BOLETIM DO INSTITUTO DE PESCA
Scientific Article

Composition of the bycatch associated with *Arapaima gigas* fisheries in lotic and lentic environments of the Cautário River basin, Rondônia, Brazil

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ABSTRACT

This study characterizes the bycatch associated with *Arapaima gigas* fisheries in the Cautário River, Rondônia, Brazil, where the species occurs as an invasive species. Fisheries monitoring was conducted during the low-water period (August to October 2025), when *A. gigas* capture rates intensify. During this period, 69 bycatch individuals were recorded, belonging to nine species, distributed in seven families and eight orders. Vertebrates were predominant, with reptiles and fish accounting for more than 68% of the incidental captures. The turtle *Podocnemis unifilis* was the most frequent species (36.23%), followed by the fish *Colossoma macropomum* (31.88%) and *Phractocephalus hemioliopterus* (11.59%). The limnological parameters remained within ranges compatible with the sampled aquatic environments and favorable to the occurrence of non-target species recorded in the fisheries. The results indicated that the high taxonomic diversity and representation of non-target species reflect the low selectivity of the fishing gear used in *A. gigas* fisheries. These findings highlight the importance of continuous monitoring of the bycatch as an essential tool for the adaptive management of *A. gigas* fisheries in the Cautário River, part of the Guaporé River basin.

Keywords: Invasive *Arapaima*; Fish stock; Guaporé River basin; Community-based fisheries; Bycatch.

Composição da fauna acompanhante associada às pescarias de *Arapaima gigas* em ambientes lóticos e lênticos da bacia do Rio Cautário, Rondônia, Brasil

RESUMO

Este estudo caracteriza a fauna acompanhante (*bycatch*) associada à pesca de *Arapaima gigas* no Rio Cautário, Rondônia, Brasil, onde a espécie ocorre como invasora. O monitoramento das pescarias foi realizado no período de águas baixas (agosto a outubro de 2025), quando a captura do *A. gigas* é intensificada. Nesse período foram registrados 69 indivíduos da fauna acompanhante, pertencentes a nove espécies, distribuídas em sete famílias e oito ordens. Entre eles, os vertebrados foram predominantes, como os répteis e peixes, que representaram mais de 68% das capturas incidentais. O quelônio *Podocnemis unifilis* foi a espécie mais frequente (36,23%), seguida pelos peixes *Colossoma macropomum* (31,88%) e *Phractocephalus hemioliopterus* (11,59%). Os parâmetros limnológicos mantiveram-se em faixas compatíveis com os ambientes aquáticos amostrados e favoráveis à ocorrência das espécies não alvo registradas nas pescarias. Os resultados apontaram que a diversidade taxonômica e a elevada representatividade de espécies não alvo das pescarias indicam baixa seletividade dos apetrechos utilizados na pesca do *A. gigas*. Essas informações evidenciam a importância do monitoramento contínuo da fauna acompanhante como ferramenta essencial para o manejo adaptativo da pesca de *A. gigas* no Rio Cautário, integrante da bacia do Rio Guaporé.

Palavras-chave: Arapaima invasor; Estoque pesqueiro; Bacia do Rio Guaporé; Pesca comunitária; Pesca acidental.

Received: January 27, 2026 | **Approved:** May 26, 2026
Section editor: Welber Senteio Smith

INTRODUCTION

Arapaima gigas (Schinz, 1822) is one of the largest scaled freshwater fish in the world, attaining lengths of up to 3 m and over 240 kg in weight (Carvalho, 2014). It represents a fishery resource of high economic, social, and cultural importance for riverine communities in the Amazon basin, whose subsistence and income are closely linked to fishing activities (Arantes et al., 2007; Gonçalves, 2018). In the state of Amazonas, Brazil, the sustainable management of *A. gigas* has become a strategy that integrates environmental conservation with the generation of community income. This practice enables the regulation of fishing, the protection of breeding areas, and the sustainable use of fishery resources, which directly benefit riverine communities (Casara, 2015). The participatory management of the species represents an example of sustainability by involving traditional communities and urban fishers, promoting the recovery of fish stocks, the generation of employment and income, as well as social and gender equity (Gonçalves & Santos, 2024).

