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Between Conservation And Income: Impacts Of Community-Based Pirarucu Management In The Middle Solimões River

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Abstract
Community-based management of pirarucu (Arapaima gigas) has emerged as a relevant strategy for conserving fishery resources while generating income for riverine communities in the Brazilian Amazon. This study aims to measure the economic, social, and environmental impacts of pirarucu fisheries management in the Médio Solimões region, using the Triple Bottom Line (TBL) accounting framework. Methodologically, the research is characterized as a case study with a documentary approach, based on the analysis of secondary data from the Annual Technical Reports of the Fisheries Management Program of the Mamirauá Sustainable Development Institute, covering the period from 2017 to 2024. Fourteen variables were selected and grouped according to the economic, social, and environmental dimensions of the TBL framework and analyzed using descriptive statistics. The results reveal positive impacts across all three dimensions, highlighting the growth in gross revenue and average income of fishers, the strengthening of community organization and female participation, and the recovery and maintenance of fish stocks, evidenced by stable average fish size and high capture efficiency within authorized quotas. Despite fluctuations associated with climatic events and institutional challenges, the management system demonstrated resilience and long-term sustainability. As an academic contribution, this study expands the application of Triple Bottom Line accounting to community-based and socio-environmental contexts, reinforcing the role of accounting as a tool for measuring and communicating economic, social, and environmental value in the sustainable management of Amazonian natural resources.

Keywords: *Community-based management. Pirarucu. Sustainability. Triple Bottom Line Accounting. Amazon.*

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I. Introduction

The concern with Amazonian biodiversity is a central point to ensure its natural wealth and to combat habitat destruction and the unsustainable exploitation of natural resources. Biodiversity provides many resources essential for human survival and economic development, yet these resources must be exploited sustainably, allowing nature to recover. Policies and actions that integrate the biodiversity of biomes and the planning of resource use are fundamental to avoid or reduce biodiversity loss and the depletion of natural resources, promoting their sustainable use (Pedrada *et al.*, 2024, p. 11).

The Amazon cannot be portrayed as an untouched wilderness or a mere resource frontier (Brondizio, 2025, p. 923). A frequently debated issue is the relationship between human occupation and its respective effects on the Amazonian biome, tending to concentrate on two strands: (i) one dealing with the disorderly exploitation of natural resources; and (ii) the one addressing the preservation of its ecosystems.

The riverine communities of the ecological system of the Amazon floodplains are social groups whose cultural diversity is manifested through specific territorialities in relation to land possession and the appropriation of natural resources (Oviedo; Bursztyn, 2017, p. 181). The traditional knowledge and practices of riverine peoples for biodiversity preservation should be recognized and used to guide public policies and natural resource management systems, aiming at sustainable forms of biodiversity management and use (Barros *et al.*, 2021, p. 13).

Ribeirinhos reside mainly along the banks of streams, flooded forests, lakes, and floodplains, adapting their lives and homes to the water cycles. During the floods, agriculture, fishing, and hunting are more difficult, while the receding and dry periods are more favorable for fishing and hunting (Silva; Souza; Silva, 2024, p. 10). The traditional populations of the Amazon resulted from miscegenation stemming from various colonization processes, being the fruit of historical exchanges between different peoples and ethnic groups, forming a legacy rich in varied sociocultural manifestations (Silva; Souza; Silva, 2024, p. 10).

The development of markets for goods and services derived from Amazon's natural resources alone is not enough to conserve the forest. Strong institutions are needed to regulate economic actors, and it is essential to recognize the interdependence between society and nature, with market approaches adapted to local contexts, rather than focusing solely on global commodity markets (Pokorny; Pacheco, 2014, p. 450).

From the 1960s onwards, there was an increase in demand for fresh fish, intensifying commercial fishing and putting pressure on floodplain fish stocks. In response to the lack of enforcement and resource depletion, communities organized to protect their lakes, resulting in fishing conflicts and the formation of regional movements such as the Lake Preservation Movement (McGrath *et al.*, 2015, p. 517).

Illegal fishing is the second most common offense in the Amazon, after deforestation, with most of this activity concentrated in the most accessible and densely populated areas (Wilkinson, 2017, p. 2). Subsistence hunting is not considered illegal in Brazil, it is permitted in Indigenous Lands and poor rural areas to ensure traditional hunting and improve food security for the rural population in poverty. However, there is evidence that subsistence hunting is increasingly linked to commercial hunting as an alternative source of income (Medeiros *et al.*, 2023, p. 170).

Local conflicts have intensified due to competition between managed resources and those obtained irregularly. The vulnerability of managed community fishing results in two consequences: the prices of products become less competitive compared to illegal fishing and bring with them new ecological risks (Juliano *et al.*, 2023, p. 15).

It is necessary to promote actions and practices that raise collective awareness about environmental issues. These initiatives should cultivate social values, knowledge, skills, attitudes, and competencies for environmental conservation, aiming at public awareness and maintaining ecological balance (Silva; Souza; Silva, 2024, p. 14).

Pirarucu management is a successful example of conservation and income generation. The biological characteristics of the pirarucu favor sustainable production, contributing to riverine autonomy and challenging predatory development models imposed on the region.

