Biological Inventory and Trapping Evaluation of Terra Firme Stream Fishes

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Abstract

The Amazonian region of southeastern Peru is a highly stable and diverse region of lowland rainforest. In recent years this region has been subject to rapid economic development through extractive practices of agriculture, logging, and mining connected directly to the building of the Interoceanic Highway which connects Peru with Bolivia and Brazil. Little documentation exists of the aquatic diversity of the region and recent extractive practices may be degrading these ecosystems. This study aims to conduct a biological inventory of fish in the headwaters stream located at Finca Las Piedras Research Station, with secondary goals of determining the impact of diel cycles on fish diversity and trapping efficiency. This study sampled 239 fish from 6 different families while finding differences in the diversity of fish sampled and the efficacy of trapping between day and night. The results indicate that, in order to obtain representative samples of Amazonian stream fish in future studies, sampling efforts must take place both day and night.

Introduction

The Amazonian region of southeastern Peru exist in alluvial and Terra Firme regions and exhibit different ecological characteristics (Chávez Michaelsen et al., 2013). As the name suggests, alluvial rainforests of southeastern Peru occupy the floodplain areas of larger rivers in the region and exhibit relatively high rates of change over geologic time as large rivers shift their paths. The term Terra Firme translates directly to “high lands” to refer to areas of rainforest seated at higher elevations outside of the river floodplain. Terra Firme rainforests are characterized by relatively flat terrain, well-draining soils, and are very stable environments that have shown little geologic change over time (Chávez Michaelsen et al., 2013; Val et al., 2021). The stability of their environment has led to high levels of diversity in all aspects of the ecosystem (Chávez Michaelsen et al., 2013; Reynel et al., 2013). However, the stability of the Terra Firme rainforests has recently been disrupted in certain areas of Peru (Chávez Michaelsen et al., 2013).

The Food and Agriculture Organization of the United Nations found South America to be the region with the highest deforestation rates from 2000-2020 (*Evaluación de los recursos forestales mundiales 2020*, 2020). During this same 20-year period, Peru rapidly increased its economic development through extractive practices of agriculture and mining, both of which contribute directly to deforestation (Chávez Michaelsen et al., 2013; Móstiga et al., 2024). The Interoceanic Highway (IOH), running from the Madre de Dios region in Peru through Bolivia and into Brazil was built between 2003 and 2011 to provide a reliable way to export resources between countries for economic benefits (Chávez Michaelsen et al., 2013).

Chávez Michaelsen et al. found an increase in non-forested areas in the Madre de Dios region of Peru beginning with the planning of the IOH and continuing through its construction and thereafter (Chávez Michaelsen et al., 2013). These trends are consistent with the findings of Laurence et al. who found that 95% of rainforest deforestation in Brazil occurred within 50km of a road, and further support the claims of Gallice et al. that the Peruvian government needs to have stricter regulation on road development in Amazonian Peru (Gallice et al., 2019; Laurance et al., 2014).

Changes in land use patterns have been shown to have impacts on both fish and other aquatic populations (Benstead et al., 2003; Chen & Olden, 2020; Lorion & Kennedy, 2009; Morrill et al., 2024.; Villéger et al., 2010). Chen and Olden compiled data from previous studies on land development and freshwater fish species assemblages on four continents across a variety of latitudes. Their comprehensive analysis showed that while levels of sensitivity vary, fish assemblages on all continents across all latitudes tested were sensitive to land development and that past land-use practices played a role in how assemblages responded to new disturbance (Chen & Olden, 2020). In a more focused study, Villéger et al. investigated the influences of anthropogenic habitat degradation on taxonomic and functional diversity of estuarine fish species in the neotropics. Their findings showed that different areas respond differently to degradation in terms of species diversity and functional specialization, emphasizing the need for increased studies in the neotropics on aquatic diversity and dynamics (Villéger et al., 2010).

This study aims to conduct a biologic inventory of fish and aquatic macroinvertebrate species in a Terra Firme stream in Madre de Dios, Peru. There were four goals of the study: (1) conduct a biological inventory of fish in the headwaters stream at Finca Las Piedras, (2) investigate differences in diversity of capture between day and night sampling periods, (3) investigate the differences in trapping efficiency between day and night, and (4) create a working dataset of Peruvian Terra Firme stream fish that can continue being developed during future studies.

