Revista de Administração Contemporânea
Journal of Contemporary Administration

ASSOCIAÇÃO NACIONAL DE PÓS-GRADUAÇÃO E PESQUISA EM ADMINISTRAÇÃO

e-ISSN: 1982-7849

Theoretical-empirical Articles

Bioeconomy in Central Amazon: Participatory Management of Pirarucu (*Arapaima gigas*)

Bioeconomia na Amazônia Central: Manejo Participativo de Pirarucu (*Arapaima Gigas*)

Ana Cláudia Torres Gonçalves*[1]
Luciane Cristina Ribeiro dos Santos [2]

ABSTRACT

Objective: to describe and critically analyze the participatory management process of pirarucu, a practice developed and monitored by the Mamirauá Institute for Sustainable Development (IDSM) in the Amazon region, highlighting its impact on local communities, its contribution to the bioeconomy and its alignment with the Sustainable Development Goals (SDGs). **Theoretical approach:** based on the premise of bioeconomy, the article also considers theories related to participatory management of natural resources and biodiversity conservation. **Method:** a qualitative approach was adopted aligned with quantitative results from data analysis of action research with experts from the Mamirauá Institute on participatory management of pirarucu in the Central Amazon. Results: The results show that the approach contributes to the conservation of the species and its habitat, promotes local eco-socioeconomic development, strengthens communities with equity, and is aligned with the bioeconomy, in addition to offering lessons for the SDGs. **Conclusions:** it is concluded that the management of pirarucu carried out by the Mamirauá Institute integrates riverside communities, incorporating traditional knowledge into management and conservation practices. This initiative conserves the species and strengthens the local economy, ensuring stable income.

Keywords: pirarucu supply chain; sustainable development; Central Amazon; bioeconomy; Sustainable Development Goals (SDG).

RESUMO

Objetivo: descrever e analisar criticamente o processo de manejo participativo do pirarucu, prática desenvolvida e monitorada pelo Instituto de Desenvolvimento Sustentável Mamirauá (IDSM) na região da Amazônia, destacando seu impacto nas comunidades locais, sua contribuição para a bioeconomia, e seu alinhamento com os Objetivos de Desenvolvimento Sustentável (ODSs). **Marco teórico**: fundamentado na premissa da bioeconomia o artigo também considera teorias relacionadas à gestão participativa de recursos naturais e conservação da biodiversidade. **Método:** adota-se abordagem qualitativa alinhada a resultados quantitativos oriundos de análise de dados provenientes de pesquisa-ação junto aos especialistas do Instituto Mamirauá sobre o manejo participativo do pirarucu na Amazônia Central. Resultados: os resultados mostram que a abordagem contribui para a conservação da espécie e seu habitat, promove o desenvolvimento ecossocioeconômico local, fortalece comunidades com equidade e alinha-se à bioeconomia, além de oferecer lições para os ODSs. **Conclusões:** conclui-se que o manejo do pirarucu realizado pelo Instituto Mamirauá integra comunidades ribeirinhas, incorporando conhecimentos tradicionais às práticas de gestão e conservação. Essa iniciativa conserva a espécie e fortalece a economia local, assegurando renda estável.

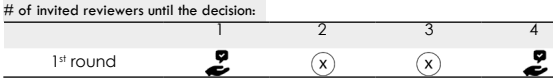
Palavras-chave: cadeia produtiva do pirarucu; desenvolvimento sustentável; Amazônia Central; bioeconomia; Objetivos de Desenvolvimento Sustentável (ODS).

* Corresponding Author.
1. Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, AM, Brazil.
2. Universidade Evangélica de Goiás, Anápolis, GO, Brazil.

Cite as: Gonçalves, A. C. T., & Santos, L. C. R. (2024). Bioeconomy in central Amazon: Participatory management of pirarucu (Arapaima gigas). *Revista de Administração Contemporânea*, 28(6), e240195. https://doi.org/10.1590/1982-7849rac2024240195.en

JEL Code: O13, Q57

Received: July 16, 2024
Last version received: November 2, 2024
Accepted: November 19, 2024
Published: January 08. 2025



INTRODUCTION

The Central Amazon region faces complex challenges, such as unsustainable exploitation of natural resources, deforestation, and socioeconomic pressures on local communities. Finding solutions that balance environmental conservation, economic development, and community well-being is of significant importance to mitigate these problems. In this scenario, discussions on the bioeconomy emerge as a promising approach, aiming to use the sociobiological and cultural diversity of the Amazon to create innovative business arrangements that reconcile environmental conservation and technological development (Costa et al., 2021; Nobre & Nobre, 2019).

The bioeconomy, initially introduced into the scientific debate by mathematician and economist Nicholas Georgescu-Roegen (1906-1994) (Georgescu-Roegen, 1975), is now supported by advances in science, technology, and innovation (Bioökonomierat, 2018; Lopes & Chiavari, 2022). This involves the production, use, and conservation of biological and natural resources, incorporating new technologies, such as industrial enzymes, new plant varieties, biofuels, and cosmetics, to promote a sustainable economy, as reported by the Center for Strategic Studies and Management Centro de Gestão e Estudos Estratégicos (CGEE, 2020). The central premise of the bioeconomy is the sustainable use of resources, valuing biodiversity, and developing environmentally sustainable production chains (CGEE, 2020; Global Bioeconomy Summit [GBS], 2015; Santos et al., 2023). This study seeks to fill the gap in the literature by integrating the participatory management of pirarucu with the principles of bioeconomy and adaptive governance. The research problem that this article proposes to answer is: How can participatory management of pirarucu, developed by the Mamirauá Institute for Sustainable Development (IDSM), contribute to the conservation of the species, the sustainable development of local communities and the achievement of the Sustainable Development Goals (SDGs) in the Amazon?

The objective of this study is to describe and critically analyze the participatory management process of pirarucu, a practice developed and monitored by the Mamirauá Institute for Sustainable Development (IDSM) in the Amazon region, highlighting its impact on local communities, its contribution to the bioeconomy, and its alignment with the Sustainable Development Goals (SDGs). In addition to documenting the management experience, this work seeks to advance knowledge by exploring how adaptive management practices can simultaneously generate economic, social, and environmental results.

Created in 1999, the Mamirauá Institute is a Ministry of Science, Technology, and Innovation research unit. Its central objective is to develop and consolidate models for small riverside communities' economic and social development through socially and environmentally appropriate technologies (Mamirauá Institute, 2021). The Mamirauá Institute's activities are aligned with the premise of bioeconomy (Instituto de Desenvolvimento Sustentável Mamirauá, 2021). The Mamirauá Institute's activities are aligned with the premise of bioeconomy (Costa et al., 2021; Nobre & Nobre, 2019), incorporating socio-environmental elements that meet the United Nations' 2030 Agenda, aiming to achieve the Sustainable Development Goals (SDGs).

In this way, the Mamirauá Institute is configured as an experience in eco-socioeconomics. This eco-socioeconomic approach seeks to positively impact the territory as a whole, benefiting those directly involved in management and promoting environmental conservation and social justice (Sampaio & Alves, 2019; Santos et al., 2020). Furthermore, the dynamics that trigger actions and their impacts on territories are as important as the results themselves (Sampaio & Alves, 2019; Sampaio & Santos, 2021; Santos, 2020; Santos et al., 2020; Vieira & Sampaio, 2022).

Participatory management of pirarucu exemplifies the bioeconomy in practice by including traditional communities and urban fishermen in the sustainable management of this species. This contributes to the recovery of stocks, the generation of jobs and income, and the promotion of social and gender equity.

The main advance of this study is the introduction of participatory management of pirarucu as a replicable bioeconomy model that integrates environmental conservation, income generation, and community participation within an adaptive governance system. Unlike conventional conservation approaches that focus exclusively on species preservation, pirarucu management incorporates adaptive governance and regenerative economics concepts, demonstrating how conservation practices can simultaneously ensure food security and promote sustainable economic development.

Compared to the existing literature on participatory management of natural resources (Folke et al., 2005; Ostrom, 1990), this study advances by demonstrating how community-based management can be an effective means not only for ecological sustainability but also for mitigating climate change and promoting social equity. The unique feature of this article is the integration of bioeconomy principles and adaptive management practices, going beyond the simple preservation of species to promote the sustainable use of natural resources, generating social inclusion and income for riverside communities.

Previous studies on pirarucu have focused primarily on the species' population recovery Castello, Stewart et al., 2011; Viana et al., 2007). This article, however, broadens the debate by including a more comprehensive socioeconomic and ecological analysis, which examines how participatory

management positively affects gender equity, local governance, and the SDGs. This multidimensional approach, which connects natural resource management to the bioeconomy and social justice, still needs to be explored in the literature and constitutes the main innovation of this study.

METHODOLOGY

The research methodological approach involves a combination of action research and case study. This methodological approach is particularly suitable for understanding socioecological systems' complex and multifaceted dynamics, such as those found in the Mamirauá Sustainable Development Reserve, monitored by the Mamirauá Institute for Sustainable Development (IDSM).

The following table systematizes the main categories highlighted in this article, divided into analytical and operational categories based on the principal works and authors relevant to each theme.

Table 1. Main categories highlighted in the article.

Analytical categories	Operative categories	Authors and works
Bioeconomy	Concepts, principles, definitions	Birch et al. (2010), Georgescu-Roegen (1971), Stahel (2016)
Regenerative economy	Concepts, principles, definitions	Fullerton (2015), Raworth (2017), Webster (2017)
Sustainability	Concepts, principles, definitions	Brundtland (1987), Elkington (1997), Sachs (2015)
Ecological sustainability	Concepts, principles, definitions	Amaral (2009), Viana et al. (2007)
Governance	Concepts, principles, definitions	Kooiman (2003), Rhodes (1996), Stoker (1998)
Participatory governance	Concepts, principles, definitions	Arnstein (1969), Cornwall (2008), Fung (2006)
Participatory management (natural resources and biodiversity)	Concepts, principles, definitions	Berkes et al. (2000), Folke et al. (2005), Ostrom (1990)
Sustainable Development Goals (SDGs)	Concepts, principles, definitions	Le Blanc (2015), Sachs (2012), United Nations (2015)

Note. Table 1 highlights the main analytical and operational categories highlighted in this article.

Each analytical and operational category was selected based on its relevance to participatory pirarucu management and its relationship to the bioeconomy. The categories bioeconomy, regenerative economy, and sustainability, for example, were chosen to support the theoretical analysis, given that they provide a framework for understanding how natural resources can be used sustainably to promote economic and social development. The category participatory governance was included to highlight the role of riverine communities in resource management, connecting the theory of adaptive governance with the practice of participatory natural resource management.

In addition, the rationale for choosing the analytical categories is related to the need to understand pirarucu management from ecological, social, and economic perspectives. For example, ecological sustainability helps assess how management practices affect ecosystems, while participatory management refers to the direct involvement of local communities in the decision-making process, ensuring conservation and responsible use of resources. All operational categories were selected based on their practical applicability, providing a guide for implementing participatory management efficiently.

