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SOCIO-ENVIRONMENTAL SURVEY OF EXCAVATED TYPE FISH FARMS IN THE MUNICIPALITY OF ARARI-MARANHÃO, BRAZIL

LEVANTAMENTO SOCIOAMBIENTAL DE PISCICULTURAS DO TIPO ESCAVADO NO MUNICÍPIO DE ARARI-MARANHÃO, BRASIL

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ABSTRACT

The aim of this study was to investigate the socio-environmental conditions of fish farming activities in the municipality of Arari, Maranhão, Brazil, carried out by the associates of the Association of Fish Farmers of Arari. A structured approach was used to characterize both the social and environmental dimensions, and an adapted sustainability assessment tool with 32 response options was employed to evaluate the level of sustainability of the enterprises. The results showed that 85% of the fish farms were classified as good, indicating a positive environmental impact and a satisfactory degree of concern for the environment. This study highlights the importance of sustainable fish farming practices and the need for appropriate government support and technology transfer to enhance regional socioeconomic development. It provides valuable insights into the socio-environmental conditions of fish farming in the municipality of Arari and its potential contribution to sustainable development in the region. These findings can serve as a guide for policymakers, researchers, and fish farmers interested in promoting sustainable fish farming practices in the region.

Keywords: Pisciculture; socio-environmental conditions; Sustainability.

RESUMO

O objetivo deste estudo foi investigar as condições socioambientais da atividade de piscicultura realizada pelos associados da ASPAR no município de Arari-MA. Foi utilizada uma abordagem estruturada para caracterizar, tanto a dimensão social quanto ambiental, bem como uma ferramenta de avaliação de sustentabilidade adaptada com 32 opções de resposta para avaliar o nível de sustentabilidade dos empreendimentos. Os resultados mostraram que 85% das pisciculturas foram classificadas como boas, indicando um impacto ambiental positivo e um grau satisfatório de preocupação com o meio ambiente. O estudo destaca a importância de práticas sustentáveis de piscicultura e a necessidade de apoio governamental adequado e transferência de tecnologia para melhorar o desenvolvimento socioeconômico da região. Os achados deste estudo fornecem informações valiosas sobre as condições socioambientais da atividade de piscicultura no município de Arari-MA e seu potencial para contribuir para o desenvolvimento sustentável na região. As descobertas deste estudo podem servir como guia para formuladores de políticas, pesquisadores e piscicultores interessados em promover práticas sustentáveis de piscicultura na região.

Palavras-chave: Piscicultura; condições socioambientais; Sustentabilidade

INTRODUCTION

Aquaculture has been used for centuries by different cultures, with archaeological records demonstrating that Egyptians were already practicing aquaculture 4,000 years ago by using fishing and fish conservation in tanks. The technique was also used by Romans, people from the Indonesian region, China, Vietnam, and other places, and has expanded through demographic growth (BRANDÃO, 2018).

Aquaculture has emerged as a sustainable and environmentally friendly alternative to traditional fishing, offering a promising solution to meet the growing global demand for food from aquatic sources (DUARTE et al., 2021; FAO, 2020). This practice not only supplies a consistent source of protein, but also enhances income generation for rural communities and alleviates pressure on wild fish stocks (DUARTE et al., 2021; NAYLOR et al., 2021).

Brazil is endowed with abundant aquatic resources and has tremendous potential for the expansion of aquaculture. As highlighted by Brandão (2018) and Figueiredo and Campos (2021), Brazil boasts over 12 million hectares of suitable water bodies for fish farming, including rivers, dams, and reservoirs. Furthermore, Brazil's diverse climate enables the cultivation of various fish species that can flourish under distinct temperature and water conditions (SOUSA; SANTANA; GARGANTINI, 2021; LIMA et al., 2022).

Despite Brazil's immense potential for aquaculture development, the country faces several challenges. The primary obstacle is inadequate infrastructure and technology required to support fish farming growth (FILHO et al., 2020; SILVA et al., 2022). Additionally, improved regulations and industry monitoring are necessary to guarantee sustainable operations and minimize environmental impacts (DUARTE et al., 2021; MORAES et al., 2022).

In the state of Maranhão (MA), for example, there are several favorable conditions for the development of aquaculture, such as excellent climatic and hydrological conditions (VIANA et al., 2021). However, the state has not yet achieved satisfactory development about this activity because of bureaucratic difficulties, such as a lack of government incentives and the non-propagation of appropriate technology available to fish farmers. Despite this, the municipality of Arari-MA is among the main cities in Maranhão that have developed aquaculture in the lowlands.

