Assessing ichthyofauna species composition at an aguajal and quebrada in the buffer zone of Tambopata National Reserve

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Just Assen

May 2025

Forest Ecology and Management

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FEM 70424

Supervision:

Dr. A.H Guzman
Dr. J.P van der Sleen
Msc. R. Bello
Msc. M.A.M Cordova

The author declares
1) that this work is his/her own and
2) that he/she has adhered to The Netherlands Code of Conduct for Academic Practice

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Introduction

The amazon area is the most diverse area in the world when it comes to ichthyofauna (Reis *et al*., 2016). With about 5160 species of fish currently known to science, an estimated number of between 3000-4000 species are yet to be described/discovered (Reis *et al*., 2016). In Peru alone, over 1000 fish species have been registered, and this number is projected to increase (Ortega *et al*., 2012). Especially on the transitional zone between the Andes and the Amazon region, biodiversity is extraordinary high (Mittermeier et al., 2011). In order to preserve the biodiversity that is embedded within the Amazonian region, it is imperative to know it's species (Miqueleiz et al., 2020). The Tambopata national reserve region is included within the Mamore-Madre de Dios Piedmont Freshwater Ecoregion (*Abell et al.,* 2008). Whereas some research has been done to fish species composition in larger rivers of the madre de dios area *(Barthem et al, 2003; Carvalho et al, 2012;* Palacios & Ortega, 2009), there are only few reports available from inside the Tambopata national reserve (Chang, 1998). In this communication, we report the fish species collected in the buffer zone of the Tambopata National reserve, located in the south east of Peru.

Other reports

In between 1982 and from 1986 several fish collections were made in the middle and upper part of the Tambopata national reserve, which resulted in 232 species caught, belonging to 36 families (Chang, 1998). Fish were caught with seines, gillnets, dipnets and hooks. One unpublished report exists from the bufferzone of the lower Tambopata region (Taricaya's work 2015). In total they sampled 140 species fish species, from the main river and 2 quebrada's. While, as of yet, no published work exists from the lower Tambopata region, reports exists of other parts of the madre de dios river basin.
The most extensive study of ichthyofauna in the region was conducted downstream of Manu national park, at los amigos. In total 287 species were found in this part of the region (Barthem et al. 2003). Furthermore, in the las Piedras river, a tributary of the madre de dios river, Carvalho et al., (2012) caught 144 species of fish, belonging to 32 families. Out of those 144 species, 55 fish species were collected in quebrada's and 94 fish species were collected in rivers. Thrid, a published report exists from the Inambari river, another upstream tributary of the madre de dios river. Here 52 species were caught, belonging to 35 genera and 13 families (Palacios & Ortega, 2009). Finally, in the alto madre de dios river, in Manu national park, 78 species were collected, belonging to 42 genera and 15 families (Tobes et al., 2021). Of particular interest is their report of a sampling point in an aguajal, an palm swamp dominated by the palm species Mauritia flexuosa, and characterized as black water bodies (Kahn & Mejia, 1990). In this aguajal tobes et al. observed 3 species. Few studies have assessed ichthyofauna inside aguajals: the only other data point comes from barthem et al*.,* who caught 123 fish in an aguajal, belonging to 4 species.

Goal of the study

In this study, we assessed the ichthyofauna composition of a quebrada and an aguajal at the bufferzone of the lower part of the Tambopata national reserve. Fish collections were conducted in a black water quebrada, originating from lake Sandoval, and an aguajal. Since little is known about fish communities inside these aguajals, sampling in this area may uncover new information about species distribution ranges, limits and fish habitat characteristics. The aim of this study is to add to the existing knowledge of species distribution and habitat from the lower Tambopata region.

Methods

Study site

Fish collection took place at Kawsay, a private conservation area located in the lower part of the madre de dios river in Peru, in the buffer zone on the boarder of the Tambopata national reserve (figure 1). In this conservation area two permanent water bodies exist: one small stream, called a quebrada and a palm swamp, called an aguajal (figure 2). Aguajals are categorised as black water bodies. The quebrada, from here onwards referred to as quebrada "Sandoval", originates from lake Sandoval, an oxbow lake inside the Tambopata national reserve. At the time of sampling, the aguajal was connected to a quebrada of unknown origin. Aguajals often contain peat, but size of the peat layer can vary considerably (Schulz et al., 2019). In this case, the sinking depth in the aguajal was around 50 centimetres deep. The water had a heavy, fruity smell. Since aguajals retain water their primary water source is rainfall, which results in acidic water with a pH as low as 3.5 (Kahn & Mejia, 1990). For both the aguajal and Sandoval quebrada pH, conductivity, temperature and parts per million were measured using a multimeter. Oxygen levels were measured using an oxygen test set. Data collection took place in the months of January and February, in the rainy season