Methods

Sampling Sites

Sampling occured in the stream at Finca Las Piedras Research Station (hereby referred to as "FLP") located in the Las Piedras District in the Tambopata Province of Madre de Dios, Peru. The section of stream bisecting FLP property is a first order stream within a mile of the headwaters and joins with a second, unnamed first order stream within the FLP property line, leaving as a second order stream. This stream is a blackwater, tannin-stained stream that is heavily channelized during the dry season and widens to a braided, marsh-like habitat during the wet season.

Five sampling sites were chosen to represent the entire stretch of stream at FLP and encompassed varied levels of flow, direct sunlight, width, and depth. Site selection was limited to areas deep enough to sampling using minnow traps, with all sites being deep enough to cover the trap entrance to its entirety. Site 1 is 178cm in length, 180cm in width, and 55cm deep. Its main characteristics are that it has very little canopy cover and very slow flow. Site 2 is 195cm in length, 236cm in width, and 91cm deep with relatively little canopy cover and very slow flow. Site 3 is 119cm long, 115cm wide, and 29cm deep. It has moderate canopy cover and is highly channelized with moderate flow compared to other sites. Site 4 is 177cm long, 300cm wide, and 65cm deep with relatively little canopy cover and a slow flow rate. Site 5 is 250cm in length, 387cm in width, and 50cm deep. It is the widest site wide relatively uniform depth, moderate canopy cover, and slow flow. Site 1 is the most upstream site and Site 5 is the most downstream.

Trap Construction

Two gee type minnow traps were constructed using materials available at FLP. Traps were 46cm long and 30.5cm in diameter, with entrance points having a 5cm diameter. The size of the entrance point was chosen because of past observations of fish size by long-term residents at FLP. Chicken wire with 15mm x 15mm holes was used to construct the body of the trap. The wire was then covered with window screen having 1.5mm holes to limit bias against fish smaller than 15mm3. Traps were held together using stainless steel wire and string was used as a tether to deploy and retrieve traps. The gee type design was chosen because studies by Budria et al. and Dow et al. found this trap design to be one of the most effective minnow trap designs for sampling (Dow et al., 2020; Budria et al., 2015)

Sampling Efforts

Traps were set both day and night for 8-hour periods. Diurnal traps were set between 07:00 and 09:30. Nocturnal traps were set between 20:30 and 21:30. Times were chosen to ensure that diurnal and nocturnal samples were taken in complete light and dark, respectively. Two sites were sampled at a given time with one trap in each site. Sites rotated each day to try to minimize trap avoidance by fish. A study by Tucker et al. found dog food to be an effective bait for minnow traps when sampling fish, and its efficacy and ample availability made it the bait of choice for this project (Tucker et al., 2023). Each trap was baited with 50g of dog food and food was replaced before every sampling effort. Sites were sampled until 5 diurnal samples and 5 nocturnal samples were collected from all 5 sites, totaling 50 samples from the stream.

Data Collection and Analysis

For objectives 1-3, deployment and retrieval times were noted for all traps, along with date, location, weather, number of fish sampled, and number of families sampled. All fish captured in traps were photographed individually and released back into the stream. Photos were used to identify fish to the lowest taxonomic rank. For all sampling efforts, total numbers of fish were recorded along with total number of families and number of individuals representing each family. For objective 4, additional data on site location, sampling date, sampling period, sampling method, and taxonomy was also recorded for development of the working dataset. Data collected to build a working dataset on Peruvian Terra Firme stream fish will be continued to be processed into a finalized dataset following the end of the internship.

Pie charts were used to visualize the total distribution of families in the stream, diurnal trapping diversity, and nocturnal trapping diversity. Pie charts were chosen to show both what families were present in respective sampling groups, but also their relative contribution to fish sampled during each grouping. A stacked bar plot was used to show trapping efficacy of diurnal and nocturnal samples to display differences side by side in an easy-to-understand manner. Effective trapping events were defined as traps containing fish upon retrieval, regardless of the total number. Ineffective trapping events were defined as traps containing no fish upon retrieval.

Results

In total, 239 fish from 6 families were sampled throughout the sampling events (Figure 1). Diurnal sampling efforts sampled 222 fish from 4 families and nocturnal sampling efforts yielded 17 fish from 4 families (Figure 2; Figure 3). Diurnal and nocturnal sampling efforts each had two unique families along with two overlapping families. *Cichlidae* and *Lebiasinidae* were only sampled during diurnal efforts, while *Doradidae* and *Heptapteridae* were only sampled during nocturnal efforts. *Characidae* and *Erythrinidae* were sampled during both diurnal and nocturnal sampling efforts.

Figure 1: Relative occurrence frequency of families throughout the course of the study. *Characidae* was the dominant family, with other families making up relatively equal portions.