This research adopts a qualitative approach based on action research and case studies, combined with quantitative techniques for monitoring ecological and socioeconomic indicators. The process was designed to capture the perceptions of local communities involved in pirarucu management and the ecological and economic implications of this practice. Action research is a participatory methodology that involves researchers and study participants working together to understand a problem and develop practical solutions. In the context of this study, action research was implemented through ongoing collaboration between researchers from the Mamirauá Institute and local communities involved in pirarucu management. This approach allows for incorporating traditional and scientific knowledge, promoting the more effective and sustainable management of natural resources.

The case of pirarucu was selected due to its ecological, economic, and cultural relevance in the Amazon. The management of pirarucu in the Mamirauá Sustainable Development Reserve serves as a practical example of bioeconomy and participatory governance. The Mamirauá Institute has been important and challenging in implementing and monitoring management practices since 1999. Thus, this study covers a 24-year analysis period from 1999 to 2023, allowing a comprehensive understanding of changes and impacts over time. Semi-structured interviews and focus groups were chosen as the core qualitative methods due to their ability to explore the experiences and perceptions of stakeholders in depth.

The interviews were conducted between March and June 2022 with 15 experts from the Mamirauá Institute for Sustainable Development and local fishermen. The interviewees were selected for their active participation in pirarucu management. Ethical aspects were carefully observed, following research ethics guidelines, including informed consent from participants.

The methodological choices were based on the theory of participatory governance (Arnstein, 1969; Fung, 2006), which emphasizes the importance of direct citizen participation in the management of shared resources. Furthermore, the theory of socioecological resilience (Folke et al., 2005) also supported the choice of methods since pirarucu management involves continuous interaction between communities and the local ecosystem.

Quantitative monitoring techniques, such as counting pirarucu stocks and recording sustainability indicators, are justified by the need to provide concrete data on the effectiveness of participatory management. The theoretical basis that supports this choice is anchored in the premise of bioeconomics (Birch et al., 2010; Georgescu-Roegen, 1971), which requires the integration of sustainable practices with the measurement of ecological and socioeconomic impacts. The theoretical approach will be presented below, focusing on the analytical and operational categories highlighted in this section. Next, the practical implications will be discussed based on the description of the participatory management process of pirarucu, a practice developed and monitored by the Mamirauá Institute for Sustainable Development (IDSM) in the Amazon region.

BIOECONOMY AND PARTICIPATORY GOVERNANCE: A THEORETICAL APPROACH

This study's theoretical approach is based on bioeconomy and participatory governance. Bioeconomy, according to Georgescu-Roegen (1971), seeks the sustainable use of natural resources, while participatory governance, according to Arnstein (1969) e Fung (2006), promotes the direct engagement of local communities in the management of natural resources.

Bioeconomy represents an intersection between biology and economics, aiming at the sustainable use of biological resources. Georgescu-Roegen (1971) was a pioneer in approaching economics from the perspective of entropy, emphasizing the need for a revaluation of natural resources within the economy. According to Birch et al. (2010), the bioeconomy is undergoing a process of neo liberalization. This means that the principles of neoliberalism are being applied to this sector, integrating scientific knowledge and biological resources with the aim of promoting economic sustainability. However, it is crucial to criticize this neoliberal approach to prevent the bioeconomy from becoming trapped in the dictates of the market economy and purely economic rationality. By treating nature merely as a resource to be exploited economically, we run the risk of neglecting fundamental social, ethical, and environmental aspects. The neoliberal vision can lead to the excessive commodification of natural resources, prioritizing profit and economic efficiency to the detriment of environmental preservation and social well-being. Therefore, it is necessary to adopt a more holistic approach that values ecological sustainability and respect for natural limits, in addition to promoting broader social justice.

Stahel (2016) contributes to the discussion by introducing the circular economy, emphasizing the recycling and reuse of biological resources as fundamental principles of the modern bioeconomy. In parallel, the regenerative economy emerges as an evolution of the bioeconomy, focusing not only on sustainability, but also on the regeneration of ecosystems.

Raworth (2017) presents Doughnut economics, which proposes planetary and social limits to ensure sustainable economic development. Fullerton (2015) explores the principles and limits of regenerative capitalism, highlighting how universal patterns can shape a new economy that promotes ecological health. Webster (2017) complements this vision with the idea of circular flows, where waste is minimized and product life cycles are extended. Participatory (or adaptive) management of natural resources and biodiversity conservation are essential for sustainability.

Participatory (or adaptive) management of natural resources and biodiversity conservation are essential for sustainability. Folke et al. (2005) discuss adaptive governance, which involves the capacity of social and ecological systems to respond to change and uncertainty. Berkes et al. (2000) address the resilience of socioecological systems, emphasizing the importance of participatory management in biodiversity conservation. Ostrom (1990) points to the need to establish organized collectives so that they can govern common goods effectively and sustainably.

Sustainability, as a central concept, was popularized by the Brundtland (1987), which defines sustainable development as that which meets the needs of the present without compromising the ability of future generations to meet their own needs. Elkington (1997) introduced the concept of the triple bottom line, which integrates the economic, social, and environmental dimensions of sustainability. Sachs (2015) expands this discussion by addressing sustainable development in a global context, highlighting the interconnection between economic, social, and environmental objectives, which provides the basis for thinking about eco-economies.

In the context of governance, Rhodes (1996) defines new governance as a process of governing without government, where multiple actors collaborate in complex networks. Kooiman (2003) explores the idea of governing as

governance, emphasizing the need for new approaches to deal with the complexity and dynamics of social systems. Stoker (1998) proposes five propositions for governance theory, highlighting the importance of participation and shared responsibility.

Participatory governance focuses on including citizens in decision-making processes. Arnstein (1969) apresents the 'ladder of participation,' which illustrates different levels of citizen engagement, from manipulation to citizen control. Fung (2006) discusses the diversity of forms of participation in complex governmental contexts, while Cornwall (2008) analyzes the models, meanings, and practices of participation, highlighting the importance of local and cultural contexts.

The Sustainable Development Goals (SDGs), established by the UN in 2015, constitute a global agenda to promote peace and prosperity. Sachs (2012) outlines the transition from the Millennium Development Goals (MDGs) to the SDGs, highlighting the need for integration to achieve sustainability. Le Blanc (2015) argues that the SDGs should be seen as interconnected goals, promoting a holistic approach to sustainable development.

Based on these theoretical concepts, the next section of this paper will address the practical application of these highlighted themes in the participatory governance of pirarucu. The challenges and opportunities in implementing a sustainable and regenerative bioeconomy will be discussed, highlighting the importance of participatory management and inclusive governance for conserving this species and Amazonian ecosystems.

BIOECONOMY AND PREMISES OF PARTICIPATORY MANAGEMENT OF PIRARUCU (ARAPAIMA GIGAS): A NECESSARY GOVERNANCE

This section aims to bring the concept of participatory governance and participatory management closer to a practical experience based on the case of participatory management of pirarucu (*Arapaima gigas*). Therefore, the background is the bioeconomy, supported by science, technology, and innovation, which seeks to use biological and natural resources to establish sustainable production chains (Bioökonomierat, 2018; GBS, 2015; Lopes & Chiavari, 2022). Sustainable production chains are established when community socio-productive arrangements are included, as in the case of the Mamirauá Institute for Sustainable Development (IDSM), giving prominence to riverside fishermen, in line with what Ostrom (1990) which highlights the need to establish organized collectives so that they can govern common goods effectively and sustainably. This is an effort to include ways of life, knowledge, and wisdom, typically of indigenous peoples and traditional populations, which function on an artisanal time scale under the logic of short, eminently territorial chains, in long chains, typically on an industrial scale (Sampaio & Alves, 2019; Santos, 2020; Santos et al., 2020; Santos et al., 2023).

In this context, participatory management of pirarucu represents a concrete example of the application of the bioeconomic premise, which demands participatory governance, as conceptualized in the previous section by Arnstein (1969), Fung (2006) and Cornwall (2008), as well as participatory management (natural resources and biodiversity) highlighted by the authors Folke et al. (2005), Berkes et al. (2000) e Ostrom (1990). This approach involves a wide range of actors along the sustainable production chain, from suppliers of inputs, such as ice, fuel, and food, to end consumers. This model promotes environmental sustainability and contributes to local economic development and social equity along the pirarucu value chain.

The pirarucu (*Arapaima gigas*) is a freshwater fish that can reach up to three meters long and weigh around 200 kilograms (Queiroz, 2000). It has significant economic importance for the rural populations of Amazonas (Viana et al., 2007) It plays an important role in the region's ecology as a species at the top of the food chain (Castello, 2004). Pirarucu fishing involves a combination of traditional technologies, such as the harpoon, and modern ones, such as gillnets (Queiroz & Sardinha, 1999). Due to intense commercial exploitation, fishing of the species was banned entirely in 1996 (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis [IBAMA], 1996).

Before the ban, pirarucu fishing occurred yearly but intensified during the dry season. Sales were generally made in small quantities at the ports of each location, directed to the bosses and *regatões*, traditional intermediaries who provided goods on credit in exchange for the production (Lima-Ayres, 1992). Due to these characteristics, the sale prices of the production were generally lower than those practiced in the market.

Community management of the species was a management measure aimed at conserving stocks and resuming commercial exploitation of pirarucu. To provide technical support for this management process, scientific research was conducted on the biology of the species and its fishing practices (Araripe et al., 2013; Arantes et al., 2010; Arantes et al., 2013; Castello, 2008a; Castello, 2008b; Castello, Stewart et al., 2011; Coutinho et al., 2010; Lopes & Queiroz, 2009; Queiroz, 2000; Queiroz & Sardinha, 1999). In addition, research was conducted on social and economic aspects (Amaral, 2007; Lima & Peralta, 2017; Peralta, 2010).

The traditional knowledge of local populations about pirarucu was identified, validated, and used (Arantes et al., 2007; Andrade et al., 2011; Castello, 2004). The proposal for a formal management system was approved and implemented

and has been monitored since 1999 in the Mamirauá Reserve (Castello et al., 2009; Figueiredo, 2013; Viana et al., 2007). Studies conducted to guide the development of the management plan for the Mamirauá Sustainable Development Reserve (RDS) identified that pirarucu accounted for 40% of all fishing production and 15% of the residents' income (Queiroz & Sardinha, 1999).

Even with the ban, some fishermen did not stop fishing pirarucu due to the lack of effective monitoring by the competent agencies. Given the status of the sustainable use conservation unit and the economic importance of pirarucu for local riverside families, efforts have been made to regulate the activity (Viana et al., 2007).

Thus, the first managed pirarucu fishing took place in 1999 and has been developed and improved over time, with a focus on adaptive management, guided by (1) principles of ecological sustainability; (2) principles of justice and equity in the distribution of obligations, benefits, and penalties; (3) economic return for fishermen; and (4) mitigation of the impacts of restrictive measures on the use of natural resources in the reserves (Amaral, 2009; Viana et al., 2007).