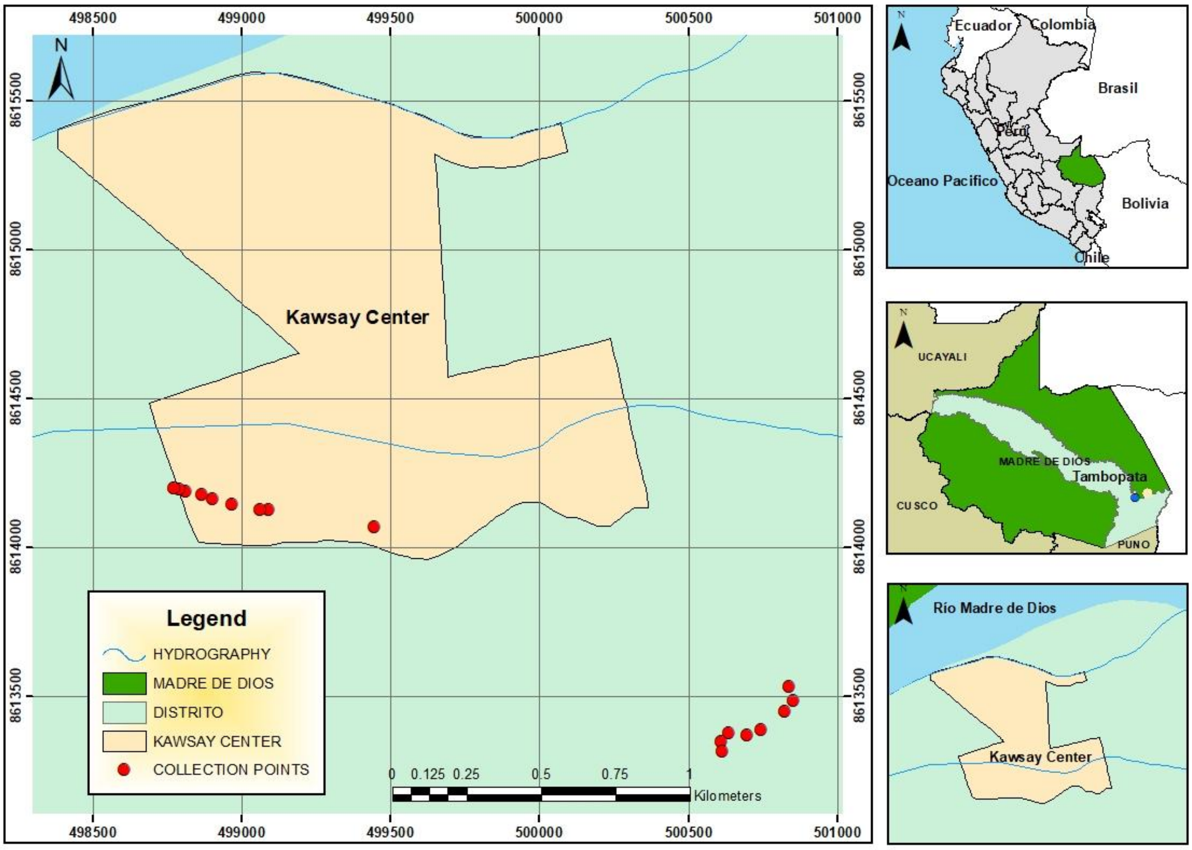

Figure 1. Map of the research area and its location within Peru. Sampling points are included. Note that the waterbodies in kawsay are not accurately depicted