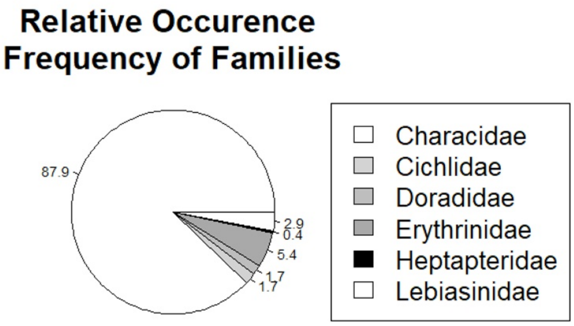

Figure 2: Relative occurrence frequency of families in diurnal samples. *Characidae* was the dominant family with other families making up relatively equal portions.

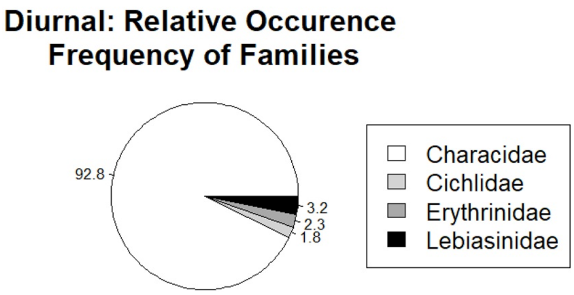

Figure 3: Relative occurrence frequency of families in nocturnal samples. *Erythrinidae* was the dominant family, followed closely by *Characidae* and *Doradidae*, with *Heptapteridae* being represented by one fish.

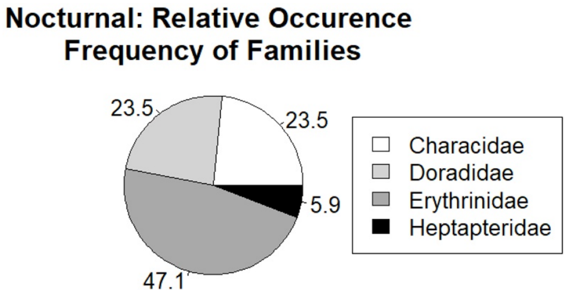

Table 1 shows the total number and proportion of fish from each family that were sampled during each sampling period and in total. *Characidae* was the most abundant family in diurnal samples and *Erythrinidae* was the most abundant family in nocturnal sampling efforts.

Figure 4 shows the differences in trapping efficiency between day and night, with Table 2 showing specific trapping outcomes overall and between day and night. Throughout the entire study, traps contained fish 34 times and were empty 16 times resulting in a 68% capture efficiency (Table 2, Figure 4). The 25 diurnal sampling efforts results in 21 traps containing fish and 4 empty traps (84% capture efficiency; Table 2, Figure 4). Nocturnal traps were less effective with 13 full traps and 12 empty traps out of 25 efforts (52% capture efficiency; Table 2, Figure 4).

Discussion

Throughout the study, *Characidae* dominated trapping efforts making up 87.9% of all fish captured (Figure 1, Table 1). These results suggest that *Characidae* is the most abundant family in the study stream, but a more intensive study is needed to confirm this. *Characidae* were captured during both diurnal and nocturnal

Table 1: Total number and proportion of families sampled in the study, split into day and night sampling efforts. *Characidae* and *Erythrinidae* were found in both sampling groups, with *Characidae* being the most dominant family overall.

	Day		Night		Total	
	Number	Proportion	Number	Proportion	Number	Proportion
Cichlidae	4	0.018			4	0.017
Lebiasinidae	7	0.032			7	0.029
Characidae	206	0.928	4	0.235	210	0.879
Erythrinidae	5	0.023	8	0.471	13	0.054
Doradidae			4	0.235	4	0.017
Heptapteridae			1	0.059	1	0.004
Total	222	1.00	17	1.00	239	1.00

Figure 4: Capture efficiency of traps in both diurnal and nocturnal sampling efforts. Diurnal samples had an efficacy of 84% while nocturnal samples had an efficiency of 52%.