Despite its importance, economies based on biodiversity, and Amazonian social and cultural values are statistically invisible because of a lasting imaginary that sees them as subsistence culture and irrelevant to the broader regional and national economy (Brondizio, 2025, p. 925).

Artisanal fishing is not only a means of subsistence but also a cultural practice rooted in riverine traditions, and constitutes a form of income for fishers. The sale of managed pirarucu faces challenges such as the geographical isolation of rural communities, the low schooling of fishers, unfair competition with illegal sales, high commercialization costs, and increasing demands from the regulatory agency (Amaral, 2007, p. 9).

The use of fishery resources is essential for the subsistence of riverine communities in the Middle Solimões. These communities practice fishing as a source of food and income, selling part of the catch to ensure their economic survival. Illegal fishing directly competes with the commercialization of production and has a significant impact on reducing stocks, which can result in food and economic insecurity for riverine communities.

The present research presents Pirarucu fishing management as a solution to mitigate this problem. The objective of this study is to measure the impacts in the economic, social, and environmental fields of the pirarucu fishing management program in the Middle Solimões region in view of the recurrent successes presented in the literature (Hora, 2020; Lubich *et al.*, 2023; Santana *et al.*, 2020).

The measurement of impacts will be carried out through Triple Bottom Line (TBL) Accounting, providing riverine communities with an empirical diagnosis that demonstrates benefits beyond financial return, also evidencing social and environmental improvements. Thus, the research strengthens the argument of the communities with funding institutions, commercialization, and public policies, in addition to valuing local knowledge and traditional practices as an integral part of Amazonian sustainability.

As an academic contribution, the present research expands the field of accounting study by applying the TBL framework in a sensitive socio-environmental context. This approach provides new paths for studies in Managerial Accounting, natural resource management, solidarity economy, and sustainability.

II. Theoretical Framework

The theoretical framework addressed in this research aims to highlight the functioning of the pirarucu fishing management system and its relationship with the environment in which it is inserted and also to

highlight some concepts pertaining to accounting's concern for economic, social, and environmental aspects, thus expanding the analytical capacity of the accounting field, contributing to an accounting practice more aligned with the principles of sustainability and socio-environmental justice.

Pirarucu Fishing Management

The pirarucu (*Arapaima gigas*) is a native species of the Amazon, with high commercial interest due to some favorable characteristics for production, such as: (i) high growth rate (up to 10 kg in the first year), (ii) high hardiness to handling, (iii) adaptability to artificial feeding, and (iv) high carcass yield (51-57%) (Santos *et al.*, 2021, p. 1).

Pirarucu management activity began in 1999 in the Mamirauá Sustainable Development Reserve (RDSM). Participatory management in Fishing Agreements (AP) to regulate access and use of resources has significantly increased pirarucu stocks and improved the living conditions of the involved riverine population (Lubich *et al.*, 2023, p. 3).

Management involves several techniques aimed at ensuring the reproduction and survival of the species, among them respect for the closed season (period where fishing is prohibited), minimum fish size, and establishment of catch quotas. For Salgado (2015, p. 22), managed pirarucu fishing has demonstrated success in recovering the species' populations in protected areas.

The creation of community management areas, where local communities have the exclusive right to fish, has proven effective in conserving the species, contributing significantly to the recovery of pirarucu populations in the Amazon (Arantes *et al.*, 2010, p. 456).

Another advance is the establishment of limits on the amount of pirarucu that can be caught in a given area and period. The implementation of fishing quotas has contributed to the recovery of pirarucu populations in various regions of the Amazon (Silvano; Ramires; Zuanon, 2009, p. 78). Quotas are defined based on scientific studies that assess the state of pirarucu populations and the carrying capacity of ecosystems.

The behavior of fish inhabiting floodplain lakes is complex and this is reflected in fishing techniques and productivity. Periodic flooding drives fishing dynamics, interfering with access to aquatic environments of the floodplain and the success of capturing many fish species in seasonal tropical rivers (Pinaya *et al.*, 2018, p. 12).

Fishing productivity varies more between protected and unprotected areas during periods of high water levels (Keppeler; Hallwass; Silvano, 2017, p. 274). Fishing is more efficient in the low water season, and when the water is high, fish are harder to catch.

Protected lakes, where fishing is prohibited, can represent a reliable reference site for assessing fishing pressure on fish preservation, ensuring that the aquatic ecosystem continues to operate in a healthy and sustainable manner, as they have better preserved fish populations compared to those found in commercial lakes, where fishing is authorized (Andrade *et al.*, 2022, p. 295).

Due to ineffective enforcement and high rates of illegal fishing, collaborative pirarucu management emerged, aiming to recover stocks and promote sustainable fishing. This method involves the engagement of local communities, who actively participate in complying with rules and enforcement (Freitas, 2019, p. 4).

Figure 1 presents the pirarucu fishing activity in managed areas. Fishing is carried out in canoes with low-power engines or even in rowing canoes due to the low depth of some rivers and lakes during the dry season.

Figure 1 - Fishing activity in a managed area

Source: author's file. Photography: Caroline Reucker (2023).