Arapaima gigas is native to the Amazon and Essequibo River basins and inhabits a wide range of continental aquatic environments, most commonly floodplain lakes, but also rivers, flooded forests and coastal drainages. During the low-water period, the species can also be found near river beaches and in small stream channels (*igarapés*) (Figueiredo, 2013). In addition to its ecological importance as a top predator that plays a key role in regulating energy and nutrient flows in aquatic ecosystems (Castello et al., 2019), *A. gigas* exhibits biological characteristics that increase its vulnerability to fishing. The species is piscivorous and prefers preying on detritivorous and omnivorous fish, although it also consumes plant material and small animals, such as aquatic insects (Oliveira et al., 2005; Pereira et al., 2026; Queiroz, 2000). Additionally, *A. gigas* possesses a modified swim bladder that functions as an accessory respiratory organ, requiring individuals to surface at regular intervals of approximately 5–15 minutes (Brauner et al., 2004; Fernandes et al., 2012; Silva et al., 2013). This predictable behavior makes it an easy target for fishers, which increases pressure on its natural stocks (Gonçalves, 2018).

In addition to being targeted by extractive fisheries, *A. gigas* has become increasingly important in aquaculture in Latin America due to its rapid growth, adaptability to commercial feeds, high-quality meat, and strong market demand (Gonzalez-Callirgos et al., 2023; Ramos & López, 2024). However, the fragility of some farming systems has led to accidental escapes of *A. gigas*, resulting in its introduction into non-native areas and subsequent impacts on local fish communities (Pereira et al., 2026; Van Damme & Carvajal-Vallejos, 2013). In the state of Rondônia, for example, the spread of *A. gigas* as an invasive species has altered the fishery dynamics in the Guaporé River basin due to its high adaptability and strong predation pressure on native fish communities (Catâneo et al., 2022; Pereira et al., 2026).

Fishing activities in Amazonian continental environments can be conducted in various modalities, depending on objectives, scale of operation, and the way resources are utilized. In this context, the intensified capture of *A. gigas*, driven by its high commercial value and cultural significance, has highlighted an additional concern associated with fishing: the incidental capture of non-target organisms, commonly referred to as bycatch (FAO, 2019).

Global estimates indicate that between 2010 and 2014, approximately 9.1 million tons of fish were discarded annually, representing 10.8% of the world's fishery production (FAO, 2020). Bycatch can involve both commercially valuable species that are exploited unsustainably, as well as threatened or legally protected species, whose capture is prohibited (Squires et al., 2021). Therefore, fishery discards represent a waste of resources and can have significant impacts on aquatic biodiversity, sometimes leading to the collapse of populations within a short period of time (Gilman, 2011; Kelleher, 2005). In this sense, understanding accidental catches is essential for improving sustainable management plans for *A. gigas*, since these events may affect not only target fisheries but also the ecological balance of associated aquatic communities.

However, the selectivity of fishing gear is often limited by technical, operational, and ecological factors, resulting in the incidental capture of non-target species in different fishery contexts, in both marine and freshwater environments (FAO, 1995; 2019). Thus, since multiple species share the same habitat, fishers rarely manage to capture only a target species without also unintentionally catching other ones (Alverson & Hughes, 1996; Pascoe, 1997).

In this context, fishery management must reconcile biological, economic, and social dimensions, addressing the environmental and social impacts associated with bycatch (Hall et al., 2000; Hilborn & Walters, 1992). Fish and other aquatic organisms accidentally caught during the fishing of a target species do not always have commercial value (Hall, 1996) and are often returned to the aquatic environment, with bycatch disposal frequently regarded as a waste of fishery resources and inconsistent with responsible fishing practices (Kelleher, 2005).

Despite this, even when they are not of commercial interest, species captured as bycatch are subject to environmental pressures that can lead to population declines (Gilman, 2011; Pauly et al., 2002). This situation becomes even more concerning when such populations are already declining or threatened with extinction (Squires et al., 2021). A typical example involves species belonging to the family Sciaenidae, considered one of the most important fishery resources in coastal and estuarine waters worldwide, and which are frequently recorded as bycatch

(Rosendo, 2022). Among them, *Stellifer microps* stands out due to its high abundance in the number of individuals discarded in fisheries, commonly recorded in estuaries of the northern and northeastern regions of Brazil (Barletta-Bergan et al., 2002), raising management concerns regarding conservation issues and the ecological and economic impacts of fishing activities (Alverson & Hughes, 1996).