Adaptive management is understood as the condition of being able to adjust or improve technical guidelines and procedures, aiming at best practices for the conservation, use, monitoring, and control of species, as well as governance and management, based on the results obtained by biological, social, and economic research.

Although there are significant studies on pirarucu conservation (Castello, McGrath et al., 2011; Castello, Stewart et al., 2011; Viana et al., 2007), the literature lacks a detailed analysis that integrates the participatory management of this species with the premise of the bioeconomy and its relationship with the Sustainable Development Goals (SDGs). One of the gaps identified is the lack of studies that explicitly link community management of pirarucu to the generation of sustainable income for local communities and the preservation of Amazonian ecosystems while also providing a replicable bioeconomy model in other regions. Another underexplored aspect is the direct impact of this participatory management on gender equity and the reduction of socioeconomic inequalities in riverside communities.

Therefore, this article seeks to fill these gaps by exploring how pirarucu management contributes to biodiversity conservation and sustainable economic development, proposing an innovative approach combining participatory governance and bioeconomy. Furthermore, by aligning this practice with the SDGs, the study provides new insights into how natural resource management can mitigate climate change and promote social justice.

Governance of participatory pirarucu management: Fishermen, technicians, and environmental authorities

The governance system of pirarucu management projects is based on local management committees and the involvement of institutions capable of establishing and enforcing standards, monitoring them, and distributing the benefits generated equitably, ensuring the continuity of the actions. Figure 1 highlights the participants and their commitments.

Fisherman

Fishermen are responsible for carrying out practical activities, which include protecting the area, characterizing fishing environments and their zoning, conducting an annual stock survey, catching fish, pre-processing and marketing them, local monitoring of activities, and equitable sharing of benefits

Technician

The technicians are responsible for guiding the fishing groups and supervising their actions, ensuring compliance with the guidelines and procedures established in the management plan. This includes compliance with resource use rules and monitoring environmental, social, economic, and sustainability indicators. These indicators include the density and population structure of the species, the size of the fish and their reproductive status, the increasing inclusion of users, decentralized management, the actions of leaders, the equitable distribution of benefits, the group's revenue, family income, and the viability of the activities.

Environmental authority

Environmental authorities at the state and federal levels are responsible for licensing, monitoring, and evaluating activities. Research institutions maintain investigation programs aimed at assessing the sustainability of activities and their ecological, socioeconomic, and sociopolitical impacts. Technicians also adjust their guidelines based on the research results, following an adaptive approach (Gonçalves, 2013).

Figure 1. Participants in the governance of pirarucu management and their commitments.
Source: The authors. The participants in the participatory management of pirarucu are fishermen, technicians, and environmental authorities

Fishermen carry out a series of activities to manage pirarucu. At different times throughout the year, they are called upon by the boards of directors of organizations to discuss fundamental issues related to management. This includes monitoring and evaluating activities (surveillance, training, counting, etc.), reviewing agreed rules, protecting the management area, planning fishing, dividing catch and sale quotas, and conducting a general assessment of annual activities. These forums are also suitable for developing and reviewing resource use rules, management area zoning agreements, and internal regulations (Amaral et al., 2011).

The governance system of pirarucu management projects is based on the concepts and principles of participatory governance, with a focus on including citizens in decision-making processes in local and cultural contexts, as highlighted above all by Arnstein (1969), Fung (2006) and Cornwall (2008).

Participatory management of pirarucu in the Middle Solimões

As highlighted by Gonçalves (2013), the pirarucu management project, which has been in effect since 1999, proposes extraction at sustainable levels. This includes adapting the mesh size of the nets used, establishing a percentage of removal of the species with due control and monitoring, and identifying the fish captured.

According to this line of reasoning, the themes of participatory (or adaptive) management of natural resources and biodiversity conservation are configured as analytical categories addressed in the theoretical basis. Effective and sustainable participatory management is necessary for the resilience of socioecological systems, as highlighted by Folke et al. (2005), Berkes et al. (2000) e Ostrom (1990).

Participatory management, or as we will now discuss it, participatory management of pirarucu (sustainable management), is a process that involves numerous activities carried out by technicians and fishermen involved in the projects. The activities carried out by the fishermen include:

(1) Mobilization and promotion of meetings;

(2) Zoning of the area;

(3) Surveillance patrols;

(4) Counting pirarucu;

(5) Defining rules of use;

(6) Making and repairing equipment;

(7) Fishing;

(8) Transporting and cleaning fish;

(9) Monitoring production;

(10) Marketing;

(11) Sharing profits from fishing and reporting.

The technical team at the Mamirauá Institute works on the following activities: (1)Supporting the social organization of groups, proposing actions, and developing mechanisms to strengthen self-management; (2) Guiding the legislation inherent to the activity; (3) Proposing adjustments to management procedures based on research results; (4) Promoting and coordinating training courses requested by fishing groups or deemed necessary to improve the performance of the activities; (5) Assisting in the development of usage standards; (6) Recording and systematizing information resulting from the activities of fishermen, preparing reports that are forwarded to the fishing licensing agency for monitoring and evaluation, which is a prerequisite for the continuity of the project of each group assisted.

Any sustainable management initiative for fishing resources that aims to capture pirarucu must advance in the development of a management plan to be submitted for assessment by the fishing licensing agency, which in the state of Amazonas is the Brazilian Institute of the Environment and Renewable Natural Resources (Ibama). This technical document describes in detail the socio-environmental context of the activity's implementation, thus making it possible to demonstrate alignment with the premise of the bioeconomy.

The management plan for fisheries resources in a given area must be based on the general objectives of a conservation unit (UC), establish zoning based on the definition of use and non-use zones, and develop a set of rules that should guide the use of the area and the management of the various fish species.

The objectives outlined in the pirarucu management plan include the following:

(1) Recovery of fish stocks in the system's aquatic environments, using fishing techniques that allow the capture of species with the minimum size permitted by law, ensuring the maintenance of population densities and structures; (2) guarantee of food security and generation of income for the communities directly involved in the management actions.

The goals are aimed at:

(1) Promoting the sustainable annual extraction of a maximum of 30% of adult pirarucu individuals

(≥ 150 cm); (2) maintain efforts to provide technical advice, follow-up, monitoring, and auditing of the management system to ensure that 70% of the pirarucus captured annually have a total length equal to or greater than 165 centimeters (Lopes & Queiroz, 2009). This size is appropriate from a biological point of view, ensuring the ecological sustainability of management through the biological regeneration of stocks.

Process for implementing participatory management of pirarucu: Participatory management

The management of pirarucu involves a set of procedures configured in practices experienced throughout the year. These practices, as named by Amaral et al. (2013), consist of seven main actions for implementing management, as shown in Figure 2.

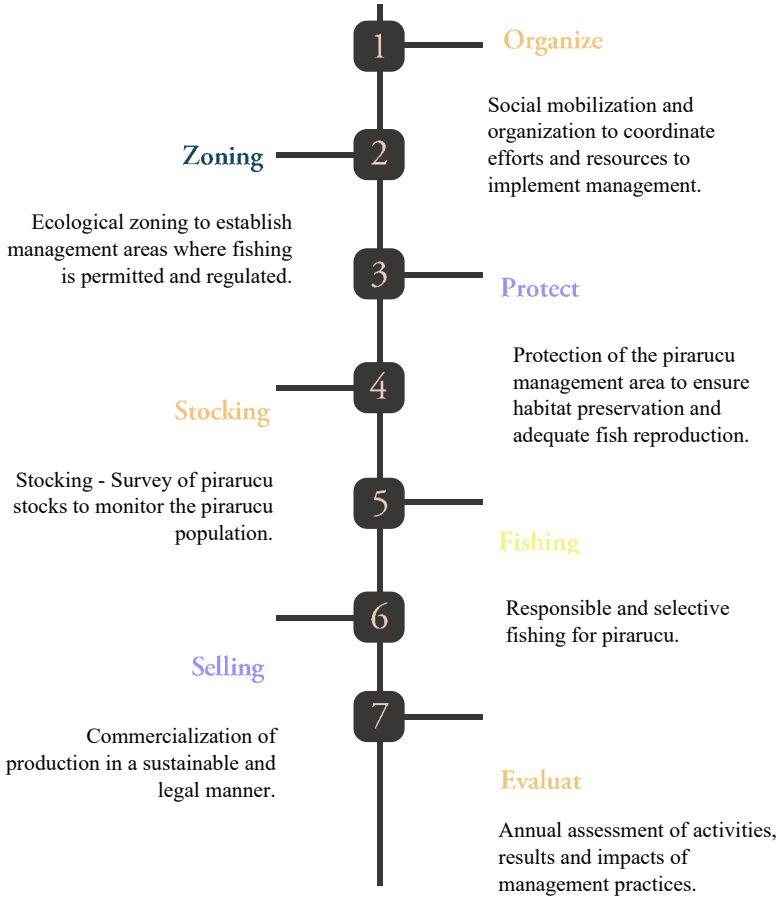


Figura 2. Seven main actions for the implementation of Pirarucu Management.

Source: Basead on Amaral, E., Torres, A. C., & Peralta, N. (2013). A avaliação participativa como ferramenta para tomadas de decisão em processos de manejo de pirarucu (Arapaima gigas). In E. S. A. Figueiredo (Ed.), Biologia, conservação e manejo participativo de pirarucus na Pan-Amazônia (pp. 213-236). Instituto Mamirauá. https://www.researchgate.net/publication/346609186_Avaliacao_Participativa_como_Ferramenta_de_Gestao_Compartilhada_no_Manejo_de_Recursos_Pesqueiros

Each practice presented in Figure 2 is detailed below:

(1) Organizing

The first practice requires greater availability from fishing groups and involves periodic assemblies or meetings. These moments are essential for evaluating the established rules and agreements and for planning activities. Management group assemblies are crucial for decision-making, including the preparation and review of internal regulations.

(2) Zoning

Zoning is an activity carried out during management group assemblies and in smaller meetings by communities. It is based on two important assumptions: guaranteeing access to and control of the resource and enabling the productive and sustainable use of the natural resource. This is crucial since pirarucu fishing is prohibited year-round in Amazonas, permitted only in conservation units (UCs) for sustainable use, indigenous lands, and areas of fishing agreements with management plans approved by Ibama/AM. Zoning involves defining the boundaries of the area and the use and non-use zones, as well as georeferencing the environments and classifying them as maintenance, commercialization, and breeding.

(3) Protect

The area is protected by daily surveillance patrols carried out in a joint effort. The management groups establish a surveillance schedule and distribute the participants into teams. Women's participation is optional due to the activity's unhealthy and risky nature. Effective protection of the area requires in-depth knowledge of the region, careful observation, and team strategies.

(4) Count

Counting the pirarucu, called the population census of the species, involves fishermen counting juveniles and adults of the species in each environment of the area. This is done using visual and auditory counts at 20-minute intervals.

(5) Fishing

Fishing takes place during the dry season, generally between September and November, and may be brought forward according to the river's low water level. Pirarucu fishing involves the use of gillnets and harpoons. The gillnet is the main equipment and is used in both purse seine fishing and lead-and-wait fishing. Fishing is a specialized activity that requires specific skills.