Communities manage the surveillance, protection, and monitoring actions related to managed pirarucu fishing, and these practices are recognized by various government levels, which are responsible for authorizing fishing and managing the management areas (Juliano *et al.*, 2023, p. 10).

In the Middle Solimões river region, in the 1970s and 1980s, the ecological movement was associated with the sustenance needs of rural area families. The socio-environmental movement was articulated as a response to a situation of scarcity, imposed by a regional context of unregulated and predatory commercial use of natural resources. The logic of the movement would be to position itself against the large 'fishing boats' that came from other municipalities to fish in the region's lakes, affecting the fish stocks that were the sustenance of local populations. For pastoral and lay leaders, community leaders, youth, and adults who were part of popular movements in favor of preservation, environmentalism represented the critical reflection of the lived social experience - of scarcity and food insecurity, of the precariousness of public services and inequality of social conditions - and the struggle to transform this reality (Bezerra, 2022, p. 105-106).

In protected areas, such as RDSs, local communities actively participate in the management of fishery resources, which has contributed to the recovery of pirarucu populations (Campos-Silva; Peres, 2016, p. 1). Community participation has proven fundamental to the success of RDSs, as communities have a deep knowledge of local ecosystems and traditional fishing practices.

Establishing property rights regimes that respect ecosystem functions is fundamental for the future of fisheries management, regulating access, use, and maintenance of natural resources, as well as creating regimes that reflect the ecological and socioeconomic context, promoting ecosystem resilience (Oviedo; Bursztyn, 2017, p. 175).

Participatory pirarucu management is an emblematic case for the bioeconomy of Amazonian sociobiodiversity, as it leverages economic and nutritional potential while conserving the environment and allowing active community participation to generate income and improve well-being (Saes *et al.*, 2023, p. 7).

The management program has significant socioeconomic impacts for riverine communities. Managed pirarucu fishing can generate income and improve the quality of life of local communities, while contributing to the conservation of the species (Silva; Souza; Silva, 2024, p. 4).

Communities that participate in pirarucu management have experienced improvements in food security and family income (Hora, 2020, p. 37). However, market insertion has generated economic challenges, leading fishers to seek new ways to add value and explore new markets (Juliano *et al.*, 2023, p. 9).

The increase in population density in the Amazon has a significant relationship with illegal activities, leading to a consequent increase in deforestation and the extraction of natural resources, among them aquatic species (Kauano; Silva; Michalski, 2017, p. 11). Challenges such as illegal fishing and habitat degradation need to be addressed in an integrated way to ensure the long-term sustainability of pirarucu stocks.

To ensure sustainability, various strategies and policies are fundamental. Monitoring and enforcement are essential components of sustainable pirarucu management. The collection of data on catches, fishing effort, and the state of pirarucu populations allows for the continuous assessment of management practices and the adaptation of strategies as needed (Freitas, 2019, p. 5).

The government implemented protection measures: pirarucu fishing is prohibited, allowing capture only in managed areas, such as Conservation Units (UC), Indigenous Lands (TI), and Fishing Agreement Areas (AAP). Currently, sustainable management involves over 300 communities and 5,000 managers, resulting in the growth of fish stocks and income generation (Juliano *et al.*, 2023, p. 9).

In the State of Amazonas, RDSs and UCs, created with various objectives and under the management of different agencies, play an important role in protecting natural resources, promoting sustainability for traditional and riverine populations (Silva; Souza; Silva, 2024, p. 4). Protected areas are important for social and environmental purposes and should be maintained, observing the physical, chemical, and biological differences between lakes, in order to subsidize the establishment of protected areas and conservation programs in tropical rivers (Keppeler; Hallwass; Silvano, 2017, p. 276).

Decisions for the controlled exploitation of natural resources depend on basic criteria for the design of the productive system that involves good environmental practices, including knowledge of ecological issues, the impact of use on the original conditions of the ecosystem, and an integral view of social, economic, and market aspects (Castro *et al.*, 2018, p. 61).

Community management of fishery resources ensures their protection and the benefits to the communities that use them. The families in these communities suffer if the resources are degraded. It is necessary to understand how families individually benefit from fishing agreements and understand their incentives to participate in community management (Schons *et al.*, 2020, p. 10).

Most management plans and APs have accumulated knowledge and trust over time, resulting in the creation of more formal rules. The existence of recognized rights for the management of natural resources, along with certain operational levels of property rights, can assist institutions and local users in developing, maintaining, and complying with management actions (Oviedo; Bursztyn, 2017, p. 190--191).

The Mamirauá Sustainable Development Institute - IDSM (2015, p. 13) annually holds a meeting to evaluate the efficiency of pirarucu fishing management in the 45 communities to which it provides advisory support, as a way to subsidize the preparation of the annual management report, which in turn is sent to IBAMA. The evaluation meeting should be attended by the majority of fishers involved in the management. The IDSM technical team begins the meeting by explaining the dynamics and criteria to be evaluated, which will be discussed in detail, point by point (Amaral *et al.*, 2011, p. 29).