In the Amazon, studies on bycatch have also been conducted in different fishery contexts, such as the bycatch of the crustacean *Farfantepenaeus subtilis* in industrial fisheries on the Amazon continental shelf (Cintra et al., 2017) and the industrial fishery of *Brachyplatystoma vaillantii* in the Amazon estuary (Marceniuk et al., 2023). However, little is known about the bycatch associated with the managed fishery of *A. gigas*, particularly in protected areas such as the Cautário River in the state of Rondônia, Brazil.

In this context, the present study aimed to characterize the composition of the bycatch associated with *A. gigas* fisheries in the Cautário River basin and to describe its occurrence across lotic and lentic environments sampled during the dry season. The environmental data obtained in the study were used to characterize the limnological conditions of the fishing sites during the monitoring period. The data from the present study provide relevant information that may contribute to conservation and management actions for the aquatic ecosystems in this region of the Amazon basin.

MATERIALS AND METHODS

Study area and characteristics

Data collection was carried out during *A. gigas* fisheries along the main channel and marginal lakes of the Cautário River basin (Fig. 1). A total of five collection points were monitored in the study area: ICMBio Base, Marginal Lake, Jacaré Stream Pool, Volta Morta, and Jardi Lake. The lotic environment corresponded to the main channel of the Cautário River, whereas the lentic environments corresponded to the marginal lakes. Sampling took place in two campaigns between August and October 2025 (dry season), with no repetition of collection points among campaigns. These activities were conducted by extractive community members and residents of the study area.