Table 1: coordinates of the sample points

POINTS	ECOLOGICAL ZONE	COORDINATES		ALTITUDE
QS1	Quebrada Sandoval	499090	8614128	198
QS2	Quebrada Sandoval	499061	8614129	198
QS3	Quebrada Sandoval	498965	8614147	199
QS4	Quebrada Sandoval	499443	8614069	196
QS5	Quebrada Sandoval	498901	8614165	199
QS6	Quebrada Sandoval	498865	8614178	200
QS7	Quebrada Sandoval	498812	8614191	200
QS8	Quebrada Sandoval	498791	8614198	201
QS9	Quebrada Sandoval	498770	8614201	201
AG1	Aguajal	500853	8613487	198
AG2	Aguajal	500636	8613379	196
AG3	Aguajal	500699	8613371	196
AG4	Aguajal	500744	8613391	198
AG5	Aguajal	500837	8613535	194
AG6	Aguajal	500824	8613452	199
AG7	Aguajal	500611	8613351	195
AG8	Aguajal	500615	8613318	195

Figure 2. pictures of the two different habitats:
The aguajal (a&b) and the Sandoval quebrada (c&d)

Fish collection

To catch fish, three methods were used. Fish were caught with seine nets, gillnets and hooks (handline fishing). Seine nets were used in flooded areas of the Sandoval quebrada and the aguajal with a water depth of less than 1.70 meters. The net was 10 meters long and 3 meters deep, with a mesh size of 5mm. Seine nets are used to surround a certain area. At the bottom they are held down by weights. Starting from the shore, we entered the flooded area and surrounded a small area of water. Once surrounded, the net was dragged out of the water.
Secondly, a 20 meters long, three layered gill net was deployed. The mesh size of the inner net was 2.5 inches whereas the mesh size of the outer net was 4.5 inches. The gillnet was deployed in the deeper parts of the aguajal and across the middle of the Sandoval quebrada. In January the trammel net was deployed for 6 hours, whereas in February it was deployed for 24 hours.
Finally, hooks were used in combination with hand line fishing. As bait, worms and beef were used. Hook sizes ranged between 0,5 cm and 5 cm.

Water measurements

pH, conductivity, temperature and parts per million were measured using a multimeter. Oxygen levels were measured using The LaMotte Dissolved Oxygen Test Kit, which has a sensitivity of 0.2mg/L an oxygen test set. Water transparency was measured through use of white boots.

Species identification

Once caught, fish were photographed either in vivo, at the location of capture, or in vitro, in a narrow aquarium, similar to (Sabaj Prez, 2009) and (Carvalho et al, 2012). All pictures were made with a Samsung galaxy S24 smartphone. After the pictures were taken, fish were conserved in 96% ethanol and later transferred to a 70% alcohol solution, in which they are stored. At the start of the identification process, fish were grouped based on morphological characteristic visible at first sight. Fish were identified to the species level by comparing our pictures and specimen with pictures available from other studies in the area, such as (Carvalho et al, 2012) and (Y-Cuyari et al., 2013) from the broader Madeira basin. Additionally, a PhD dissertation was consulted with over 300 fish species depicted from the Madre de dios basin (Floris 2015). When in doubt, experts were consulted and in some cases identification keys were used. Species were classified according to the Eschmeyer Catalog, version from February 2025.

Results and discussion

In total, 203 specimen were caught, out of which 37 species were identified, belonging to 5 orders and 16 families (see table 1). 12 specimen were not yet identified to the species level. A photo list of the species that were caught is provided in Appendix 1. Of the identified species, only *Hemigrammus lunatus* is missing. With a total of 22 identified and 5 unidentified species, species belonging to the order of the Characiformes were most abundant (55.1%) followed by Cichliformes (20.4%) with 7 identified species and 3 unidentified species and Siluriformes (18.4%), also with 7 identified species and 2 unidentified specimen. 2 species belonging to the order of Cyprinodontiformes were caught, whereas Gymnotiformes were represented by just one species.
There was only one species that was found in both the quebrada and the aguajal, which was *Gasteropelecus sternicla*. None of the other species showed overlap between the aguajal and the Sandoval quebrada. Although the water bodies are not precisely mapped, at some points the distance between the aguajal and Sandoval quebrada is less than a kilometre. While in January the pH in the aguajal was lower compared to the pH of the Sandoval quebrada(5.62 vs 6.25) they reached similar values by February, likely due to the progression of the rainy season. The observed difference in pH are therefor not enough to explain the difference in species composition. Perhaps comparing the lowest pH values during the year may be more informative. It is possible that oxygen values are an important factor in explaining the observed difference. Unfortunately, tests to measure oxygen concentrations in the aguajal failed. While this might be due to faulty equipment, another possibility is that oxygen levels were too low to be measured. However, when properly working, the oxygen test set that was used should be able to pick up concentrations as low as 0.2 mg/L.