Triple Bottom Line (TBL) Accounting

Economic, social, and environmental impacts appear as a consequence of high consumption by the world's population. For Kimura and Hatano (2007, p. 174), managers at all levels, both in the public and private sectors, and other stakeholders must be aware of these impacts and assume their responsibilities. Thus, the need arose to evaluate performance taking into account the environment, local communities, and other stakeholders, beyond those with direct and transactional relationships, such as employees, suppliers, and customers (Hubbard, 2009, p. 180).

Elkington (1998, p. 37), who introduced the concept and coined the term *Triple Bottom Line* (TBL), believes that companies need to adopt appropriate tools and develop relevant management systems to build credibility and stakeholder engagement. For Norman and MacDonald (2004, p. 243), the notion of TBL Accounting was already present in management, consulting, investment, and Non-Governmental Organization environments.

TBL Accounting emerged with the aim of producing sustainability reports capable of meeting stakeholder needs, preserving the environment, protecting natural resources, and achieving sustainable development (Safi; Jaafar; Tarkh, 2023, p. 47). The concept of sustainability has three interdependent and interrelated components in common: social, environmental, and economic (Azevedo; Barros, 2017, p. 287).

In the literature, there is little agreement on what sustainable production is. One adopted definition is that of the *Lowell Center for Sustainable Production* (LCSP) which understands sustainable production as the creation of goods and services by non-polluting processes, efficient in the use of resources, economically viable, and socially safe and satisfactory (Alayón; Säfsten; Johansson, 2017, p. 694).

TBL Accounting is based on the three dimensions of sustainability: economic, social, and environmental. The economic dimension refers to the ability to generate profit and ensure financial sustainability. The social dimension involves the responsibility to promote social well-being, including fair labor practices, equal opportunities, and contribution to community development. The environmental dimension, in turn, concerns the responsible management of natural resources and the minimization of negative environmental impacts (Savitz; Weber, 2013, p. 45).

The practical application of TBL Accounting involves the adoption of specific metrics and indicators for each of the three dimensions: in the economic scope, traditional financial indicators are usually used, such as net profit, return on investment (ROI), and profit margin; for social indicators, we have the employee turnover rate, workplace diversity, and the social impact of the company's operations; and in the environmental aspect, we see carbon footprint, energy and water consumption, and waste management (Nicholls, 2009, p. 112).

Production sustainability is the result of the behavior of all partners in the logistics chain. Tools are needed to capture this sustainability, in addition to the adoption of more user-friendly tools to support the systematic process of searching for best practices and innovative ideas considering the TBL perspective (Azevedo; Barros, 2017, p. 288).

TBL Accounting can contribute to identifying opportunities for innovation and efficiency. In the economy, impacts can involve competition practices and fiscal contributions; in the environment, the use of natural resources and energy; and in people, employment practices and working conditions in the supplier chain. These impacts are interrelated, where actions in one area can influence another (GRI, 2024, p. 11).

The addition of social and environmental dimensions to the traditional financial focus of accounting strongly influences the way of measuring sustainability, but still lacks standardized methods to assess these three pillars in a balanced way, which are also represented in the literature by the "3Ps", from the English *people*, *planet* and *profits* (Goh *et al*., 2020, p. 2). This lack of standardization makes comparison between companies and sectors difficult (Hubbard, 2009, p. 177).

Most companies that develop advanced eco-efficient and sustainability-oriented management tools recognize that, to provide robust suggestions for the development and commercialization of future products, they need a multiplicity of resources, in order to ensure quality, but with lower socio-environmental impact (Elkington, 1998, p. 48).

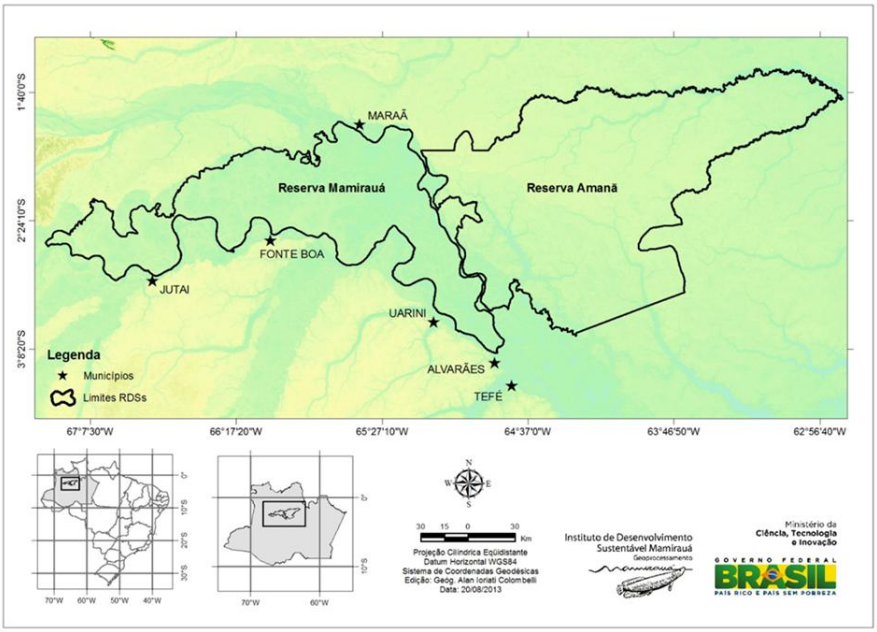
III. Methodology

The study was conducted in the Mamirauá Sustainable Development Reserve (RDSM) and the Amanã Sustainable Development Reserve (RDSA) located in the Middle Solimões region, and their surroundings, as

observed in Figure 2. Both are state reserves, under the management of SEMA-AM and have fishing agreements advised by the Fisheries Management Program (PMP) of the Mamirauá Sustainable Development Institute (IDSM).