The municipality of Arari-MA stands out in pisciculture activity, which represents a local practice with great potential as it is a great source of food and income (VIANA et al., 2021). However, examining the socio-environmental conditions of fish farming in the municipality of Arari-MA is important because it can shed light on the specific challenges and opportunities encountered by fish farmers in this region (OLIVEIRA et al., 2021; GOMES et al., 2022).

Therefore, the objective of this study was to conduct a survey of the socio-environmental conditions of the fish farming activity of the members of the Association of Fish Farmers of Arari (ASPAR) in Arari-MA through studying local activity development to describe the degree of sustainability, aiming at the possibility of determining improvements and opportunities to make the activity more sustainable.

MATERIALS AND METHODS

Study Area

This study was conducted in the municipality of Arari, MA, Brazil, which is in the Baixada Maranhense region. Arari municipality is located south of the equator, with the following geographical coordinates at its extreme points: 3°15'41"S and 44°52'22"W for the west point, 44°52'41"W for the east point, and 44°35'37"W and 03°26'43"S latitude for the south point. The municipal seat is located at 3°27'00"S and 44°46'48"W (Silva, 2021)

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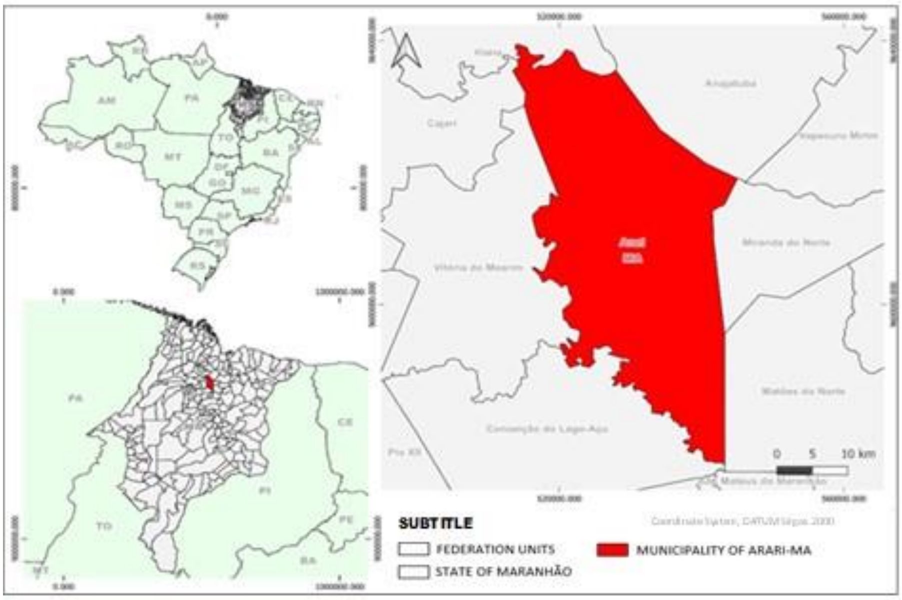
Figure 1. Map of the location of the municipality of Arari, Maranhão, Brazil



Data Collection

Social Characterization of Fish Farmers

Thirteen dugout fish farms and their respective fish farmers from ASPAR were evaluated. To characterize the social and business aspects, a structured questionnaire with four sections based on the methodology of ROTTA (2003) was developed. Additionally, to evaluate the sustainability level of the enterprises, a structured questionnaire proposed by Oliveira (2012) and Pardo-Carrasco (2006) was adapted to fit the type of fish farming studied, with 32 answer options divided into four sections.

Environmental Characterization of the Enterprise and Activity

The president of ASPAR made the coordinates of all the fish farms available, which served as the basis for the generation of the location map from satellite images of Google Earth Pro version 7.3 (2022), which offers users advanced features such as importing and GIS data export. The physical characteristics of the properties were identified and located using QGIS STANDALONE 3.22, which is an open-source program that serves to process geospatial data, in addition to using data from IBGE (2017).