(6) Selling

The commercialization of the production of managed pirarucu occurs in several stages. Before management, pirarucu fishing took place throughout the year, with small quantities sold at the port of each location, mainly to traditional intermediaries. In the context of management, the commercialization process involves more elaborate stages, such as offering the product in a business round promoted by the technical advisory team, preparing a purchase and sale contract for the production, monitoring the production, issuing the fish transit guide, etc.

(7) Evaluating

The annual evaluation is conducted at the end of the one-year cycle and includes the sale of the production, the distribution of the income among those involved, and the accounting of the resources. This evaluation occurs in two stages, first restricted to the management group and then with the participation of the technical team from the Mamirauá Institute. This assessment is essential to identify the strengths and weaknesses in the conduct of activities and to define improvement strategies. Furthermore, it supports the request for a new fishing quota to Ibama/AM.

The pirarucu management process advised by the Mamirauá Institute involves, in general , the efficiency of collective organization, respect for established standards, the ability to deal with unforeseen events, the frequency of surveillance rounds, and the reliability of counting data, performance in production and marketing processes, the distribution of fishing income and the commitment of beneficiaries to the execution of activities.

RESULTADOS DO PROCESSO DE MANEJO PARTICIPATIVO DE PIRARUCU

The participatory pirarucu management process results are remarkable, with significant impacts on the social, ecological, and economic spheres, which align with the bioeconomy's premises. Throughout the article, natural resources are reassessed every year using techniques such as pirarucu counting for decision-making, which is in line with the premise of Georgescu-Roegen (1971). Likewise,

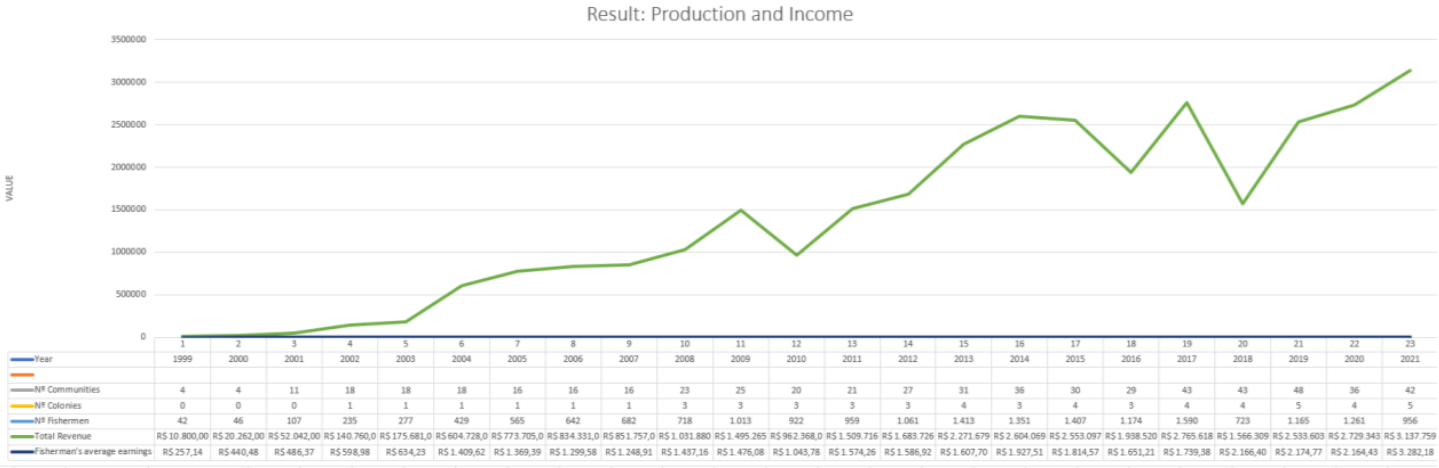
scientific knowledge is being integrated with biological resources to promote economic sustainability (Birch et al., 2010). In order to give robustness to these results, the main ones are highlighted:

Beneficiaries and scope: Os projetos de manejo, de forma geral, beneficiam diversas populações tradicionais e pescadores urbanos em mais de 22 municípios do estado do Amazonas. Estima-se que entre 2019 e 2021 mais de 4.500 pessoas tenham sido diretamente beneficiadas, gerando renda a partir do manejo de pirarucu (Relatório Seminário Projeto Parceria para conservação da biodiversidade da Amazônia, 2018, p. 8).

In 2017, it was identified that pirarucu management covered seven federal conservation units (UCs), sevens state UCs, five indigenous lands, and four areas of fishing agreements. Of these, 23 areas were surveyed, representing 78% of the total and 12,501,043 hectares of forest in protected areas (Relatório Seminário Projeto Parceria para conservação da biodiversidade da Amazônia, 2018, p. 8).

Social organizations involved: A wide variety of organizations are involved in pirarucu management, including community associations, sectoral associations, formal fishermen's organizations (associations, colonies, and fishing unions), and cooperatives. Currently, it is estimated that more than 250 organizations work with pirarucu management in the state of Amazonas.

Production, income, and markets: Pirarucu management occurs in more than 1,200 aquatic environments in the Amazon. In 2016, the stock of adult and juvenile pirarucus was 417,982, representing a 60% increase between 2012 and 2016, an average annual growth of 12%. Fishing in Amazonas in 2016 involved 33,204 pirarucus, generating a gross income of R$ 7 million for the communities (Relatório Seminário Projeto Parceria para conservação da biodiversidade da Amazônia, 2018, p. 8). Figure 3 highlights the main results of participatory management in the areas assessed.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Nº Communities	4	4	11	18	18	18	16	16	16	23	25	20	21	27	31	36	30	29	43	43	48	36	42
Nº Colonies	0	0	0	1	1	1	1	1	1	3	3	3	3	3	4	3	4	3	4	4	5	4	5
Nº Fishermen	42	46	107	235	277	429	565	642	682	718	1.013	922	959	1.061	1.413	1.351	1.407	1.174	1.590	723	1.165	1.261	956
Total Revenue	R$ 10.800,00	R$ 20.262,00	R$ 52.042,00	R$ 140.760,0	R$ 175.681,0	R$ 604.728,0	R$ 773.705,0	R$ 834.331,0	R$ 851.757,0	R$ 1.031.880	R$ 1.495.265	R$ 962.368,0	R$ 1.509.716	R$ 1.683.726	R$ 2.271.679	R$ 2.604.069	R$ 2.553.097	R$ 1.938.520	R$ 2.765.618	R$ 1.566.309	R$ 2.533.603	R$ 2.729.343	R$ 3.137.759
Fisherman's average earnings	R$ 257,14	R$ 440,48	R$ 486,37	R$ 598,98	R$ 634,23	R$ 1.409,62	R$ 1.369,39	R$ 1.299,58	R$ 1.248,91	R$ 1.437,16	R$ 1.476,08	R$ 1.043,78	R$ 1.574,26	R$ 1.586,92	R$ 1.607,70	R$ 1.927,51	R$ 1.814,57	R$ 1.651,21	R$ 1.739,38	R$ 2.166,40	R$ 2.174,77	R$ 2.164,43	R$ 3.282,18

Figure 3. Results of management in areas supported by the Mamirauá Institute.

Source: Instituto de Desenvolvimento Sustentável Mamirauá. (2021). *Relatório Anual de Atividades*. Instituto de Desenvolvimento Sustentável Mamirauá. As shown in the graph in Figure 3, in 2021, the Mamirauá Institute advised 42 communities in 12 management areas. The data in Table 1 indicate the number of communities and fishing organizations served, the number of people benefited per year, gross revenue, and average earnings per fisherman. Over 22 years of activity (1999-2021), more than 6,750 tons of pirarucu were produced, generating gross revenue of more than R$ 32 million. From 2003 to 2004, it is noteworthy that the average earnings per fisherman more than doubled in value, increasing from R$ 634.23 to R$ 1,409.62. This is because, in 2003, the four management groups did not receive the full value of the production delivered by the buyer.

The recovery of pirarucu stocks was visible in the first years of management implementation. Data from 2017 show a population growth of 427% in the areas assessed by the Mamirauá Institute. Figure 4 shows the indicators of managed pirarucu production.

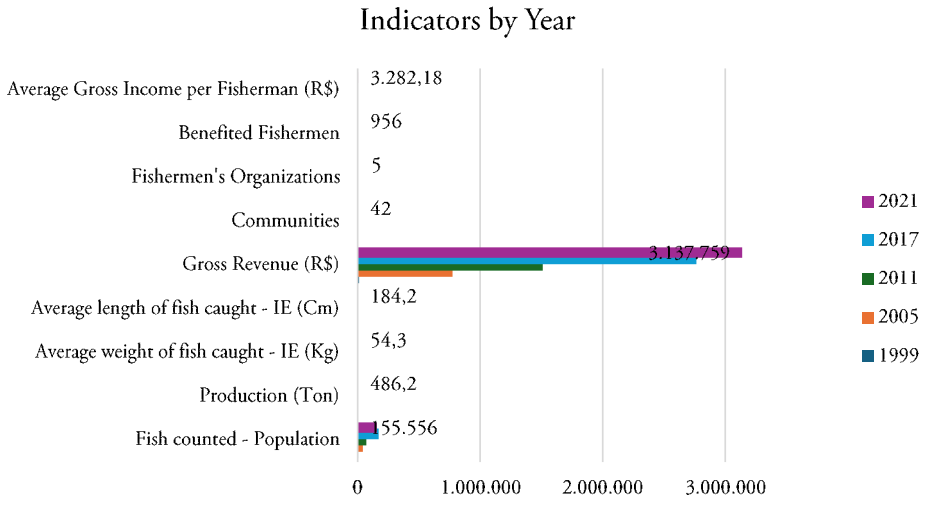


Figure 4. Indicators of managed production in areas supported by the Mamirauá Institute.

Source: Instituto de Desenvolvimento Sustentável Mamirauá. (2021). *Relatório Anual de Atividades*. Instituto de Desenvolvimento Sustentável Mamirauá. OIt can be seen that over the years, despite the growth in production and the fact that fishing occurs every year, the average length of fish has been increasing, from 170 centimeters in 1999 to 184.2 centimeters in 2021, which corroborates the statement that fishing, as it has been occurring, respecting basic management premises such as minimum size, reproductive period, and established quotas, is sustainable.

Evidence of increased income for fishermen, recovery of stocks, and reduced pressure on the species (Campos-Silva & Peres, 2016; Figueiredo, 2013) has led to the dissemination of the experience and created conditions for its replication (Campos-Silva & Peres, 2016; Castello, McGrath et al., 2011; Figueiredo, 2013). Currently, participatory management of pirarucu fishing includes hundreds of small local communities, inside and outside protected areas, in several states of the Brazilian Amazon and with international scope, in parts of the Amazon, such as Peru, Colombia, Bolivia, and British Guiana (Gonçalves et al., 2018).