Entry into the Mamirauá RDS and Amanã RDS for research was authorized by the State of Amazonas Secretariat of Environment - SEMA-AM, with the consent of IDSM, which provides advisory support for research work in the RDSs.

Figure 2 -- Research area



Source: Mamirauá Sustainable Development Institute (IDSM, 2024).

The choice of the Middle Solimões as the study area is justified by the strategic importance of this region for Pirarucu management and by the need to understand local dynamics in a context of environmental and socioeconomic pressures. By focusing on the Mamirauá and Amanã RDSs, this research not only strengthens the visibility of these reserves but also contributes to the replication of sustainable models in other areas of the Amazon.

This research is configured as a case study of the Pirarucu Fisheries Management Program in the Middle Solimões, with documentary research as its methodological procedure. Secondary data made available by the IDSM Annual Technical Reports, from 2017 to 2024, were analyzed, comprising community management activity in 10 APs in the Mamirauá and Amanã RDSs, and their surroundings. These documents bring together systematized information on fishery production, commercialization, social participation, and environmental monitoring carried out within the scope of the APs.

From this database, 14 variables were selected, grouped according to the three dimensions of TBL Accounting, as observed in Table 1, with the aim of capturing the main results generated by the management.

Table 1 - Variables used to measure management impacts

Nº	Variable	Dimension	Justification
1	Gross Revenue	Economic	This variable allows sizing the financial volume generated by pirarucu fishing activity, evidencing the economic relevance of management for each area and its potential for generating revenue for the involved communities.
2	Operational Cost	Economic	Analyzing operational costs is fundamental for evaluating the financial viability of the activity. This variable allows identifying the proportion of expenses necessary for management execution and subsidizing economic efficiency analyses.
3	Net Revenue	Economic	By subtracting operational costs from gross revenue, this variable reveals the direct economic result of the activity, being essential for verifying the financial sustainability of management in the medium and long term.
4	Average Income per Person	Economic	Average income per manager is a direct indicator of the individual economic impact of the program. This metric is fundamental for analyzing the improvement in living conditions of the benefited fishers.
5	Average Price per Kg	Economic	The average price per kilogram of pirarucu reflects the value added to the product and is related to the organization of the productive chain, access to markets, and the valorization of sustainably managed fish.

6	People Benefited	Social	This variable allows estimating the social reach of management, indicating how many people were impacted directly or indirectly by the activity, and also measuring benefits in terms of inclusion and food security.
7	Female Participation	Social	The presence of women in management is na important indicator of gender equity and social inclusion. By highlighting this variable, it allows reflection on gender dimensions in community practices and access to generated benefits.
8	Participating Communities	Social	This variable expresses the level of adherence to the program, the territorial scope of management, and the capillarity of its operation. It is useful for evaluating the dissemination of the practice and its capacity for community mobilization.
9	Authorized Quota	Environmental	Reflects the volume of fishing legally permitted by the environmental agency. This variable is relevant for understanding the sustainable exploitation limits defined based on population control of the species.
10	Captured Quota	Environmental	Indicates the volume effectively fished within established limits, being an indicator of the degree of efficiency and compliance with sustainability rules of management.
11	Fishing Performance	Environmental	The relationship between what was authorized and what was effectively fished measures the operational performance of management, revealing factors such as mobilization capacity, climatic conditions, and logistical efficiency.
12	Average Fish Size	Environmental	The increase or maintenance of the average fish size over time can be interpreted as a sign of population health of the species and the effectiveness of management in stock conservation.
13	Fish Counted	Environmental	The number of juvenile and adult pirarucu counted is the basis for calculating the authorized quota. This variable represents the main evidence of recovery or decline of fish stocks.
14	Lakes Counted	Environmental	The quantity of lakes where fish counting was performed provides a measure of the environmental control effort and the scope of the surveillance strategy, reflecting the commitment to sustainable management of natural resources.

Source: produced by the author.

The 14 collected variables underwent descriptive statistical analysis in order to summarize and understand the characteristics of the variables. The documentary analysis of the annual technical management reports allows the construction of a time series with indicators grouped according to the three dimensions of TBL Accounting.

IV. Results And Analysis

Pirarucu management in the Middle Solimões region constitutes an essential practice both for the ecological sustainability of aquatic ecosystems and for the economy and social organization of the involved riverine communities. The APs represent examples of this strategy, being the result of the articulation between local traditional knowledge, community organization, and the technical-scientific support of institutions such as IDSM.

Economic Impact Of Management

Management provides a source of income for families who, in some cases, do not have other viable economic alternatives. Despite the demonstrated successes, local income generation from fishing continues to be modest, often complementing family income instead of providing substantial financial support (Saes *et al.*, 2023, p. 14).