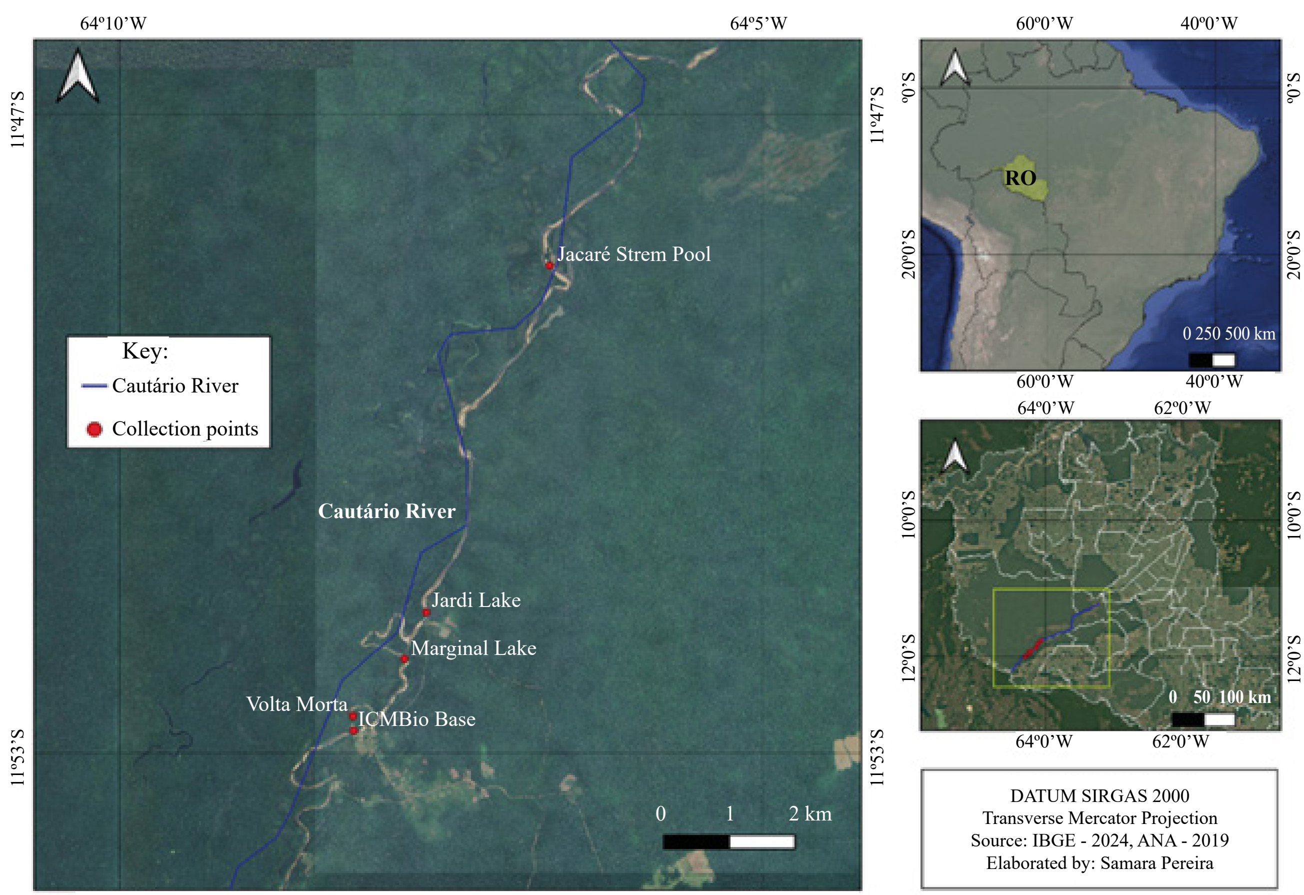

Figure 1. Location of *Arapaima gigas* fishing sites in the Cautário River Extractive Reserve, in the state of Rondônia, Brazil.

Managed fishing of *Arapaima gigas* and identification of associated bycatch

For the present study, fishing sectors were identified and selected, followed by counts of *A. gigas* conducted by managers and environmental agents, according to the methodology recommended by Castello (2004). After these steps, camps were set up for community members near the fishing sites, aiming to improve access to the fisheries and to facilitate the cleaning, storage, and transport of the captured *A. gigas* specimens.

Fishing activities were conducted under environmental license No. 12/2023-CGFau/DBFlo, issued by Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), and the research project was approved by the Ethics Committee on the Use of Animals of the Universidade Federal de Rondônia, under No. 003-2024-A.

During the fisheries, gillnets of different sizes were used, with mesh sizes ranging from 26 to 31.5 cm between opposite knots, in order to reduce the likelihood of capturing native fish species and small individuals. The nets used in the study measured 70-m long and 3-m high, corresponding to the dimensions commonly used by fishers in the region. The nets were deployed using different techniques, namely set, encircling and driving (Ferreira, 2022). During fishing activities, the gillnets were inspected every 3 hours and remained in the water for a total of 24 hours, allowing the release of native ichthyofauna accidentally entangled in the nets whenever possible.

After inspection of the fishing gear, the entangled specimens were photographed and recorded on field data sheets for subsequent identification using specific taxonomic keys for fish (Queiroz et al., 2013). The identification of the chelonians was based on the guide by Ferrara et al. (2017), while identification of the crocodilian (*Caiman crocodilus*) followed the morphological criteria described by Magnusson et al. (2010). Handling of the individuals was carried out rapidly, followed by the immediate release of the specimens, in order to avoid stress and potential harm to the animals.

Limnological and environmental data collection

Parallel to the *A. gigas* fisheries, physical–chemical water data were collected to assess environmental conditions. For this purpose, the parameters selected were temperature (°C), dissolved oxygen (DO), hydrogen potential (pH), and electrical conductivity (EC). For the collection of environmental data, a digital multiparameter probe (Senso Direct 150) and the colorimetric method (ALFA-KIT) were used. Measurements were taken twice during the fisheries, at the five collection points, at a mean depth of 0.5 m. All data were tabulated in electronic spreadsheets and subsequently analyzed using specific statistical software.

Statistical analysis of the data

The frequency values of fish and other vertebrates identified as bycatch, as well as the physical–chemical water parameters, were subjected to descriptive statistics to calculate mean values and standard deviations (SD ±), following Zar (2010). These analyses were used to describe the taxonomic composition of the associated bycatch and to characterize the environmental conditions of the sampled fishing sites during the study period.

RESULTS

During the *A. gigas* fisheries, 69 bycatch individuals were captured, belonging to nine species, distributed in seven families and eight orders. The composition of the associated bycatch was dominated by vertebrates, with emphasis on ichthyofauna and herpetofauna (Table 1).

The associated bycatch was composed mainly of two taxonomic classes, reptiles and fish, which together accounted for more than 68% of the total incidental captures (Fig. 2). With 36.23%, chelonians of the species *Podocnemis unifilis* stood out as the most frequent among the captures. In contrast, the fish *Colossoma macropomum* accounted for 31.88% of bycatch occurrences.

The third most frequent species, also belonging to the fish group, was the catfish *Phractocephalus hemioliopterus*, which accounted for 11.59% of the captures. The remaining six species, with individual relative frequencies ranging from 1.45 to 10.15%, represented by fish (*Potamotrygon motoro*, *Chelus fimbriata*, *Piaractus brachypomus*, *Pseudoplatystoma tigrinum*, and *Cichla kelberi*) and the reptile (*C. crocodilus*), occurred less frequently, together accounting for 20.3% of the total individuals recorded.