The pirarucu products that reach the market are fresh meat, dried meat, skin and leather, scales, tongues, and carcasses. Most of these products are consumed in the metropolitan region of Manaus, the capitals of the Southeast region, and countries abroad, such as the United States, Mexico, Italy, Chile, Germany, Spain, and Japan.

According to Dias (2021) pirarucu management also benefits the local economy considerably. The Amazon's extractive communities work with a basket of forest products — there is a period dedicated to pirarucu, another to latex for rubber production, then to collecting seeds for the cosmetics industry, and so on, but pirarucu has, each year, represented an increasing volume within this basket, generating the largest revenue.

Although the achievements are significant, the pirarucu extractive chain still needs help. One of them is that the consumer needs to perceive the value of the initiative, which means that the communities earn little per kilo of fish sold, often not even covering its cost. Asproc believes that to reverse this situation, better communication is necessary. "People go to the supermarket, see our brand of fish, and do not know what sets us apart from other pirarucus, which came from a process that exploits communities and destroys the environment. We still have not been able to communicate this difference well" (Dias, 2021, p. 5). The lack of public policies that recognize the importance of the protection service provided by these communities is another point that is constantly debated. However, there are challenges related to the need for more infrastructure, which makes the work challenging and expensive. "In places that are so isolated, sometimes there is no place to buy ice to transport the fish, or there is no boat to rent, like renting a truck or a car, to do our service" (Dias, 2021, p. 5).

Despite the challenges related to the economic issue, the demands of communities for technical assistance to implement and approve their management plan for the species grow every year. This is because (1) most communities do not want to work illegally or marginalized; (2) fishing for the species is part of the culture of these populations; and (3) the income from management is concentrated, enabling investment in the acquisition of goods and services, which is not possible with the fragmented income from other fisheries.

In addition to contributing to the composition of domestic income, the revenue from pirarucu fishing has enabled investment in the acquisition of fishing gear and improvements to vessels, as well as in the construction and/

or adaptation of floating units to support surveillance and also for the reception and pre-processing of production, providing significant improvements in the hygienic and sanitary conditions of production.

Work and social benefits: In management, income comes from the production obtained by catching pirarucu in annual fishing events. All group members receive in fish or revenue, the amount or value proportional to their dedication to activities inherent to management. In 2016, production in Amazonas was around 1,900 tons, which generated gross revenue of almost R$ 10 million. It is estimated that the activity mobilizes more than 15 thousand people, whether in the supply of inputs (ice, fuels, and foodstuffs), in local commerce in the cities, in the transportation of production and pre-processing of production, and the fish industries.

The formal inclusion of urban fishermen from the surroundings of protected areas and other fishing associations in the management system occurred through formal processes and documents brokered by the government called fishing agreements (Figueiredo, 2013). There was social recognition of fishermen for their sustainable actions and participation in forums for dialogue on public policies for the class and their access to social rights. In addition, the promotion of gender equity in management was observed. In 2017, 38% of the participants and beneficiaries of pirarucu management were women, an unprecedented milestone in the region (Gonçalves et al., 2018).

Future projections: By 2024, Amazonas' production of 5,000 tons of pirarucu and revenues of over R$ 25 million are expected. Furthermore, the aim is to expand management organizations' access to two important public policies: (1) Minimum Price Guarantee for Sociobiodiversity Products (PGPM-Bio), with a price set at R$ 9.33/kg, and (2) economic subsidy for fishermen in a sustainable pirarucu management regime, with the payment of R$ 1.00/kg sold (Decree No. 41,829/2020 (Decreto n.º 41.829, 2020).

Several action fronts aim to add value to managed pirarucu. The first of these, initiated in 2015, with the support of Sebrae/AM and Instituto Innovates, refers to the recognition of the geographical indication (GI) of the Mamirauá Region for managed pirarucu with the National Institute of Industrial Property (INPI). The GI in the denomination of origin (DO) category includes the floodplain areas of the territory of nine municipalities (Tefé, Alvarães, Uarini, Maraã, Japurá, Fonte Boa, Jutaí, Tonantins, and Juruá) (Figure 5). This process aims to recognize the notoriety of this area, allowing production with quality standards that result in a product with high added value aimed at reaching unique markets. The legal representation of the handlers for the use of the GI is the Federation of Pirarucu Handlers of the Mamirauá Region (Femapam), which, in addition to regulating the use of the seal, represents the handlers in political dialogues and in mapping new markets for the product.

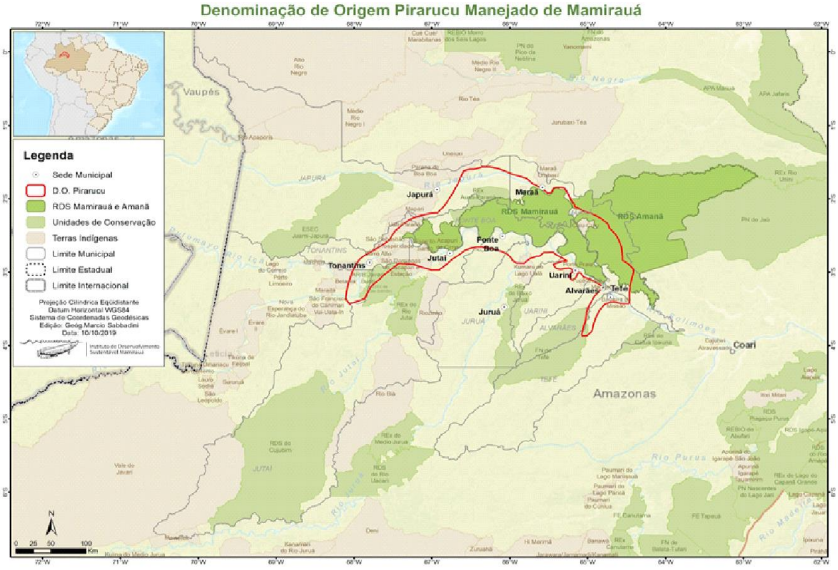


Figure 5. Scope of the Geographical Identification project and Femapam's activities.

Source: Instituto de Desenvolvimento Sustentável Mamirauá (IDSM). (2021). Relatório Anual de Atividades. Instituto de Desenvolvimento Sustentável Mamirauá. Legend: Municipal headquarters, D.O. Pirarucu, RDS Mamirau and Amanã, Conservation units, Indigenous territories, Municipal boundary, State boundary, International boundary.

Another ongoing initiative, in collaboration with the Institute of Forest and Agricultural Management and Certification (IMAFLORA) and a group of institutions in the Middle and Upper Solimões region, is the Rede Origens Brasil. This digital platform offers information provided by local producers of a specific product. In the case of industrialized products, the Origens Brasil Seal is combined with a QR Code. When decoded with a cell phone, this QR Code directs the consumer to the location of origin of the raw material. It provides information about the producers, such as their names, ages, and photographs, as well as information about the culture of the people and the territory of origin. This seal has proven to be an important tool for promoting and valuing pirarucu managers and their production. In 2023, this initiative reached its fourth successful year.

Another ongoing initiative is led by the State Commission for Organic Production (CPOrg) to certify managed pirarucu. This recognition will be a differentiating factor in the market, contributing to the appreciation of production and, consequently, to an increase in managers' incomes.

The continued growth of management is attracting more support organizations to participate in this process, including city halls, through the production and environment departments. They are becoming potential technical managers for ongoing management projects. In this sense, they seek to train their technical teams to assist communities. In addition, there was a movement to create central associations, federations, and cooperatives to represent more groups in a given territory, thus increasing the negotiating power for better production prices. These organizations seek to structure themselves by acquiring and financing vessels, ice factories, and cold storage facilities to gain greater autonomy over production and replace important links in the chain. Institutional markets maintained by the government, such as the National School Feeding Program (PNAE), the School Meal Regionalization Program (PREME), the Food Acquisition Program (PAA), and the Armed Forces, among others, are also stakeholders in the pirarucu chain.

International organizations, such as the United States Agency for International Development (USAID), the United States Forest Service (USFS), and the Gordon & Betty Moore Foundation, have supported actions aimed at a sustainable pirarucu production chain. Figure 6 summarizes the main results of participatory pirarucu management.

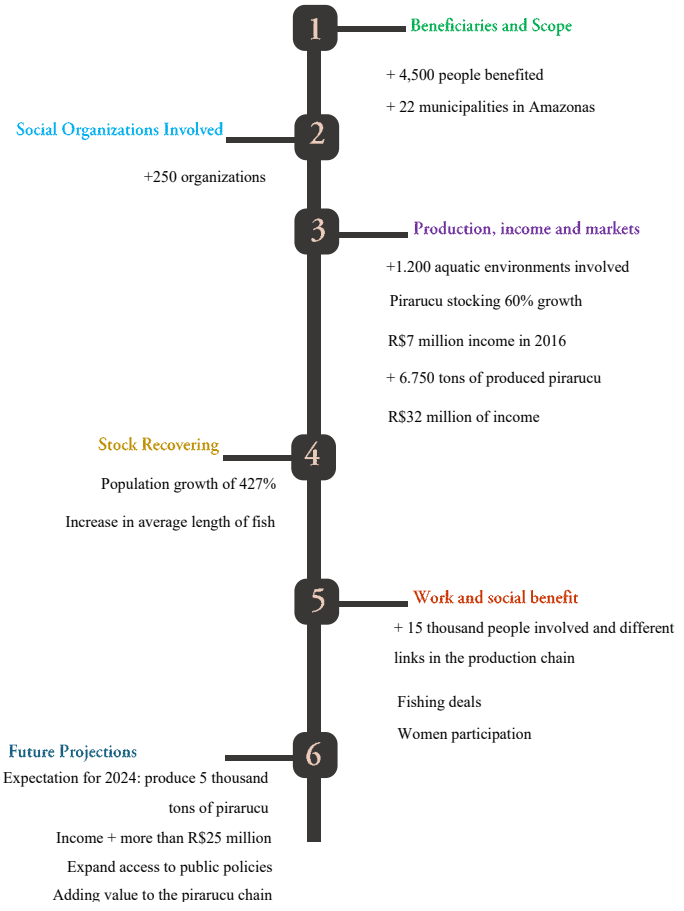


Figure 6. Summary of the main results of participatory management of pirarucu.

Source: The authors. The main results of the participatory management of pirarucu included six distinct stages and achieved significant results in 2021.

Participatory management of pirarucu and its alignment with the SDGs

Since the United Nations (UN) Sustainable Development Goals (SDGs) should promote a holistic approach to achieving sustainable development (Le Blanc, 2015; Sachs, 2012; United Nations, 2015), athe actions carried out by the Mamirauá Institute within the scope of participatory management of pirarucu in the Middle Solimões region, in the Central Amazon, directly contribute to nine SDGs.