Tabel 2. species list

Number	Order	Family	Species
1	Characiformes	Erythrinidae	*Hoplias malabaricus* (Bloch, 1794)
2		Serrasalmidae	*Mylossoma duriventre* (Cuvier, 1818)
3		Anostomidae	*Schizodon fasciatus* Spix & Agassiz, 1829
4		Curimatidae	*Cyphocharax spiluropsis* (Eigenmann & Eigenmann 1889)

5		Bryconidae	*Brycon amazonicus* (Agassiz, 1829)
6		Gasteropelecidae	*Gasteropelecus sternicla* (Linnaeus, 1758)
7		Tetragonopterinae	*Tetragonopterus argenteus* Cuvier, 1816
8		Characidae	*Phenacogaster pectinata* (Cope, 1870)
9			*Roeboides sp.*
10		Acestrorhamphidae	*Ctenobrycon hauxwellianus* (Cope, 1870)
11			*Hemigrammus unilineatus* (Gill, 1858)
12			*Hemigrammus lunatus* Durbin, 1918
13			*Astyanax bimaculatus* (Linnaeus, 1758)
14			*Astyanax sp. 1*
15			*Psalidodon fasciatus* (Cuvier, 1819)
16			*Bario oligolepis* (Günther, 1864)
17			*Astyanax abramis* (Jenyns, 1842)
18			*Holopristis neptunus* (Zarske & Géry 2002)
19			*Gymnocorymbus thayeri (*Eigenmann, 1908)
20			*Moenkhausia cotinho* Eigenmann, 1908
21			*Moenkhausia dichroura* (Kner, 1858)
22			*Brachychalcinus copei* (Steindachner, 1882)
23			*Odontostilbe*
24			*Characidae sp. 1*
25			*Hemigrammus sp. 1*
26			*sp. 1*
27			*sp. 2*
28	Gymnotiformes	Sternopygidae	*Eigenmannia virescens* (Valenciennes, 1836)
29	k	Cichlidae	*Bujurquina cordemadi* Kullander, 1986
30			*Aequidens tetramerus* (Heckel, 1840)
31			*Apistogramma linkei* Koslowski, 1985
32			*Apistogramma staecki*
33			*Apistogramma sp. 1*
34			*Apistogramma sp. 2*

35			*Apistogramma sp. 3*
36			*Crenicara punctulata* (Günther, 1863)
37			*Cichlasoma boliviense* Kullander, 1983
38			*Saxatilia semicincta* (Steindachner, 1892)
39	Siluriformes	Callichthyidae	*Gastrodermus cf. bilineatus*
40			*Callichthys callichthys* (Linnaeus, 1758)
41			*Hoplisoma cruziense (Knaack 2002)*
42			*Hoplisoma trilineatum* (Cope, 1872)
43		*Loricariidae*	*Pterygoplichthys punctatus*
44			*Pterygoplichthys sp.1*
45			*Hypostomus sp.1*
46		*Doradidae*	*Platydoras costatus* (Linnaeus, 1758)
47		*Auchenipteridae*	*Trachelyopterus galeatus* (Linnaeus, 1766)
48	Cyprinodontiformes	*Rivulidae*	*Moema pepotei* (Costa, 1993)
49			*Moema sp. 1*

Limitations

From other studies, Characiformes and Sluriformes are known as the most diverse orders in the madre de dios basin (Palacios & Ortega, 2009; Carvalho et al, 2012; Chang, 1998). Our relative lack of Sluriformes may be related to our limited success with gillnets. In this study 41 species (83.7%) were caught with seine netting, opposed to only 5 species caught with gillnets (10.2%) and 6 species caught with hooks (12.2%). The limited success of the gillnets might be caused by the fact that fish were able to see the green net in the black waters and hence just avoid it. Furthermore, gillnets are vulnerable to damage caused by caimans and hence should be checked once every 2 hours. In this study, it was not feasible to check the net during night hours. Therefor, we only deployed the net overnight once, in Februari, which resulted in 4 species caught. Assessing fish species composition in the aguajal was particularly changeling for a number of reasons: First of all, the aguajal was located 3.5km from our camp, meaning that we had to carry the equipment for 3.5 kilometers through the rainforest. Secondly, the structure of the aguajal made it hard to fish with seine nets: there were many branches on the bottom, which may have allowed fish, especially ground dwellers, such as Sluriformes, to easily escape from underneath.