The analysis of the economic variables associated with sustainable pirarucu management in the Middle Solimões, between 2017 and 2024, reveals significant fluctuations in the financial and productive indicators of the system, reflecting both the economic potential of the activity and its vulnerabilities in the face of environmental, logistical, and institutional factors within each AP. These fluctuations evidence the importance of comparative analyses over time.

The systematic observation of these indicators provides concrete subsidies to understand the resilience of the management system in the face of contextual changes and to guide adjustments in the management strategies adopted by the communities. Table 2 presents the historical series of the main economic variables associated with participatory pirarucu management in the Middle Solimões, from 2017 to 2024, allowing a longitudinal analysis of the economic performance of the management system.

Table 2 - Economic impact of management in RDSM and RDSA from 2017 to 2024 (in Brazilian local currency)

Variable	2017	2018	2019	2020
Gross Revenue	3.234.108,40	2.202.159,15	3.021.624,37	3.355.781,75
Operational Cost	286.807,00	239.130,75	376.058,70	382.001,50
Net Revenue	2.947.301,40	1.963.028,40	2.645.565,67	2.973.780,25
Average Income per Person	2.034,03	2.327,86	2.428,96	2.519,36
Average Price per Kg of pirarucu	4,26	5,14	5,17	4,95

Variable	2021	2022	2023	2024
Gross Revenue	3.561.781,65	4.892.571,40	4.784.921,46	3.997.674,48
Operational Cost	494.532,82	494.446,72	622.735,37	817.226,54
Net Revenue	3.067.248,83	4.398.124,68	4.162.186,09	3.180.447,94
Average Income per Person	3.398,65	4.160,35	4.704,94	3.973,83
Average Price per Kg of pirarucu	6,45	6,68	6,66	7,77

Source: Annual Fisheries Management Report (2017 to 2024) - PMP/IDSM.

Gross revenue showed strong variation in the period, starting from BRL 3.23 million in 2017 to a peak of R$ 4.89 million in 2022, followed by a slight drop in the subsequent years, years marked by the occurrence of extreme drought in the region. This trajectory shows a general growth trend, despite the setbacks presented in 2018, 2023, and 2024.

Net revenue, which deducts operational costs, followed a similar pattern. The growing trajectory of net revenue points to a progressive improvement in the economic efficiency of the activity, highlighting the years 2021 and 2022, which, despite growth in gross revenue, maintained a very close cost value, leveraging net revenue in 2022.

The operational cost of fishing also increased substantially, jumping from BRL 286 thousand in 2017 to BRL 817 thousand in 2024. The increase accompanies both the growth in production scale and the increase in logistical and input costs, especially in the context of the extreme droughts of 2023 and 2024. However, when compared to the growth in net revenue, it is observed that the overall profitability of the activity remained positive, reinforcing that management has been economically viable.

The variable average income per person is one of the most relevant for measuring the direct impact on management beneficiaries. The value jumped from R$ 2,034.03 in 2017 to R$ 4,704.94 in 2023, retreating only in 2024, to R$ 3,973.83. The accumulated inflation for the period, based on the National Broad Consumer Price Index (IPCA), released by IBGE (2025), was 40.83%. Considering that the extreme values of the series (2017 and 2024) show an evolution of 95.37%, it can be inferred that there is a tendency for income growth in the period, indicating improvement in the economic conditions of the involved families, especially when compared to the initial levels of the series.

The average price per kg of pirarucu obtained an appreciation of 82.4% in the period. This increase is the result of better articulation with buyers and compliance with the established minimum price, which is fundamental for the valorization of the managed product. The price stability between 2021 and 2023 (around R$ 6.66) followed by the expressive growth in 2024 reinforces a dynamic of a heated market and valorization of the community-based and ecological origin of the product.

The analysis of economic variables demonstrates that participatory pirarucu management has promoted positive effects on the economy of the involved communities, especially in direct income generation, revenue growth, and product valorization.

Social Impact Of Management

Participatory pirarucu management has established itself as a strategy not only for environmental conservation and income generation but also for social strengthening of Amazonian communities.

The data analysis reveals important transformations in the composition of beneficiaries, in gender participation, and in the territorial scope of management. Table 3 presents the historical series of the main social variables related to participatory pirarucu management in the Middle Solimões, from 2017 to 2024. The information was obtained from the annual fisheries management reports of the Mamirauá Institute.

Table 3 - Social impact of management in RDSM and RDSA from 2017 to 2024

Variable	2017	2018	2019	2020	2021	2022	2023	2024
People Benefited	1.590	946	1.244	1.332	1.048	1.176	1.017	1.006
Male Participation	-	648	806	858	682	719	606	644
Female Participation	-	298	438	474	366	457	411	362
Female Participation (%)	-	31,50	35,21	35,59	34,92	38,86	40,41	35,98
Participating Communities	43	43	48	36	42	41	34	34

Source: Annual Fisheries Management Report (2017 to 2024) - PMP/IDSM.

The total number of people directly benefited by management showed significant fluctuations in the period. In 2017, the highest number of beneficiaries was recorded (1,590), followed by an abrupt drop in 2018 (946) and a partial recovery in 2019 (1,244). From then on, the numbers remained relatively stable, hovering between 1,000 and 1,300 beneficiaries until 2024. This variation can be interpreted as a reflection of several factors.