SDGs 1, 2, and 12 (no poverty; zero hunger and sustainable agriculture; and responsible consumption and production) are directly aligned with the initial conception of pirarucu management, which originated between 1996 and 1999. The initiative was created to reverse the scarcity of fishery resources, particularly pirarucu, which resulted from disorderly fishing in several areas. In its early years (1999-2001), the initiative demonstrated that by respecting the basic premises of sustainable management, such as the species' reproductive period, the minimum size established for slaughter (150 cm), and the removal of sustainable quotas of no more than 30% of the fish stock, combined with the protection of the territory and solid governance of the projects, it is possible to guarantee food security and, at the same time, generate jobs and income for the rural populations of the Amazon. The management of pirarucu transformed areas that previously suffered from a scarcity of resources into regions with overpopulations of several species of fish. A statement that supports this transformation is the following: "At the beginning of the work, it was difficult to even catch piranha for bait; today, we choose what to eat." Noble fish, such as pirarucu and tambaqui, became part of the diet of these families. In addition, the management significantly reduced the time dedicated to fishing for subsistence and small-scale commercial and large-scale collective activities of pirarucu and other species.

No que se refere ao ODS 8 (trabalho decente e crescimento econômico), os projetos de manejo sustentável representam um modelo de negócios que não apenas atende às necessidades das populações rurais da Amazônia, aprimorando suas atividades culturais e cotidianas, mas que também facilitam o acesso a políticas públicas, como linhas de crédito para produtores familiares, benefícios assistenciais junto à Previdência Social e o Seguro Defeso. Essa iniciativa contribui para o fortalecimento da economia dos municípios. Em 2019, estima-se que tenham sido gerados mais de 10 milhões de reais diretamente com o manejo naquele ano, dos quais mais de 2,5 milhões foram arrecadados por grupos de pescadores assessorados pelo Instituto Mamirauá, promovendo investimentos na economia local por meio da aquisição de bens e serviços.

About SDG 8 (decent work and economic growth), sustainable management projects not only represent a business model that meets the needs of rural populations in the Amazon, improving their cultural and daily activities, but also facilitate access to public policies, such as credit lines for family farmers, social security benefits, and unemployment insurance. This initiative contributes to strengthening the economy of municipalities. In 2019, it was estimated that more than R$ 10 million were generated directly from management that year, of which more than R$ 2.5 million were raised by groups of fishermen advised by the Mamirauá Institute, promoting investments in the local economy through the acquisition of goods and services. SDGs 5 and 10 (gender equality and reduction of inequalities) are also considered in management projects, especially when defining criteria for obtaining the right to fish for pirarucu commercially. These criteria include participation in meetings and assemblies, surveillance patrols of the territory, and involvement in various management-related activities. As a result, any person, whether young or adult, male or female, in good health, can participate in some of the activities and receive gains, whether in fish or income, proportional to their effort and performance. In 2021, women's participation in management projects advised by the Mamirauá Institute represented 42% of the beneficiaries.

Another significant contribution of pirarucu management to the SDGs is related to its intrinsic connection with forest preservation. Pirarucu management areas do not suffer deforestation or fires since the flooded forest acts as a food source for many species of fish that make up the pirarucu diet and provides habitat and shelter for these fish. Therefore, pirarucu management contributes to maintaining the rain cycle, playing an effective role in the fight against global climate change (SDG 13).

In addition, pirarucu management aligns with SDGs 6, clean water and sanitation, and 7, affordable and clean energy. This is due to the implementation of pirarucu pre-processing units that improve working and production conditions. These innovative units treat river water, making it drinkable for consumption and use in production processes. The production of photovoltaic solar energy is also an essential part, powering the pumping and water treatment systems and the lighting of the production units. The Mamirauá Institute has installed two units in 2022 and plans to build three more between 2024 and 2026.

These floating units for receiving and pre-processing pirarucu have the following objectives: to improve working and production conditions, to strengthen groups of pirarucu handlers in the Middle Solimões region and their production arrangements, and to develop and implement technologies appropriate to the production reality in the Amazon floodplain. This is complemented by training on good practices in pirarucu handling, raising awareness among producers about the importance of adopting care when handling fish to improve the hygienic and sanitary quality of production. The summary of the SDGs and the actions developed by the Mamirauá Institute is shown in Table 1, and it is worth emphasizing that all the practices mentioned are related to the premise of the bioeconomy.

Table 2. Participatory management of pirarucu in the Middle Solimões region and its contribution to the SDGs.

SDG	Action by Instituto Mamirauá
SDG 1 — Eradication of poverty	Work and income for communities
SDG 2 — Zero hunger and sustainable agriculture	Food security
SDG 5 — Gender equality	Women participate in the production process
SDG 6 — Drinking water	Production unit with river water treatment
SDG 7 — Affordable and clean energy	Production unit with photovoltaic solar energy
SDG 8 — Decent work and economic growth	Sustainable management of fishing resources
SDG 10 — Reduction of inequalities	Access to public policies and credit lines
SDG 12 — Responsible production and consumption	Sustainable management of the pirarucu chain
SDG 13 — Action against global climate change	Protection and maintenance of the forest

Note. Table 1 highlights the actions carried out by the Mamirauá Institute that were identified as corresponding to the fulfillment of the mentioned SDGs.

GENERAL ANALYSIS AND DISCUSSION OF RESULTS

The results of this study were obtained from the theoretical knowledge described, combined with interviews and focus groups, which allowed us to identify the perceptions of local communities about the social and economic impacts of pirarucu management. These qualitative data were complemented by quantitative indicators, such as population growth of the fish, exemplified by the 427% increase in stocks, demonstrating sustainable management's effectiveness.

Thus, the participatory management of pirarucu, developed and monitored by the Mamirauá Institute for Sustainable Development (IDSM) in the Amazon, presents itself as an example of integration between participatory governance and bioeconomy, aligned with the UN Sustainable Development Goals (SDGs). The study highlights the effectiveness of this approach in mitigating climate change and promoting economic and environmental sustainability.

Regarding governance and its participatory approach, according to the definitions of Rhodes (1996), Kooiman (2003) e Stoker (1998), the new governance is seen as a collaborative process without a centralized command, where multiple actors are involved in complex networks for decision-making. In the context of pirarucu management, this is evident in the active participation of local communities in resource management, reflecting the idea of participatory governance (Arnstein, 1969; Cornwall, 2008; Fung, 2006). Levels of citizen engagement vary but tend to promote greater control and shared responsibility over natural resources.

The participatory approach of the Mamirauá Institute incorporates the principles of adaptive governance discussed by Folke et al. (2005) and the resilience of socioecological systems according to Berkes et al. (2000). Pirarucu management, involving local communities in monitoring and decision-making, demonstrates the effectiveness of participatory management in promoting sustainability and conserving biodiversity. Ostrom (1990) emphasizes the need for organized collectives to effectively manage common goods, which is clearly observed in the Mamirauá Institute model.

Likewise, the practice described by the Mamirauá Institute is intrinsically linked to the premise of the bioeconomy, which aims to use biological resources sustainably to promote economic development (Costa et al., 2021; GBS, 2015; Nobre & Nobre, 2019). Integrating traditional and scientific knowledge in pirarucu management exemplifies how the bioeconomy can be applied practically and sustainably, providing economic benefits to local communities and preserving ecosystems.

Participatory arapaima management is aligned with several UN Sustainable Development Goals (SDGs), especially those related to life below water (SDG 14), climate action (SDG 13), and poverty eradication (SDG 1). The practice promotes the conservation of aquatic resources, contributes to climate change adaptation and mitigation, and provides a sustainable source of income for local communities, helping to reduce poverty.

Analysis by analytical category

Bioeconomy

Participatory pirarucu management exemplifies a practical bioeconomy case, where natural resources are managed sustainably, with economic and social benefits for local communities. This model is aligned with the principles of bioeconomy, as described by Georgescu-Roegen (1971) and Stahel (2016), by promoting the efficient and regenerative use of natural resources and creating economic value from biodiversity conservation.

Regenerative economy

Pirarucu management goes beyond simply preserving natural resources. It involves practices that regenerate the Amazon's aquatic ecosystems, which is close to the proposal of a regenerative economy. Authors such as Raworth (2017) defend the need to restore ecological systems, and the work results demonstrate that community management of pirarucu contributes to the resilience of Amazonian ecosystems and the recovery of pirarucu populations.

Sustainability

The results show how pirarucu management meets the three pillars of sustainability (environmental, social, and economic), as proposed by Elkington (1997) and the Brundtland Report (Brundtland, 1987). The sustainable management model ensures the preservation of pirarucu, promotes the economic development of riverside communities, and strengthens social cohesion while contributing to the Sustainable Development Goals (SDGs).

Ecological sustainability

The study highlights the importance of ecological sustainability based on the principles discussed by Viana et al. (2007) e Amaral (2009), which address the conservation of biodiversity and the integrity of ecosystems. Pirarucu management preserves local ecosystem services and strengthens natural cycles, demonstrating a direct relationship between sustainable resource use and long-term environmental protection.

Governance

Governance is an important factor for the success of pirarucu management, as shown in the study. The practices described in the paper reflect the concepts of governance in networks and collaborative processes discussed by Rhodes (1996) and Kooiman (2003). The participation of diverse actors (local communities, NGOs, governments) in managing natural resources is aligned with these principles, creating a shared governance model that increases conservation effectiveness.

Participatory governance

The participatory management model of pirarucu is a clear example of participatory governance, as defined by Arnstein (1969), Fung (2006) e Cornwall (2008). The active involvement of local communities in decision-making on the management of natural resources ensures greater legitimacy, equity, and long-term sustainability, in addition to promoting the resilience of social and ecological systems.

Participatory management

Participatory management of natural resources, such as pirarucu, is approached based on the concepts of co-management discussed by Folke et al. (2005) and Ostrom (1990). The results indicate that pirarucu management, by integrating communities' traditional knowledge with scientific knowledge, promotes effective management of natural resources, ensuring their sustainability and expanding socioeconomic benefits for the populations involved.

SUSTAINABLE DEVELOPMENT GOALS

Participatory arapaima management is directly aligned with the UN Sustainable Development Goals (SDGs), as evidenced by the work results. The model contributes to goals such as poverty eradication (SDG 1), zero hunger (SDG 2), responsible consumption and production (SDG 12), combating climate change (SDG 13), and reducing inequalities (SDG 10). Authors such as Sachs (2012) and Le Blanc (2015) discuss the importance of integrating these goals into local practices, such as natural resource management, to promote sustainable and inclusive development.

The results of the work on participatory arapaima management are firmly grounded in the analytical and operational categories discussed in the methodology. These categories provide the theoretical framework necessary to understand how the management model combines aspects of bioeconomy, regenerative economy, and sustainability while applying principles of participatory governance and natural resource management to achieve practical and replicable results. Ultimately, pirarucu management demonstrates how academic knowledge of bioeconomy and governance can be applied in authentic contexts to promote sustainable development and meet the Sustainable Development Goals (SDGs).

ASPECTS THAT ADVANCE KNOWLEDGE

Although the description of the participatory management process of pirarucu offers a rich and detailed view, it is necessary to advance the analysis to explore how this practice contributes innovatively to bioeconomy and participatory governance. Pirarucu management, in addition to being an exemplary case of species conservation, establishes a replicable model of adaptive governance, which can be applied to other ecosystems facing similar challenges.