Seine netting was the most successful method in these habitats, meaning that species that are likely to get caught with seine nets are well represented in the dataset. All together, this may explain the lack in Sluriformes and a bias towards smaller species, mostly belonging to the order of Characiformes. While we had limited success with the gillnets, we did catch four species that were not caught with the other methods. *Mylossoma duriventre*, *Saxatilia semicincta*, a *Hypostomus sp.* and *Platydoras costatus* were all caught only with gill nets. Similar for hand line fishing, *Hoplias malabaricus*, *Brycon amazonicus* and *Trachelyopterus galeatus* were exclusively caught with hooks.

Compared to other studies in the area, we caught relatively many cichlids with a limited effort. While very diverse, most cichlid species are known to prefer slow flowing quebrada's or still waters and our focus on these habitats has discovered cichlids not previously known to the area, such as *Apistogramma linkei* and *Crenicara punctulata*.

Wet season

As mentioned earlier, sampling took place in January and February. These months are characterised by the rainy season. At this time of the year, parts of the forest become flooded and because of the increase in habitat, fish densities decrease. As a result, it becomes more difficult to catch fish. This also shows in our data. In January a total of 85 specimen were caught for quebrada Sandoval and 45 specimen were caught for the aguajal. In Februari, 43 specimen were caught for the quebrada and 23 specimen were caught in the aguajal. By march, the water levels were so high that fishing attempts were unsuccessful: only one specimen was caught and the aguajal was not reachable. Yet, sampling in the rainy season may reveal information about species migration and habitat preferences. Moreover, the progression of the rainy season is noticeable in the water measurements. In January the pH value of the aguajal was 5.62, whereas in February a pH of 6.10 was measured. As for the Sandoval quebrada, similar values were measured for both months, but an increase was observed in March (table 2).

Table 3. water parameters for the aguajal and Sandoval quebrada. In march the aguajal was not reachable, so there are no values for that month.

Water measurements	month	Cond. (µs/cm)	ppm	PH	T° (°C)	Ox. D (mg/L)	Trans. (cm)	Depth (cm)
Sandoval quebrada	January	39	19	6.25	25.2	3.0	98	1.90
	February	36	18	6.27	25.5	-	105	2.00
	March	46	22	6.54	24.2	3.4	18	4.5
Aguajal	January	47	24	5.62	24.5	-	35	1.30
	February	41	21	6.10	25.2	-	32	1.35

Aguajal

In January and February 9 species were identified in the aguajal, which is more than any other study has reported. In 2003, Barthem *et al* encountered *hemigrammus ocellifer*, *serrapinus dorsimaculatus* and one unidentified *serrapinus sp.* in the aguajal that he sampled near los amigos, higher up in the madre de dios river. In 2021, Tobes et al found the following three species to occur in an disturbed aguajal: *Moenkhausia oligolepis* (70 specimens),*Crenicichla semicincta* (3 specimens) and *Hoplias malabaricus* (1 specimen). In unpublished work from 2015, Julio found 4 species in an aguajal, namely: *Pyrrhulina vittata*, *Gymnotus carapo*, *Rivulus christinae* and *Apistogramma lueling*. The species composition of the aguajal in this study shows little resemblance with those of the other aguajals sampled. Out of the 9 species that were found inside the aguajal, just 3 belong to the order of Characiformes. Furthermore, we found 4 species belonging to the order of sluriformes, whereas other studies reported none

Comparing fish species composition between aguajals is difficult due to unclearities in the definition of aguajals. Generally, aguajals are defined as palm swamps dominated by the palm species Mauritia flexuosa. However, unclarities arise about the characteristics of the waterbody. Some authors define aguajals as permanent, mostly isolated water bodies, whereas others point out that aguajals can completely dry out. These differences in life history can be decisive for answering questions about fish species occurrences.

Aguajals that are at risk of drying out may be more likely to contain species belonging to the Rivulidae and related families (killifish), who's reproduction cycle is adapted to the drying up of pools (Hrbek & Larson, 1999), and species belonging to the family of Loricariidae (armoured catfish), who may be able to travel small distances in search of water bodies (Schaefer, 1997).