The active permanence of participants depends heavily on the perception of fairness in the distribution of benefits, recognition of individual contributions, and rigorous application of the norms provided for in the

APs' Internal Regulations. Disorganization, non-compliance with rules, and the absence of penalties for infractions are pointed out as discouraging factors that negatively affect the engagement of some managers.

Female participation in management shows a growth trend over the analyzed period. Starting in 2018, the annual reports began to include women's participation in the APs. The proportion of women benefited reached 40.41% in 2023, before slightly retreating to 35.98% in 2024. The valorization of women's work, associated with the increasing presence of women in stages of community organization, monitoring, and even in surveillance and fishing, contributes to explaining this advance. Although male participation remains predominant, the data point to greater inclusion of women in the productive chains associated with management.

The number of communities directly involved in the APs varied expressively between years. In 2017 and 2018, the total was 43 communities, a number that rose to 48 in 2019, indicating a moment of territorial expansion. However, from 2020 onwards, a gradual retraction is observed, reaching 34 communities in 2023 and 2024. The reduction in the number of participating communities indicates the need for attention to institutional sustainability and continuous technical support to the APs, in order to guarantee the maintenance of the social benefits generated by management. Despite the numerical reduction, it is important to consider that the permanence of over 30 active communities indicates institutional resilience of management and continuity of its regional scope.

Socially, pirarucu management has promoted the strengthening of community organization, fostering spaces for democratic participation and valuing the protagonism of women and local leaders. Evaluation and coordination meetings, as well as fish counting, surveillance, and evisceration activities, are often carried out in a regime of collaboration and rotation, stimulating cooperation and the feeling of belonging to the collective.

Environmental Impact Of Management

Community-based pirarucu management in the Middle Solimões region has as one of its main premises environmental conservation through the sustainable use of fishery resources. The analysis of environmental variables evidences the effects of this management system on the population dynamics of pirarucu, aquatic ecosystems, and the environmental monitoring efforts carried out by the involved communities.

Table 4 presents the data of environmental variables related to participatory pirarucu management in the Middle Solimões between 2017 and 2024. This data allows for an analysis of the ecological sustainability of management, enabling the assessment of the health of fish stocks, the effectiveness of community conservation practices, and the capacity for environmental regeneration of the managed aquatic ecosystems.

Table 4 - Environmental impact of management in RDSM and RDSA from 2017 to 2024

Variable	2017	2018	2019	2020	2021	2022	2023	2024
Authorized Quota	13.763	6.349	12.239	13.152	9.691	13.500	14.983	13.597
Captured Quota	12.940	6.169	9.637	10.850	9.137	12.816	12.926	9.479
Capture Efficiency (%)	94,00	95,80	78,70	82,50	94,30	94,90	86,30	69,70
Average Fish Size (cm)	178,20	176,10	178,90	180,10	184,20	180,00	178,00	179,00
Juveniles Counted (Bodecos)	104.627	113.355	91.843	92.949	85.069	90.016	90.678	95.230
Adults Counted	66.087	77.168	69.073	68.520	70.487	72.292	64.560	56.916
Lakes Counted	264	280	240	241	237	194	197	191

Source: Annual Fisheries Management Report (2017 to 2024) - PMP/IDSM.

The authorized fishing quotas for pirarucu, which reflect the sustainable estimate of fish removal, varied expressively in the analyzed period. After an initial peak in 2017 (13,763 units), there was a major drop in 2018 (6,349). This was a technical decision by the Mamirauá Institute based on the fragility of stocks identified in the counts of that year compared to previous years, even for groups that had good performance in the evaluation. Although the absolute number of adult fish seemed high, there was a drop in stocks compared to previous years, which led to a precautionary policy in defining quotas, aiming to avoid overfishing and ensure management sustainability.

Another factor that impacted the quota reduction was concern about the sale price of pirarucu. The trend of stagnation or even a drop in the price of pirarucu has a direct relationship with the definition of the quota request because without proper price adjustment, groups may demand increasingly larger quotas to compensate for the low price, causing pressure on stocks.

The recovery of quotas in subsequent years, with emphasis on 2023 (14,983), demonstrates the regeneration potential of pirarucu populations under management, the result of surveillance practices, closed seasons, and respect for community rules. In 2024, there was a new reduction in the quota (13,597), which is associated with the extreme drought event in the region, which hindered the counting work.

The captures performed generally followed the behavior of the authorized quotas, with emphasis on the years of higher capture in 2017 (12,940 units), 2022 (12,816), and 2023 (12,926). In 2024, an accentuated drop in captures is observed (9,479), even in the face of a still high quota. This drop is also associated with the extreme drought faced that year, with direct consequences on the operationality and logistics of fishing.

The capture efficiency, calculated as the ratio between captures performed and authorized quotas, fluctuated between 94% (2017) and 69.7% (2024). The years 2018, 2021, and 2022 recorded the highest efficiencies (above 94%), indicating greater utilization of available quotas. The decreasing trend in efficiency in the last two years requires attention and monitoring, as it can directly impact economic results and the perception of management success.