One of this study's main advances lies in adaptive management's capacity to respond to constantly changing environmental and socioeconomic conditions, reinforcing the resilience of socioecological systems. According to Ostrom (1990) e Folke et al. (2005), the effectiveness in managing common goods, such as pirarucu, depends on the ability to adjust management practices based on continuous data on ecosystem health and community needs. This study contributes to this discussion by demonstrating how continuous monitoring of pirarucu stocks and the active engagement of riverside communities results in sustainable governance.

In addition, by connecting the practice of participatory management with the premise of the bioeconomy, this study advances by showing how an integrated approach can simultaneously promote natural resource conservation and local economic development. Unlike conventional models of natural resource exploitation, which often prioritize profit over sustainability, pirarucu management incorporates the sustainable use of biological resources as a central pillar of the bioeconomy (Birch et al., 2010; Georgescu-Roegen, 1971). This alignment between conservation and sustainable income generation offers a new path for development in vulnerable regions such as the Amazon.

By comparing the results of this study with the existing literature, participatory management of pirarucu brings innovations beyond the simple conservation of the species. The practice promotes social equity, generates income, and improves food security while preserving biodiversity and mitigating the impacts of climate change. These aspects advance the field of commons governance, demonstrating that the inclusion of local communities in the decision-making process strengthens ecological and economic outcomes.

FINAL CONSIDERATIONS

Participatory pirarucu management in the Central Amazon exemplifies how environmental conservation can be effectively integrated with sustainable development. However, more than just preserving an emblematic species such as pirarucu, this study advances by showing how this management also contributes to local communities' economic and social development, aligning with the United Nations Sustainable Development Goals (SDGs).

The study's main advance is demonstrating that participatory management of pirarucu, in addition to being a tool for biodiversity conservation, serves as a bioeconomy model that promotes environmental sustainability and generates positive impacts on social equity. Compared to conventional approaches, which often focus exclusively on conservation, the model presented here shows that conservation practices can generate food security, create decent jobs, and promote gender equality and social inclusion.

The results directly answer the research question by demonstrating how participatory management of pirarucu contributes to the conservation of the species, the sustainable development of local communities, and the achievement of the SDGs in the Amazon. Furthermore, this practice incorporates concepts of adaptive governance and socioecological resilience, aligning with Folke et al. (2005) e Ostrom (1990), theories. It allows local communities to participate actively in monitoring and making decisions about using natural resources.

Despite the advances presented, participatory management faces logistical challenges, such as more adequate infrastructure and limited communication of this model's benefits to the end consumer. These limitations can restrict the economic potential of the communities involved and make it difficult to expand the model to other regions. In addition, the need to recognize public policies that value the environmental services communities provide is also a barrier to strengthening this model.

Future studies can investigate ways to overcome these logistical challenges, exploring new marketing models that improve the economic return to the communities involved and more effective communication strategies that value products resulting from sustainable management. Further research could focus on replicating this model in other ecosystems, assessing its applicability in different socio-environmental contexts, and designing public policies to support the development of the bioeconomy in the most isolated regions of the Amazon.

Finally, the participatory management of pirarucu demonstrates that it is possible to integrate environmental conservation, economic development, and social equity in a single model. The experience of this study offers valuable lessons not only for Amazon but also for other regions facing similar challenges. By promoting a sustainable approach to using natural resources, this model can be replicated globally, contributing to the mitigation of climate change and the development of a bioeconomy that is fair and inclusive.

REFERENCES

Amaral, E. (2007). A comunidade e o mercado: Os desafios na comercialização de pirarucu manejado das Reservas Mamirauá e Amanã, Amazonas, Brasil. *Uakari, 3*(2), 9-19. https://mamiraua.org.br/documentos/cfd7e9f0c5a414f0efb1b6cf19fa9a6c.pdf

Amaral, E. S. (2009). *Economia do pirarucu manejado: Análise das experiências de manejo sustentável na Amazônia*. Instituto de Desenvolvimento Sustentável Mamirauá.

Amaral, E., Torres, A. C., & Peralta, N. (2013). A avaliação participativa como ferramenta para tomadas de decisão em processos de manejo de pirarucu (Arapaima gigas). In E. S. A. Figueiredo (Ed.), *Biologia, conservação e manejo participativo de pirarucus na Pan-Amazônia* (pp. 213-236). Instituto Mamirauá. https://www.researchgate.net/publication/346609186_Avaliacao_Participativa_como_Ferramenta_de_Gestao_Compartilhada_no_Manejo_de_Recursos_Pesqueiros

Amaral, E. F., Freitas, C. E. C., & Vieira, I. M. (2011). Manejo comunitário de pirarucu na Reserva de Desenvolvimento Sustentável Mamirauá, Amazonas, Brasil. *Boletim do Instituto de Pesca*, *37*(3), 235-244.

Andrade, L. C. A., Amaral, E. S. R., Silva, N. B., & Queiroz, H. L. (2011). A method for assessing the quality of pirarucu countings. *Uakari*, *7*(1), 29-40. https://mamiraua.org.br/documentos/4afcc1bc9e307016834d8170425f0443.pdf

Arantes, C. C., Castello, L., & Garcez, D. S. (2007). Variações entre contagens de Arapaima gigas (Schinz) (Osteoglossomorpha, Osteoglossidae) feitas por pescadores individualmente em Mamirauá, Brasil. *Pan-American Journal of Aquatic Sciences, 2*(3), 263-269. https://www.researchgate.net/publication/242216386_Variacoes_entre_contagens_de_Arapaima_gigas_Schinz_Osteoglossomorpha_Osteoglossidae_feitas_por_pescadores_individualmente_em_Mamiraua_Brasil

Arantes, C. C., Castello, L., Stewart, D. J., Cetra, M., & Queiroz, H. L. (2010). Population density, growth and reproduction of arapaima in an Amazonia river floodplain. *Ecology of Freshwater Fish, 19*(3), 455-465. https://doi.org/10.1111/j.1600-0633.2010.00431.x

Arantes, C. C., Castello, L., & Cetra, M. (2013). Environmental influences on the distribution of arapaima in Amazon floodplains. *Environmental Biology of Fishes, 96*(10-11), 1257-1267. http://doi.org/10.1007/s10641-011-9917-9

Araripe, J., Rêgo, P. S. do, Queiroz, H., Sampaio, I., & Schneider, H. (2013). Dispersal capacity and genetic structure of Arapaima gigas on different geographic scales using microsatellite markers. *PLOS One, 8*(1), e54470. https://doi.org/10.1371/journal.pone.0054470

Arnstein, S. R. (1969). A Ladder of Citizen Participation. *Journal of the American Institute of Planners*, *35*(4), 216-224. https://doi.org/10.1080/01944366908977225

Berkes, F., Colding, J., & Folke, C. (Eds.). (2000). *Navigating Social-Ecological Systems: Building resilience for complexity and change*. Cambridge University Press.

Bioökonomierat. (2018). *Global Bioeconomy Summit Communiqué*. Global Bioeconomy Summit.

Birch, K., Levidow, L., & Papaioannou, T. (2010). Sustainable Capital? The Neoliberalization of Nature and Knowledge in the European "Knowledge-based Bio-economy". *Sustainability*, *2*(9), 2898-2918. http://doi.org/10.3390/su2092898

Brundtland, G. H. (1987). *Our Common Future*. Oxford University Press.

Campos-Silva, J. V., & Peres, C. A. (2016). Community-based management induces rapid recovery of a high-value tropical freshwater fishery. *Scientific Reports, 6*(34745). http://doi.org/10.1038/srep34745

Castello, L. (2004). A method to count pirarucu: Fishers, assessment and management. *North American Journal of Fisheries Management, 24*(2), 379-389. https://www.researchgate.net/publication/233271399_A_Method_to_Count_Pirarucu_Arapaima_gigas_Fishers_Assessment_and_Management

Castello, L. (2008a). Nesting habit of Arapaima gigas (Schinz) in Amazonian floodplains. *Journal of Fish Biology, 72,* 1520-1528. https://doi.org/10.1111/j.1095-8649.2007.01778.x

Castello, L. (2008b). Lateral migration of Arapaima gigas in floodplains of the Amazon. Ecology of Freshwater Fish, 17(1), 38-43. https://doi.org/10.1111/j.1600-0633.2007.00255.x

Castello, L., McGrath, D., & Beck, P. S. A. (2011). Resource sustainability in small-scale fisheries in the Lower Amazon floodplains. *Fisheries Research, 110*(2), 356-364. http://doi.org/10.1016/j.fishres.2011.05.002

Castello, L., Stewart, D. J., & Arantes, C. C. (2011). Modeling population dynamics and conservation of arapaima in the Amazon. *Reviews in Fish Biology and Fisheries, 21*, 623-640. https://doi.org/10.1007/s11160-010-9197-z

Castello, L., Viana, J. P., Watkins, G, Pinedo-Vasquez, M., & Luzadis, V. (2009). Lessons from integrating fishers of Arapaima in small-scale fisheries management at the Mamirauá Reserve, Amazon. *Environmental Management, 43*(2), 197-209. https://doi.org/10.1007/s00267-008-9220-5

Centro de Gestão e Estudos Estratégicos. (2020). *Oportunidades e Desafios da Bioeconomia - Proposta de Observatório em Bioeconomia*. Centro de Gestão e Estudos Estratégicos, 2020. https://www.cgee.org.br/documents/10195/6917123/CGEE_ODBIO_Prop_Obs_Bioec.pdf

Costa, F. A., Ciasca, B. S., Castro, E. C. C., Barreiros, R. M. M., Folhes, R. T., Bergamini, L. L., Solyno, S. A., Sobrinho, Cruz, A., Costa, J. A., Simões, J., Almeida, J. S., & Souza, H. M. (2021). *Bioeconomia da sociobiodiversidade no estado do Pará*. The Nature Conservancy (TNC Brasil), Banco Interamericano de Desenvolvimento (BID), Natura. https://www.tnc.org.br/content/dam/tnc/nature/en/documents/brasil/projeto_amazonia_bioeconomia.pdf

Coutinho, E. S. S., Bevilacqua, L., & Queiroz, H. L. (2010). Population dynamics modeling of Arapaima gigas. *Acta Amazonica, 40*(2), 333-345. https://doi.org/10.1590/S0044-59672010000200012

Cornwall, A. (2008). Unpacking 'Participation': Models, meanings and practices. *Community Development Journal*, *43*(3), 269-283. http://doi.org/10.1093/cdj/bsn010

Decreto nº 41.829/2020. (2020). Diário Oficial do Estado do Amazonas no dia 21 de janeiro de 2020. https://ads.am.gov.br

Dias, A. (2021). Manejo do pirarucu na Amazônia: um case bem-sucedido. Exame. https://bit.ly/3OZHpUp

Elkington, J. (1997). *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*. Capstone Publishing.