Sustainability Evaluation

Leripio (2001), in his research "GAIA: A Method for Managing Environmental Aspects and Impacts," proposed that the sustainability levels of fish farms be classified into three colors: green, red, and yellow. Using this methodology, responses obtained from the questionnaire were regrouped and classified according to the colors. According to Oliveira (2012), to facilitate the understanding and interpretation of information, positive responses that presented good environmental sustainability practices were classified as green, those that represented a problem were classified as red, and those that did not fit reality were classified as yellow. Thus, to determine the sustainability level of the fish farms, the following equation for calculating sustainability created by Leripio (2001) and adapted by Oliveira (2012) was used:

$$\text{Sustainability} = \frac{(Total\ number\ of\ green\ boxes)\,(100)}{(Number\ of\ questions) - (Total\ number\ of\ yellow\ boxes)}$$

(Eq. 1).

The level of sustainability of the fish farms was expressed as a percentage and obtained by multiplying the total number of green boxes by 100, dividing by the number of questions, and subtracting the number of yellow boxes. Based on these results, the degree of sustainability was determined as shown in Table 1.

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Table 1. Reference for the classification of fish farm sustainability

Criteria	Classification
Less than 30%	**Critical**
Between 30% and 50%	Poor
Between 50% and 70%	Adequate
Between 70% and 90%	Good
Above 90%	Excellent

Data collected from the questionnaire were entered into a spreadsheet file to facilitate the understanding and analysis of the content for the implementation of environmental aspects and impact management (GAIA), as described by Leripio (2001).

RESULTS AND DISCUSSION

The coordinate points were used to create a location map of the fish farms. As shown in the map (Figure 2), all fish farms were located within the territorial limits of the municipality, especially in rural areas and in the Trizidela I and II villages, with only one farm located on the margins of BR-222 near Rabela village. The fish farms were named P01, P02, P03, P04, P05, P06, P07, P08, P09, P10, P11, P12, and P13 based on their respective geographic coordinates.

Figure 2. Location of the fish farm points of the Association of Fish Farmers of Arari, Maranhão (ASPAR)

