged to three species of characins (*Tetragonopterus* sp., *Astyanax* gr *bimaculatus*, *Moenkhausia intermedia*), two to the trahira *Hoplias malabaricus* and one to a dwarf cichlid *Apistogramma* sp. (Table 1). Overall FO of pirarucu larvae was 15.6%. Within groups, FO was 15% for the characins, 50% for *H. malabaricus*, and no larvae were identified in the stomachs of *Apistogramma* sp and *M. intermedia*. *Tetragonopterus* sp. had the highest FO (83.3%), followed by *A. bimaculatus* (7.4%) (Table 1). Four *Tetragonopterus* sp. contained one intact larva, and one had two intact larvae in the stomach. *Astyanax* gr *bimaculatus* contained only larvae fragments and *H. malabaricus* contained one intact larva.

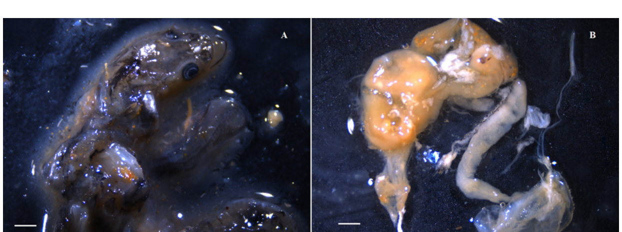

Figure 1. Larva of pirarucu, *Arapaima gigas* (A) found inside the stomach of a characin *Tetragonopterus* sp. (B). Scale bar = 0.5 mm. This figure is in color in the electronic version.

Four species of *Tetragonopterus* occur in the study region (Silva *et al.* 2016). *Tetragonopterus argenteus* Cuvier, 1816 is an opportunistic herbivore (Muniz *et al*. 2019) and *T. chalceus* Spix & Agassiz, 1829 is a herbivore-insectivore to omnivore (Goulding *et al.* 1988), while the diet of *T. anostomus* Silva & Benine, 2011 and *T. araguaiensis* Silva, Melo, Oliveira & Benine, 2013 is not known. The presence of intact pirarucu larvae in the stomach of *Tetragonopterus* sp. supports the opportunistic feeding behaviour in this genus, as the larvae are likely easy prey, supporting Lowe-McConnell (1999) regarding the influence of biology and environmental conditions on a species' feeding habit.

Astyanax bimaculatus is an omnivore tending to herbivory and insectivory (Adrian *et al*. 2001; Vilella *et al*. 2002). However, the ingestion of fish by *A. bimaculatus* has been reported previously with FO of 24% (Adrian *et al*. 2001; Vilella *et al*. 2002). Fish is considered an accessory dietary item of this species, as it is not predominant in its natural diet (Adrian *et al*. 2001; Vilella *et al*. 2002), which is likely reflected in the low FO of pirarucu larvae in *A.* gr *bimaculatus* in our sample. Characins, especially *Tetragonopterus* sp., can be considered predators of pirarucu larvae, which are small enough to be ingested.

Hoplias malabaricus are found mainly in shallow waters, near submerged vegetation or pond margins (Sabino and Zuanon 1999). Juveniles feed on insects, and adults prey on fish (Carvalho *et al*. 2002). Therefore, they are considered

Table 1. Biometric data of opportunistic fish species collected in an outdoors earthen breeding pond of pirarucu, *Arapaima gigas* and frequency of occurrence (FO) of pirarucu larvae in the stomach contents. N = number of fish.

Species	Weight (g)	Total length (cm)	N	N with larvae in stomach	FO (%)
Characidae					
Tetragonopterus sp.	2.24 ± 1.22	5.70 ± 0.68	6	5	83.3
Astyanax gr bimaculatus (Linnaeus, 1758)	1.79 ± 0.60	5.48 ± 0.58	54	4	7.4
Moenkhausia intermedia Eigenmann, 1908	3.4	7.4	1	0	0
Erythrinidae					
Hoplias malabaricus (Bloch, 1794)	1.25 ± 0.11	5.70 ± 0.42	2	1	50
Cichlidae					
Apistogramma sp.	1.11	4.9	1	0	0

predators in fish farming (Godoy *et al*. 2021). In turn, *Apistogramma* sp. are small (less than 5 cm in length) and their diet is mainly composed of small invertebrates (Kullander 2018). Both species had small representation in our sample, thus the evidence is not conclusive on their potential as predators of pirarucu larvae.

The biological interactions of dominance and predation are known stressors that can compromise fish growth and immunity over time (Barcelos *et al*. 2000). Characins are diurnal predators in the water column, while trahiras are nocturnal, benthic ambush predators (Sabino and Zuanon 1999; Lowe-McConnell 1999), and their presence in the pond may represent an additional stress factor to the pirarucu larvae. Unsuccessful attacks on larvae may cause injuries, which may become infected and result in indirect mortality by predator fish. Other fish species in the pond (predators and non-predators) can also act as potential intermediate or paratenic hosts of metazoan parasites of pirarucu, leading to disease outbreaks in the farm (Araújo *et al*. 2009).

Although the presence of other fish species in the breeding ponds is expected, the presence of two characin predators raises the need for a more careful preparation and maintenance of the ponds. To inhibit the growth of undesired fish fauna, it is recommended to (a) dry and disinfect the ponds prior to the breeding period; (b) place a screen or a fish mesh in the pond inlet pipe to avoid that eggs or larvae of other fish enter the pond; and (c) trawl-netting the pond periodically to remove unwanted fish. Finally, the early harvest of pirarucu larvae from the breeding ponds increases the survival rate of the progeny and, in addition to the abovementioned recommendations, could contribute to reduce losses to predation in the cultivation environment.

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