Physical–chemical parameters of the water

The physical–chemical parameters of the water (DO, temperature, EC, and pH) were monitored concurrently with fishing activities, providing an overview of the limnological and environmental conditions during the study period (Table 2). These data were used to characterize the environmental context in which the bycatch was recorded, allowing a broader interpretation of the fishing sites during the monitoring period.

Table 1. Taxonomic composition and capture frequencies of the associated bycatch in *Arapaima gigas* fisheries conducted in the Cautário River, Rondônia, Brazil.

Taxonomy	Absolute frequency	Relative frequency (%)
Chondrichthyes		
Myliobatiformes Potamotrygonidae		
Potamotrygon motoro (Müller & Henle, 1841)	3	4.35
Actinopterygii		
Siluriformes Pimelodidae		
Phractocephalus hemioliopterus (Bloch & Schneider, 1801)	8	11.59
Pseudoplatystoma tigrinum (Valenciennes, 1840)	1	1.45
Characiformes Serrasalmidae		
Colossoma macropomum (Cuvier, 1818)	22	31.88
Piaractus brachypomus (Cuvier, 1818)	1	1.45
Cichliformes Cichlidae		
Cichla kelberi (Kullander & Ferreira, 2006)	1	1.45
Reptilia		
Testudines		
Podocnemididae		
Podocnemis unifilis (Troschel, 1848)	25	36.23
Chelidae		
Chelus fimbriata (Schneider, 1783)	1	1.45
Crocodilia Alligatoridae		
Caiman crocodilus (Linnaeus, 1758)	7	10.15
Total	69	100

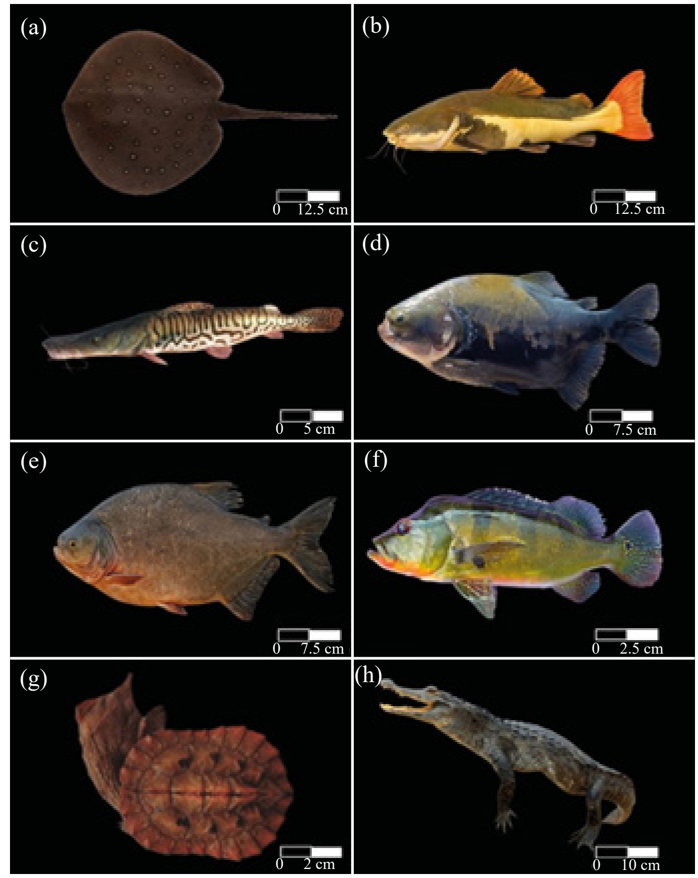

Figure 2. Animal species of the associated fauna from *Arapaima gigas* fisheries. (a) *Potamotrygon motoro*, (b) *Phractocephalus hemioliopterus*, (c) *Pseudoplatystoma tigrinum*, (d) *Colossoma macropomum*, (e) *Piaractus brachypomus*, (f) *Cichla kelberi* (adapted from Andrade & Pelicice, 2022), (g) *Chelus fimbriata* (adapted from Lasso et al., 2018), (h) *Caiman crocodilus*.

Table 2. Physical and chemical parameters of the environments in which *Arapaima gigas* fisheries were conducted in the Cautário River Extractive Reserve, Rondônia, Brazil.