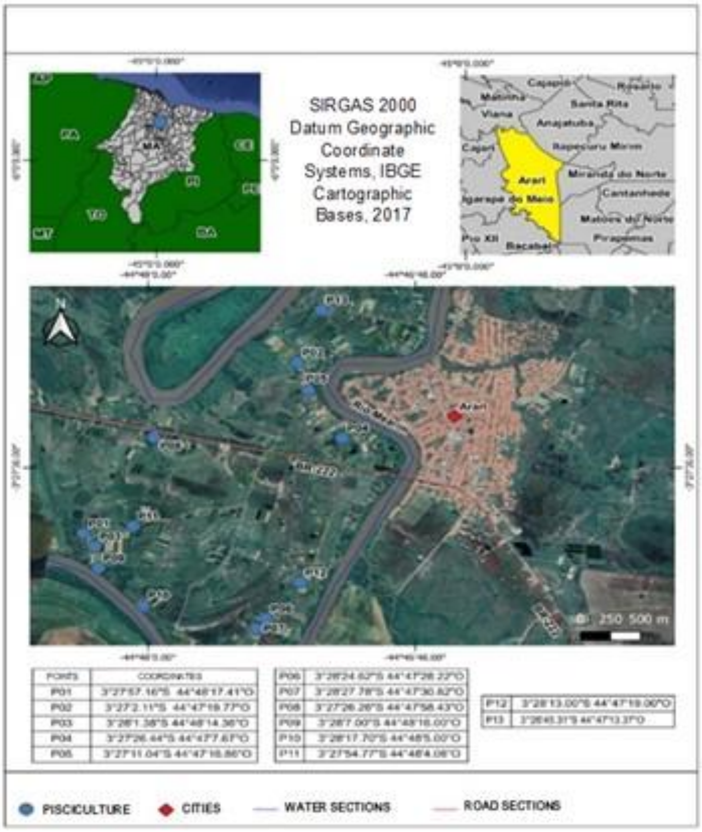

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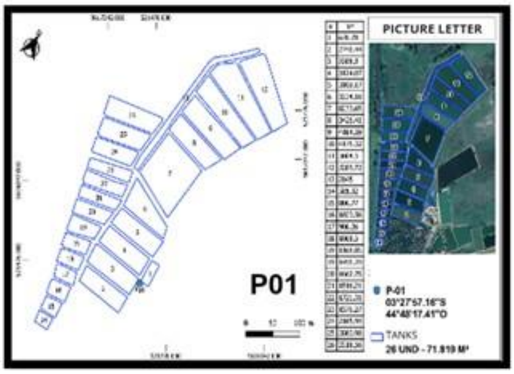
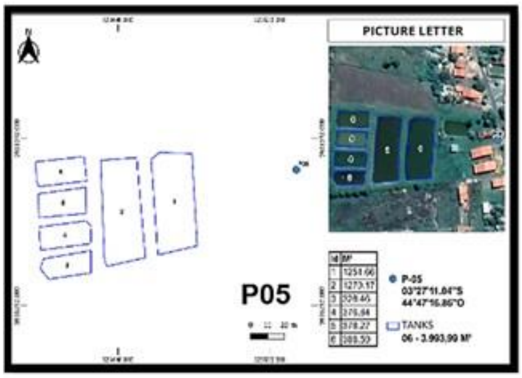
Figure 3. Layout of the physical projects of the largest (P01) and smallest (P05) properties in terms of the size of the built fish farming project





Profile of Fish Farmers in Arari-MA

Most owners had diverse educational backgrounds, with 23.1% of fish farmers having completed higher education, followed by the same percentage with technical training and incomplete elementary education. This result differs from Silva's (2010) study in southeastern Pará, where most respondents had little formal education or only elementary education. However, Ferreira (2018) found that 38.5% of respondents had completed higher education.

The majority of the evaluated fish farmers (69.2%) had been engaged in the activity for more than 10 years, while only over 15% had been working for more than three years and 5–10 years. This result was like that found by Trombeta et al. (2020), with 56% of fish farmers working in the activity between three and 10 years, and by Lopes et al. (2020) in the lower Parnaíba region in the city of Araioses, MA, where fish farmers claimed to have been active for more than three years.

Regarding their income source, 53.8% of respondents stated that fish farming was their only source of livelihood, whereas 46.2% had another source of income. Many fish farmers invested in other activities, such as agriculture, livestock, pig breeding, poultry, açaí plantations, bananas, and vegetables, taking advantage of the municipal water potential of the Mearim River Basin. Additionally, some fish farmers were public municipal servants. Ferreira (2018) found a similar result, with 39% of respondents having fish farming as their main source of income, followed by livestock farming, agriculture, and other activities.

Characterization and Analysis of the Fish Farming Projects in Arari-MA

Most producers (69.2%) decided to invest in fish farming because they had property that was not generating income and saw this activity as a profitable opportunity. This result is like that of Ferreira (2018), although other motivations for working in fish farming were also identified. To obtain a good income, Ayuba (2019) highlighted the importance of knowing what to raise, how to raise it, where to raise it, and the best time for market production, as well as ensuring quality throughout the production process.

Most producers (84.6%) developed their own projects, while in another study in Guapé, Minas Gerais, Oliveira (2012) found that 73.3% of respondents had their projects developed by specialized professionals. This suggests that most Arari projects were not designed with the environmental aspects of the area in mind.

When asked about technical assistance, the majority (53.8%) answered that they received continuous monitoring, while 30.8% did not receive monitoring, and 15.4% received it sporadically. Compared with other cities in Minas Gerais, the technical participation in ASPAR was more significant, with about seven producers receiving monthly technical assistance from the National Rural Learning Service (Senar) in partnership with the Brazilian Support Service for Micro and Small Enterprises (Sebrae) to monitor the development of the activity in all aspects, from preparation of the pond to commercialization.

Management in Aquaculture

The stocking density in the analyzed fish farms was 1 fish/m² in 84.6% of the units and 0.5 fish/m² in 15.4%. In a 40 × 100 tank, a density of 1 fish/m² represented 4,000 fish, while 0.5 fish/m² represented 2,000 fish. Oliveira (2012) reported an average stocking density of 120 fingerlings/m², ranging from 83 to 166 fingerlings/m².

All fish farmers provided commercial feed, with 46.2% using pelleted feed, 46.2% using extruded feed, and 7.7% using mash feed. Lopes et al. (2020) found that 87% of breeders used commercial extruded feed. Oliveira (2012) obtained different results, finding that 100% of the sampled fish farms used commercial extruded feed. The preference for pelleted and extruded feeds can be explained by the fact that one has a lower price and the other has water stability, reducing the impact on water quality and improving the nutrient balance.

Most fish farmers (69.2%) provided one to three bags of feed per day, while 30.8% provided five to 10 bags per day. Oliveira (2012) found that the amount of feed provided was adjusted according to needs, and the frequency was usually twice a day, with approximately 4.3 tons of feed consumed per day.