The average size of captured pirarucus remained relatively stable and high over the years, with values varying between 176.1 cm (2018) and 184.2 cm (2021). The persistence of high average sizes indicates that the fish are reaching maturity before capture, which is a positive indicator of biological sustainability. Community control of fishing, combined with compliance with closed seasons and rules on minimum sizes, is contributing to maintaining the population integrity of the species.

The data on 'bodecos' (juvenile pirarucu) counted, with numbers always higher than those of counted adult pirarucus is an indicator of sustainability. The counted fish and monitored lakes point to the continuous effort to control populations. In 2017, 104,627 'bodecos' and 66,087 pirarucus were recorded in 264 lakes. In the analyzed period, a progressive decrease was observed in the number of lakes counted (from 280 in 2018 to 191 in 2024). Despite this, the maintenance of a regular counting effort demonstrates the engagement of communities in participatory environmental management, being a differential of pirarucu management compared to other forms of fishing exploitation in the Amazon.

The variations in quotas, captures, and counting efforts reflect both the plurality of Amazonian environments and the adaptability of managing communities. The maintenance of high average capture sizes and the results of population regeneration are signs that, despite challenges, management continues to be an effective strategy for sustainable management, integrating traditional knowledge and environmental conservation practices.

From an environmental point of view, pirarucu management has played a fundamental role in the recovery and maintenance of fish stocks, especially in areas that, in the past, faced periods of severe fish scarcity due to predatory fishing and the absence of control. Reports from older managers indicate that, before the implementation of the APs, there was deep degradation of the lakes, with severe impacts on local biodiversity.

The surveillance of lakes and respect for closed seasons and capture quotas have contributed to the regeneration of pirarucu stocks and other associated species, such as tambaqui and tucunaré. However, the environmental effectiveness of management depends directly on collective adherence to practices of preserving aquatic environments. Insecurity during surveillance, caused by the presence of armed invaders and the logistical difficulty of accessing the lakes, has compromised the protection effort and fish counting, decreasing the quality of data used to define quotas and, consequently, weakening the incentives for conservation.

V. Final Considerations

The results of pirarucu fishing management are not expressed only in terms of economic return, but also in social benefits, such as strengthening community organization, generating locally distributed income, and valuing the role of women, in addition to positive environmental impacts, such as conserving natural stocks and recovering degraded aquatic ecosystems.

The choice of TBL Accounting as a theoretical basis for measuring the impact of pirarucu fishing management in the Middle Solimões is particularly appropriate and justified by the very complex and integrated nature of this productive system. Pirarucu management goes beyond the extraction of a natural resource; it involves community management practices, environmental conservation, income generation, strengthening social cohesion, and the transmission of traditional knowledge.

This multiplicity of dimensions finds in TBL Accounting the most coherent approach for comprehensively measuring its impacts. By incorporating the economic, social, and environmental dimensions, TBL Accounting offers a more complete and sensitive model to the Amazonian context, enabling an expanded reading of the results and real impacts of management on the territories and involved communities.

TBL Accounting, although still little applied in community and traditional-based contexts, offers an important conceptual framework for translating these diverse forms of value (economic, social, and environmental) into useful information for evaluation, decision-making, and public policy formulation. Accounting, in this context, acts as a tool for recording, analyzing, and communicating the value generated in multiple dimensions.

In the case of pirarucu management, the economic impacts are measurable by the income obtained by participants from the commercialization of managed fish, which is distributed proportionally to participation in

activities such as counting, surveillance, and fishing. This distribution involves objective criteria that can be systematized by accounting practices of performance control, revenue allocation, and efficiency evaluation.

In the social dimension, accounting can help map the generation of collective and individual value: the number of people benefited, the strengthening of female participation, investments in education, health, and family infrastructure made with income from management. These aspects, which are often not monetarily measurable, can be translated into social impact indicators, which integrate the social balance of a community.

The environmental dimension, in turn, is central in pirarucu management. Respect for quotas, protection of spawning areas, surveillance against predatory fishing, and maintenance of fish stocks represent collective environmental assets, whose monitoring and valuation are part of Socio-Environmental Accounting. The very counting of pirarucus is an activity that generates essential data for measuring the natural stock, which can be understood as a biological asset subject to accounting control and valuation, following the models of Environmental Accounting and standards applicable to natural assets.

The analysis of the impacts of pirarucu fishing management in the Middle Solimões region from the TBL Accounting perspective revealed a heterogeneous and dynamic system, with significant results in the economic, social, and environmental dimensions. The historical series from 2017 to 2024, based on the IDSM annual management reports, allowed for the identification of advances and challenges in each of these dimensions.

The limitations encountered in the present study rest on the methodological choice and the approach through the lens of TBL Accounting. Although TBL Accounting provides a framework for integrating economic, social, and environmental dimensions, it depends on researcher interpretations and encounters challenges in quantifying certain social and environmental impacts.

For future research, it is suggested to replicate this study in other regions of the Amazon or in different contexts of natural resource management. Studies can also deepen the integration between TBL Accounting and more refined metrics of social and environmental impact, capable of reducing dependence on subjective interpretations.

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