Collection points	Parameters			
	DO (mg/L)	Temperature (°C)	Conductivity (µS/cm)	pH
ICMBio Base	7.75	29.70 ± 00	33.94	8.30
Marginal Lake	7.73	31.02 ± 0.01	31.63	7.60
Jacaré Stream Pool	7.94	27.85 ± 0.49	33.38	7.90
Volta Morta	7.80	27.55 ± 0.66	36.63	7.80
Jardi Lake	7.62	31.00 ± 0.50	33.43	8.20

DISCUSSION

The results obtained in this study showed that incidental bycatch was composed mainly of chelonians, frugivorous, and carnivorous fish, followed by caimans. The frequency of bycatch of these animals remains a recurring challenge in *A. gigas* fisheries conducted in the Cautário River Extractive Reserve region.

However, the presence of *P. unifilis* in fishing nets corroborates the classic observations of Miorando et al. (2013), who described the high susceptibility of this species to incidental capture during critical phases of its life cycle, such as reproductive movements. Similarly, studies conducted in other Amazonian river systems indicate that the use of gillnets tends to strongly impact chelonian populations in areas with intense fishing activity (Rebêlo & Pezzuti, 2000).

When comparing the results of the present study with investigations conducted in the Guaporé River basin, it is observed that the composition of the captured fauna varies according to the environmental context, the hydrological period, and the selectivity of the fishing gear used. In the study conducted by Sousa et al. (2021), fishery landings carried out by fisher colonies in the Guaporé and Mamoré River basins (Rondônia) were characterized by the predominance of piscivorous fish species such as the catfish *Pseudoplatystoma* spp. and *P. hemioliopterus*, followed by scaled fish *Cichla pleiozona*, *Colossoma macropomum* and *A. gigas*, reflecting the high abundance of these species and their economic importance to regional fisheries.

In the present study, conducted during the dry season, the associated fauna was composed predominantly of medium- and large-sized fish species, represented by *C. macropomum* and *P. hemioliopterus*. These differences in the composition of the bycatch indicate that methodological, spatial, and seasonal factors directly influence the structure of the recorded fauna, reinforcing the dynamic nature of inland fisheries in the Guaporé River region and adjacent areas (Sousa et al., 2021).

Colossoma macropomum, together with *P. brachypomus* and some hybrids of these species, comprise the group known as “round fish,” which are of great importance to national aquaculture (Kubtiza, 2004). From an ecological perspective, *C. macropomum* contributes significantly to seed dispersal in the flooded forests of the Amazon basin and also stands out as a fishery resource of major regional importance (Hilsdorf et al., 2022). In the wild, this species can reach approximately 30 kg and is considered the second largest scaled fish in the Amazon basin, surpassed only by *A. gigas* (Goulding & Carvalho, 1982).

In this context, the impacts of incidental capture become relevant not only from a fisheries perspective but also from an ecological and socio-environmental point of view, as they involve native species essential to the functioning of Amazonian aquatic ecosystems. In this scenario, chelonians also play an important ecological role in seed dispersal (Eisenberg et al., 2017), which favors the regeneration of floodplains with fruit-bearing trees that sustain the survival of occasional frugivorous fish, such as *C. macropomum* (Oliveira, 2022).

Moreover, the traditional knowledge of the riverine communities, built through daily activities experienced in the environment and passed down through generations, is essential for the management of chelonian populations during fishing activities (Andrade, 2017). According to Vogt (2008), populations of *P. unifilis* are declining in several regions of the Amazon basin due to excessive harvesting. Despite this, the species still shows high densities in several protected areas, such as the Manu Reserve (Peru) and the Trombetas, Guaporé, Purús, Juruá, and Jaú rivers (Brazil). Thus, it is not considered a threatened species, nor does it face an imminent risk of extinction (Vogt, 2008).

In the study area, which is the Cautário River Extractive Reserve, there are management regulations that strictly govern the capture of chelonians, in accordance with the management plan of the unit (ICMBio, 2017). The most common genus in this region is *Podocnemis* (Balestra, 2016), which also has a wide distribution in the tropical lowlands of northern South America, occurring both in the Orinoco River basin and the Amazon River basin, including extensive areas of Venezuela as well (Brazaitis et al., 1996; Vogt, 2008).