Tabel 4. species list of the aguajal

Aguajal	*January*	*February*
Gasteropelecus sternicla	*20*	*x*
Hemigrammus lunatus	*2*	*x*
Moenkhausia cotinho	*x*	*11*
Gastrodermus cf. bilineatus	*13*	*1*
Callichthys callichthys	*7*	*7*
Pterygoplichthys punctatus	*3*	*x*
Pterygoplichthys sp.1	*x*	*1*
Moema pepotei	*x*	*1*
Moema sp.1	*x*	*2*

Conclusion

So far 37 specimen were identified to the species level, belonging to 5 orders and 16 families. No overlap was found in species composition between the aguajal and the Sandoval quebrada. By developing this project, a scientific foundation was established to identify the ichthyofauna composition in an aguajal and quebrada at the bufferzone of the Tambopata National reserve. With this study, a larger project is initiated: Sampling will be continued until the end of this year, for 2-3 days in each month.

Acknowledgements

I would like to express my gratitude and appreciation to those who supported me with successfully completing this chapter of my study and early career. I would like to thank Raul for hosting me and facilitating the fieldwork. I would like to thank Miguel for sharing his knowledge and skills on the ichthyofauna of the Madre de Dios area and for helping out with the fieldwork. Without your support we would not nearly have caught as many fish (species!). I also thank Miguel for taking me through the species identification process. Last but not least I would like to thank Peter and Alejandra for their helpful suggestions, insights and course guidance.

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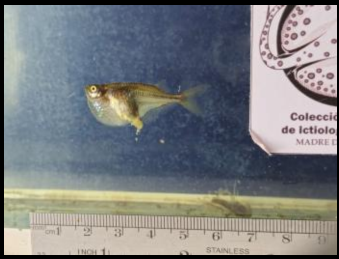
Appendix

Photo list

Gasteropelecus sternicla



Gasteropelecus sternicla

Tetragonopterus argenteus

Phenacogaster pectinata

Roeboides sp.

Ctenobrycon hauxwellianus

Hemigrammus unilineatus

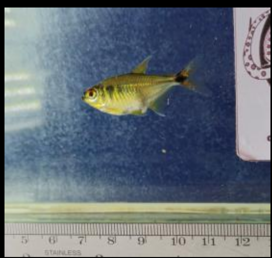
Astyanax abramis

Astyanax bimaculatus

Astyanax sp. 1

Psalidodon fasciatus

Bario oligolepis



Holopristis neptunus

Gymnocorymbus thayeri

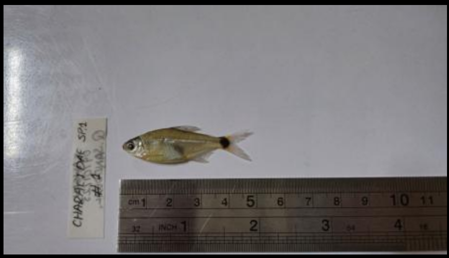
Moenkhausia cf. Cotinho

Moenkhausia dichroura

Brachychalcinus copei

Mylossoma duriventre

Odontostilbe sp. 1



Characidae sp. 1

Characiformes sp. 1

Characiformes sp. 2

Eigenmannia virescens


Odontostilbe sp.


Bujurquina cordemadi


Aequidens tetramerus

apistogramma linkei

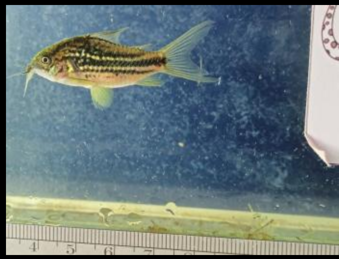

apistogramma staecki


apistogramma staecki

Crenicara punctulata


Cichlasoma boliviense

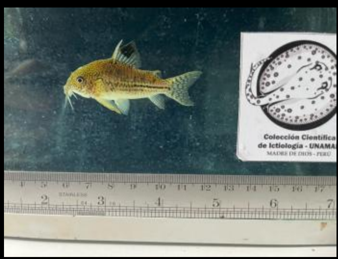
Saxatilia semicincta



Gastrodermus cf. bilineatus

Gastrodermus cf. bilineatus

Hoplisoma cruziense



Hoplisoma trilineatum

Callichthys callichthys

Pterygoplichthys punctatus

Pterygoplichthys sp.1

Hypostomus sp. 1

Platydoras costatus

Moema pepotei

Moema sp. (hembra?)

Trachelyopterus galeatus