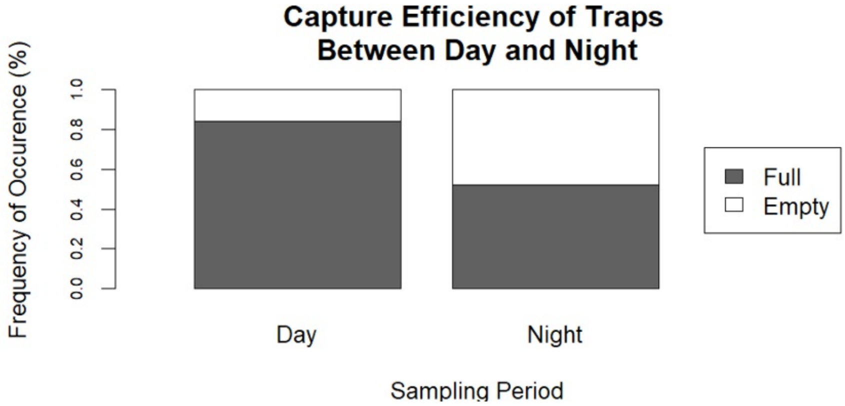

Table 2: Summary of trapping events, separated into day and night efforts. Day traps were full more often than night traps, with an overall success rate of 68% through 50 sampling efforts.

	Day		Night		Total	
	Number	Proportion	Number	Proportion	Number	Proportion
Full	21	0.84	13	0.52	34	0.68
Empty	4	0.16	12	0.48	16	0.32
Total	25	1.00	25	1.00	50	1.00

sampling efforts but were captured more often during diurnal sampling efforts (Table 1). These results point to species in *Characidae* primarily having a diurnal life history, with nocturnal captures assumed to be uncharacteristic. It was also uncommon for *Characidae* to be trapped individually, with almost all samples having multiple Characids. Nocturnal samples had more individual catch, again pointing to the uncharacteristic nature of the events, but a more in-depth study on *Characidae* life history in southeast Peru is needed to prove these assumptions. It is believed that multiple genus and species were captured within the family *Characidae*, but without DNA analysis this belief cannot be confirmed.

Erythrinidae was the second most common family captured during this study, being captured during both diurnal and nocturnal samples (Figure 1, Table 1). *Erythrinidae* was the most common family captured during nocturnal sampling efforts (Table 1, Figure 3). *Erythrinidae* did not show a strong connection to either diurnal or nocturnal sampling. *Erythrinidae* were captured both individually and in small groups with further studies on *Erythrinidae* behavior needed to outline the social structure of the family. *Cichlidae* and *Lebiasinidae* were captured only during diurnal sampling efforts and *Doradidae* and *Heptapteridae* were captured only during nocturnal sampling efforts (Table 1, Figure 2, Figure 3). It is assumed that this is representative of the life history strategies of each family with respect to southeast Peru, but further research is needed to confirm this pattern. There are most likely outliers to this pattern within the study stream or in similar streams throughout the region.

Minnow traps were found to be more effective at capturing fish in the day compared to at night (Figure 4, Table 2). Many factors can contribute to this including the design of the trap, trap placement within the stream, and differences in life history between diurnal and nocturnal species of the study stream. Budria et al. and Dow et al. found separately that trap color plays a role in capture efficiency and may have played a role in this study ((Dow et al., 2020; Budria et al., 2015).

Despite nocturnal trapping efforts being less effective at capturing fish during this study, they are a critical inclusion to future research on headwater streams of the neotropics. In total, 6 families were captured throughout the course of this study, but only 4 were captured by diurnal sampling efforts (Table 1, Figure 2). Not including nocturnal sampling would have biased results away from the families *Doradidae* and *Heptapteridae* causing them to be underrepresented or not represented at all. To obtain representative samples of tropical headwater streams in the future, both diurnal and nocturnal sampling efforts must be included.

Studies like this provide the basis for future studies on impacts of land development and are becoming increasingly important as widespread deforestation continues in the neotropics. The numerous studies cited in this report outlining the impacts of land use changes on aquatic assemblages reinforce the need for more studies in the neotropics, a region currently underrepresented in fisheries research. Chen and Olden collected data from four continents and numerous latitudes, but had no tropical data included in their study (Chen & Olden, 2020). This highlights the lack of research in the neotropics. The study by Villéger et al. took place in the neotropics, however it focused on estuarine regions that have already begun being developed (Villéger et al., 2010).

This is a common trend in neotropical fish research where most studies focus on larger rivers and estuaries that have long been utilized by human civilizations. However, as construction of roads increases access to undeveloped land it is rapidly becoming important to begin research on smaller water bodies such the small Terra Firme stream in this study. We cannot effectively quantify how land development impacts aquatic ecosystems without first knowing what species are present in said systems. Basic research plays a large role in setting the groundwork for future studies and needs to be emphasized in understudied neotropical areas.