In the present study, it was observed that, in addition to fish and turtles, individuals of the crocodilian species *C. crocodilus* were entangled in the fishing gear, which are also frequently caught in gillnets during commercial fisheries (Guimarães, 2019). According to the fishers, caimans interfere with fishing by feeding on fish caught in the gear and often damage the fishing equipment when they become entangled (Peres & Carkeek, 1993). The most frequent crocodilian species in the study area is *C. crocodilus*, which inhabits various types of wetland environments, such as lakes, *igarapés*, floodplains, and inundated areas, and is one of the most abundant crocodilian species in the Neotropical region (Farias et al., 2013).

The reduction of stocks resulting from the incidental capture of the species recorded in this study, including fish, chelonians, and crocodilians, can trigger long-lasting and, in some cases, difficult-to-reverse changes in aquatic ecosystems, especially when combined with other natural and anthropogenic stressors (Gilman et al., 2023).

However, in the case of stationary nets, reducing the time the nets remain in the water and increasing the frequency of inspection are measures that may help minimize incidental capture and associated mortality (Collins et al., 2025). These measures increase the likelihood of finding bycatch animals that are still alive and remove them, thereby reducing mortality (Alarcon et al., 2009) and contributing to the sustainability and conservation of the local ecosystem (Campos-Silva & Peres, 2016).

A large part of the solutions to the impacts caused by gillnets lies in the empirical knowledge of the fishers (Amorim et al., 2019). This knowledge complements scientific studies in understanding species dynamics and guiding management practices, as fishers recognize the damages caused gillnets. They can identify areas and seasonal periods of the highest concentration of target species and determine when the use of such fishing gear is appropriate or should be avoided (Alarcon et al., 2009). These actions underscore the importance of organization and active participation of riverine communities and fishers in improving the management and governance of local fishery stocks.

In this study, the physical–chemical water parameters, such as DO, temperature, EC, and pH, were used to characterize the limnological conditions of the sampled environments during the monitoring period. The values recorded in the five collection points provide a descriptive environmental context for the occurrence of bycatch and indicate conditions compatible with the maintenance of aquatic biota reported for Neotropical environments (Maldonado & Goitia, 2013; Van Damme & Carvajal-Vallejos, 2013). In this sense, these data complement the interpretation of the fishing environments and reinforce the importance of continuous environmental monitoring in managed fisheries.

The incidental capture of non-target species in fisheries is still poorly understood in Brazil, and the available information is insufficient to assess the real impact on bycatch (Vasconcelos Filho et al., 2024). Thus, although research continues to advance, the population and ecosystem effects of incidental capture of non-target fishery species remain poorly understood, highlighting the need for further studies to fill these gaps regarding fisheries in the Amazon region (Gilman et al., 2023).

CONCLUSION

The bycatch associated with the managed fishery of invasive *A. gigas* in the Cautário River was composed mainly of fish and reptile species, indicating low selectivity of the fishing gear used during the monitored period. The records obtained in lotic and lentic environments showed that incidental captures occurred in different fishing settings of the Cautário River basin during the dry season. In addition, the physical–chemical parameters of the water contributed to the environmental characterization of the sampled sites, providing complementary information for the interpretation of the bycatch records. Together, these findings reinforce the importance of monitoring associated fauna and environmental conditions in the managed fishery of *A. gigas* as support for management and conservation actions in the region.

CONFLICT OF INTEREST

Nothing to declare.

DATA STATEMENT AVAILABILITY

All data relevant to the study are included in the article.

AUTHORS' CONTRIBUTION

Conceptualization: Pereira, Samíria B. B., Sousa, R. G. C.; **Investigation:** Pereira, Samíria B. B., Silva, E. F. O., Pereira, Samara B. B., Varão, C. A. R., Barreto, R. R.; **Supervision:** Pereira, Samíria B. B., Sousa, R. G. C.; **Writing – review & editing:** Chagas, T. Q., Gonzaga Junior, M. A.; **Validation:** Gonzaga Junior, M. A., Sousa, R. G. C.; **Final approval:** Souza, R.G.C.

FUNDING

Fundação de Amparo ao Desenvolvimento das Ações Científicas e Tecnológicas e à Pesquisa do Estado de Rondônia.

Grants no: 0012.000492/2023-07 and 0012.000162/2025-75.

ACKNOWLEDGMENTS

The authors would like to thank the traditional communities of the Extractive Reserve of the Cautário River for their fundamental support during field activities and experimental fisheries.

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