Figueiredo, E. S. A. (Ed.). (2013). *Biologia, conservação e manejo participativo de pirarucus na Pan-Amazônia*. Instituto Mamirauá.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*, 441-473. https://doi.org/10.1146/annurev.energy.30.050504.144511

Fullerton, J. (2015). *Regenerative Capitalism: How Universal Principles and Patterns Will Shape Our New Economy*. Capital Institute.

Fung, A. (2006). Varieties of participation in complex governance. *Public Administration Review*, 66, 66-75. https://doi.org/10.1111/j.1540-6210.2006.00667.x

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*. Harvard University Press.

Georgescu-Roegen, N. (1975). *Bio-Economic aspects of entropy, entropy and information in science and Philosophy,* J. Zeman éd. Amsterdam.

Global Bioeconomy Summit. (2015). Communiqué Global Bioeconomy Summit 2015: Making bioeconomy work for sustainable development, Berlin Birch, 2015. https://gbs2020.net/wp-content/uploads/2021/10/Communique_final_neu.pdf

Gonçalves, A. C. (2013). O manejo participativo de pirarucu (Arapaima gigas) nas Reservas de Desenvolvimento Sustentável Mamirauá. In E. S. A. Figueiredo (Ed.), *Biologia, conservação e manejo participativo de pirarucus na Pan-Amazônia* (pp. 267-277). Instituto Mamirauá.

Gonçalves, A. C. T., Cunha, J. B. C., & Batista, J. S. (2018). O Gigante Amazônico: Manejo Sustentável de Pirarucu. Instituto Mamirauá.

Instituto de Desenvolvimento Sustentável Mamirauá. (2021). *Relatório Anual de Atividades*. Instituto de Desenvolvimento Sustentável Mamirauá.Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. (1996). Portaria nº 08, de 2 de fevereiro de 1996.

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. (1996). Portaria nº 08, de 2 de fevereiro de 1996. https://www.ibama.gov.br/component/legislacao/?view=legislacao&legislacao=98742#:~:text=PORTARIA%20N%C2%B0%2008%2C%202%20DE%20FEVEREIRO%20DE%201996.&text=Par%C3%A1grafo%20%C3%9Anico%20Para%20efeito%20desta,Bacia%20do%20Rio%20-Araguaia%2FTocantins.

Kooiman, J. (2003). *Governing as Governance*. SAGE Publications.

Le Blanc, D. (2015). Towards integration at last? The sustainable development goals as a network of targets. *Sustainable Development*, 23(3), 176-187. https://doi.org/10.1002/sd.1582

Lima, D. M., & Peralta, N. (2017). *Aspectos socioeconômicos do manejo do pirarucu na Amazônia*. *Revista Amazônica, 12*(1), 45-59.

Lima-Ayres, D. M. (1992). *A Raposa e o Jabuti: Os Patronos e os Caboclos no Médio Solimões*. Editora Fiocruz.

Lopes, C. L., & Chiavari, J. (2022). *Bioeconomia na Amazônia*: Análise conceitual, regulatória e institucional. Climate Policy Initiative. https://acervo.socioambiental.org/acervo/documentos/bioeconomia-na-amazonia-analise-conceitual-regulatoria-e-institucional http://www.plataformademocratica.org/Arquivos/Futuribles2/Futuribles2_ProjetoAmaz%C3%B4nia4.0.pdf

Lopes, P. F., & Queiroz, H. L. (2009). Uma revisão das fases de desenvolvimento gonadal de pirarucus Arapaima Gigas (Schinz, 1822) por meio da análise macroscópica como uma proposta para unificação destes conceitos e sua aplicação prática nas reservas Mamirauá e Amanã. *Uakari, 5*(1), 39-48. https://mamiraua.org.br/documentos/3c3a63659fcf07f47c6cf4821e0735e6.pdf

Nobre, I., & Nobre, C. (2019). *Projeto 'Amazônia 4.0': Definindo uma terceira via para a Amazônia*. *Futuribles*, (2), 7-20. https://fundacaofhc.org.br/arquivos/Futuribles2/Futuribles2_ProjetoAmazo%CC%82nia4.0.pdf

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.

Peralta, N. (2010). *Desenvolvimento sustentável e manejo do pirarucu: Estudos de caso na Amazônia*. Universidade Federal do Pará.

Queiroz, H. L. (2000). Natural History and Conservation of pirarucu, Arapaima gigas, at the Amazonian Varzea: red giants in muddy waters. (Tese de doutorado), University of St. Andrews.

Queiroz, H. L., & Sardinha, F. S. (1999). *Desenvolvimento sustentável da pesca do pirarucu na Amazônia Central*. In H. L. Queiroz & W. G. Crampton (Eds.), *Estratégias para Manejo Sustentável de Recursos Pesqueiros na Amazônia* (pp. 129-148). Sociedade Civil Mamirauá.

Raworth, K. (2017). *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. Chelsea Green Publishing.

Relatório Seminário Projeto Parceria para conservação da biodiversidade da Amazônia. (2018). *Manejo de pirarucu em Unidades de Conservação e Terras Indígenas da Amazônia*. Coletivo do Pirarucu.

Rhodes, R. A. W. (1996). The New Governance: Governing without Government. *Political Studies*, *44*(4), 652-667. https://doi.org/10.1111/j.1467-9248.1996.tb01747.x

Sachs, J. D. (2012). From millennium development goals to sustainable development goals. *The Lancet*, *379*(9832), 2206-2211. https://www.thelancet.com/journals/a/article/PIIS0140-6736(12)60685-0/abstract

Sachs, J. D. (2015). *The Age of Sustainable Development*. Columbia University Press.

Stahel, W. R. (2016). The circular economy. *Nature*, 531(7595), 435-438. https://doi.org/10.1038/531435a

Stoker, G. (1998). Governance as theory: Five propositions. *International Social Science Journal*, 50(155), 17-28. https://doi.org/10.1111/1468-2451.00106

Sampaio, C. A. C., & Alves, F. K. (2019). Ecossocioeconomias: Um conceito em construção. *Revista da FAEEBA, 27*(52). https://doi.org/10.21879/faeeba2358-0194.2018.v27.n52.p13-25

Sampaio, C. A. C., & Santos, L. C. R. (2021). Ecossocioeconomia empresarial: conciliando cadeia produtiva sustentável e arranjo socioprodutivo territorial. In *10º En ANPPAS*. Campinas, São Paulo.

Santos, L. C. R. (2020). *Diretrizes de gestão interorganizacional da cadeia produtiva alinhadas ao produto orientado à sustentabilidade.* [Tese de doutorado em Engenharia De Produção E Sistemas), Pontifícia Universidade Católica do Paraná, Curitiba.

Santos, L. C. R., Canciglieri Jr., O., & Sampaio, C. A. C. 2. (2020). Reflexões sobre a cadeia produtiva de produto orientado à sustentabilidade. *Revista Brasileira de Planejamento e Desenvolvimento, 9*(2), 214-227. https://doi.org/10.3895/rbpd.v9n2.1193

Santos, L. C. R. dos, Sampaio, C. A. C., Grimm, I. J., Sander, J. A., Barreto, W. de S., Romano, R. G. (2023). *Cadeia produtiva sustentável: Teorias e abordagens ecossocioeconômicas*. Editora UEPG.

United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. UN General Assembly.

Viana, J. P., Castello, L., Damasceno, J. M. B., Amaral, E. S. R., Estupiñán, G. M. B., Arantes, C., Batista, G. S., Garcez, D. S., & Barbosa, S. (2007). Manejo Comunitário do Pirarucu Arapaima gigas na Reserva de Desenvolvimento Sustentável Mamirauá - Amazonas, Brasil. In *Áreas Aquáticas Protegidas como Instrumento de Gestão Pesqueira. Série Áreas Protegidas do Brasil* (Vol. 4, pp. 239-261). Ministério do Meio Ambiente e IBAMA.

Viana, J. P., Damasceno, J. M. B., Castello, L., Amaral, E. S., & Estupiñán, G. M. (2007). *Manejo de pirarucu na Reserva Mamirauá: Desafios e resultados*. Instituto de Desenvolvimento Sustentável Mamirauá.

Vieira, P. H. F., & Sampaio, C. A. C. (2022). Ecossocioeconomias na encruzilhada do antropoceno: Uma perspectiva sistêmica-transdisciplinar. *Revista Historia Ambiental Latinoamericana y Caribeña (HALAC), 12*, 168-208. https://doi.org/10.32991/2237-2717.2022v12i1

Webster, K. (2017). *The Circular Economy: A Wealth of Flows*. Ellen MacArthur Foundation Publishing.

Authorship

Ana Cláudia Torres Gonçalves*

Instituto de Desenvolvimento Sustentável Mamirauá

Estrada do Bexiga, n. 2584, Fonte Boa, CEP 69553-225, Tefé, AM, Brazil

E-mail: ana.claudia@mamiraua.org.br

https://orcid.org/0000-0001-8839-8268

Luciane Cristina Ribeiro dos Santos

Universidade Evangélica de Goiás

Av. Universitária, Km 3,5, Cidade Universitária, CEP 75083-515, Anápolis, GO, Brazil

E-mail: lu.ribeirocrs@hotmail.com

https://orcid.org/0000-0001-6148-4254

* Corresponding Author

Copyrights

Authors' Contributions

1st author: project administration (lead), formal analysis (equal), conceptualization (equal), data curation (equal), investigation (lead), methodology (equal), writing - original draft (equal), writing - review & editing (equal), supervision (lead), validação (líder),validation (lead), visualization (equal)

2nd author: formal analysis (equal), conceptualization (equal), data curation (equal), investigation (supporting), metodologia (igual), methodology (equal), writing - original draft (equal), writing - review & editing (equal), visualization (supporting).

Conflict of Interests

The author informed that there is no conflict of interests.

Funding

The authors reported that there was no funding for the research in this article.

Plagiarism Check

RAC maintains the practice of submitting all documents approved for publication to the plagiarism check, using specific tools, e.g.: iThenticate.

Peer Review Method

This content was evaluated using the double-blind peer review process. The disclosure of the reviewers' informationon the first page, as well as the Peer Review Report, is madeonly after concluding the evaluation process, and with the voluntary consent of the respective reviewers and authors.

Data Availability

The authors claim that all data used in the research have been made publicly available, and can be accessed via the Harvard Dataverse platform:

Gonçalves, Ana Cláudia Torres; Santos, Luciane Cristina Ribeiro dos, 2025, "Replication Data for: Bioeconomy in Central Amazon: Participatory Management of Pirarucu (Arapaima gigas) published by RAC-Revista de Administração V1. https://doi.org/10.7910/DVN/BJRQQO

RAC encourages data sharing but, in compliance with ethical principles, it does not demand the disclosure of any means of identifying research subjects, preserving the privacy of research subjects. The practice of open data is to enable the reproducibility of results, and to ensure the unrestricted transparency of the results of the published research, without requiring the identity of research subjects. RAC is a member of, and subscribes to the principles of the Committee on Publication Ethics (COPE) for scholarly publication.

RAC is a member of, and subscribes to the principles of the Committee on Publication Ethics (COPE) for scholarly publication