Conclusion

As road construction in southeastern Peru increases land development, aquatic ecosystems will be impacted. This study aimed to conduct a biological inventory and evaluate trapping efficiency in a small, headwaters stream, a critically underrepresented ecosystem in neotropical fish research. Over 200 fish were sampled from 6 different families, with different families being found in diurnal and nocturnal samples. Nocturnal trapping efforts were found to be less effective than diurnal efforts but remain crucial to obtaining representative samples of stream diversity due to wide ranging life history strategies of neotropical fish. Basic research is becoming an increasingly important asset as undeveloped areas in the neotropics continue to be converted to agriculture, mined, and cleared for economic gain. We cannot understand how land development impacts aquatic systems if we have no baseline of what species occur in the systema and how they interact with their environment.

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Works Cited

Benstead, J. P., Douglas, M. M., & Pringle, C. M. (2003). Relationships of Stream Invertebrate Communities to Deforestation in Eastern Madagascar. *Ecological Applications,* 13(5), 1473–1490. https://doi.org/10.1890/02-5125

Budria, A., DeFaveri, J., & Merilä, J. (2015). Comparison of catch per unit effort among four minnow trap models in the three-spined stickleback (*Gasterosteus aculeatus*) fishery. *Scientific Reports*, 5(1), 18548. https://doi.org/10.1038/srep18548

Chávez Michaelsen, A., Huamani Briceño, L., Fernandez Menis, R., Bejar Chura, N., Valera Tito, F., Perz, S., Brown, I. F., Domínguez Del Aguila, S., Pinedo Mora, R., & Alarcón Aguirre, G. (2013). Regional Deforestation Trends within Local Realities: Land-Cover Change in Southeastern Peru 1996–2011. *Land*, 2(2), 2. https://doi.org/10.3390/land2020131

Chen, K., & Olden, J. D. (2020). Threshold responses of riverine fish communities to land use conversion across regions of the world. *Global Change Biology,* 26(9), 4952–4965. https://doi.org/10.1111/gcb.15251

Dow, A., Curti, J., & Fergus, C. (2020). It's a Trap! An evaluation of different passive trap types to effectively catch and control the invasive red swamp crayfish (*Procambarus clarkii*) in streams of the Santa Monica Mountains. *Biological Invasions*, 11. https://doi.org/10.3391/mbi.2020.11.1.04

Evaluación de los recursos forestales mundiales 2020. (2020). FAO. https://doi.org/10.4060/ca8753es

Gallice, G. R., Larrea-Gallegos, G., & Vázquez-Rowe, I. (2019). The threat of road expansion in the Peruvian Amazon. *Oryx*, 53(2), 284–292. https://doi.org/10.1017/S0030605317000412

Laurance, W. F., Clements, G. R., Sloan, S., O'Connell, C. S., Mueller, N. D., Goosem, M., Venter, O., Edwards, D. P., Phalan, B., Balmford, A., Van Der Ree, R., & Arrea, I.

B. (2014). A global strategy for road building. *Nature*, 513(7517), 229–232. https://doi.org/10.1038/nature13717

Lorion, C. M., & Kennedy, B. P. (2009). Relationships between deforestation, riparian forest buffers and benthic macroinvertebrates in neotropical headwater streams. *Freshwater Biology*, 54(1), 165–180. https://doi.org/10.1111/j.1365-2427.2008.02092.x

Morrill, D. P., Main, J., Davenport, G., Adams, G. L., & Adams, S. R. (2024). Taxonomic and functional homogenization of fish assemblages in an Ozark river associated with pasture land use and constructed water bodies. *Ecology of Freshwater Fish*, n/a(n/a), e12802. https://doi.org/10.1111/eff.12802

Móstiga, M., Armenteras, D., Vayreda, J., & Retana, J. (2024). Decoding the drivers and effects of deforestation in Peru: A national and regional analysis. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-024-04638-x

Tucker, S., Hrabak, T., Cozzola, A., Benson, R., & Forsythe, P. (2023). Minnow trap styles and baiting strategies on round goby (*Neogobius melanostomus*) capture rates: Lessons from a complex invasion front. *Management of Biological Invasions*, 14(4), 731–748. https://doi.org/10.3391/mbi.2023.14.4.10

Villéger, S., Miranda, J. R., Hernández, D. F., & Mouillot, D. (2010). Contrasting changes in taxonomic vs. Functional diversity of tropical fish communities after habitat degradation. *Ecological Applications,* 20(6), 1512–1522. https://doi.org/10.1890/09-1310.1