Fish biometry is performed in most fish farms to calculate the amount of feed needed, controlling the amount distributed in the tanks and allowing verification of the health status of the fish (CORRÊA & SILVA, 2022). Leftover feed was collected to prevent decomposition and the release of excess nutrients into the system.

In 46.2% of the fish farms, frequent monitoring was carried out for all water quality parameters, whereas 23.1% frequently monitored transparency, 15.4% frequently monitored pH, 7.7% frequently monitored temperature, and 7.7% frequently monitored oxygen. Oliveira (2012) found that most fish farmers only monitored water temperature frequently, and the periodicity of monitoring other parameters was sporadic.

The main difficulties faced by fish farmers were the price of fish (61.5%), lack of credit lines (23.1%), strong competition with other fish farms (7.7%), and bureaucratic legalization (7.7 %). Barros, Martins, and Souza (2018) stated that the cost of feed acquisition (11%), lack of technical assistance (5%), and obtaining fingerlings (4%) were the most mentioned challenges by fish farmers. Corrêa and Ribeiro (2020) also highlighted the high price of feed and excessive bureaucracy in environmental legislation as challenges faced by fish farmers in Santa Catarina.

Most fish farms (76.9%) sold fish on the property. Most sales were directed to the state (69.2%) and 30.8% to the municipality. Lopes et al. (2020) found that 100% of fish farmers sold fresh fish to their communities. Selling directly to consumers generated higher individual profits and lower marketing costs, allowing fish to be sold at lower prices. Fish processing was not performed on any of these properties. Oliveira (2012), on the other hand, found that in most fish farms, fish were processed on the property.

Characterization and Environmental Analysis

Conama Resolution No. 413 of 2009 established the guidelines for the environmental licensing of aquaculture enterprises. According to the Resolution, most of the evaluated enterprises presented a physical-structural project smaller than five hectares, classifying them as small-scale. The exception was fish farm P01, which had 26 breeding tanks and an area of 71,819 m² and was thus classified as medium scale.

In terms of sustainability, Figure 3 presents the results obtained for the degree of sustainability of the fish farms. Most fish farms presented good sustainability, with individual results ranging from 60% to 80% according to the sustainability classification. These results were like those observed by Nunes et al. (2017) in their sustainability analysis of indicators of fish farming management.

Figure 4 presents the sustainability classification based on the model proposed by Leripio (2001). Most fish farms were classified as good (85%), while 15% were classified as adequate. This indicates the environmental appreciation of the fish farmers, with only necessary efforts to comply with legislation.

Regarding property rights and compliance with legislation, all fish farmers stated that they complied with legally required standards. However, according to Andrade (2020), the lack of documentation proving the regularization of enterprises may imply a high rate of irregular activities.

Most fish farms did not interfere with access to public use areas. Of the fish farms analyzed, only 7.7% presented interference with access to public use areas. In addition, residents were employed at 92.3% of the fish farms, which improved the social and cultural aspects of the community.

Regarding worker safety, the results showed that most fish farms paid adequate salaries, provided potable water and food to workers, and provided personal protective equipment. However, only 30.8% of fish farms offered employees training in general safety, personal hygiene, and first aid. It is important to highlight that employee training is essential in a biosafety program, keeping everyone involved in fish breeding properly trained on correct handling procedures and sanitary care (BARCELLOS, 2022).

Regarding the conservation of protected areas, most fish farmers had knowledge of permanent protection

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areas, and only 7% of the properties occupied these areas with delimitation and compensation. In addition, 46.2% of the fish farms underwent reforestation to mitigate the impact caused by vegetation removal in the protected areas. However, 53.8% of respondents had not undergone reforestation.

In summary, the results indicated that the majority of the analyzed fish farms presented good sustainability and complied with legally required standards. However, there are opportunities for improvement in employee training and mitigation of the impact caused by vegetation removal in protected areas.

Table 3. Physical dimensions of fish farms

Fish farm	Number of tanks	Water surface area (m²)
P01	26	71,819.00
P02	19	37,410.22
P03	09	13,403.11
P04	12	24,051.37
P05	06	3,993.99
P06	07	15,827.34
P07	05	6,676.38
P08	11	16,751.62
P09	15	49,745.53
P10	10	22,733.20
P11	11	26,708.46
P12	03	5,228.12
P13	04	12,486.39

Figure 3. Sustainability levels of the analyzed fish farms

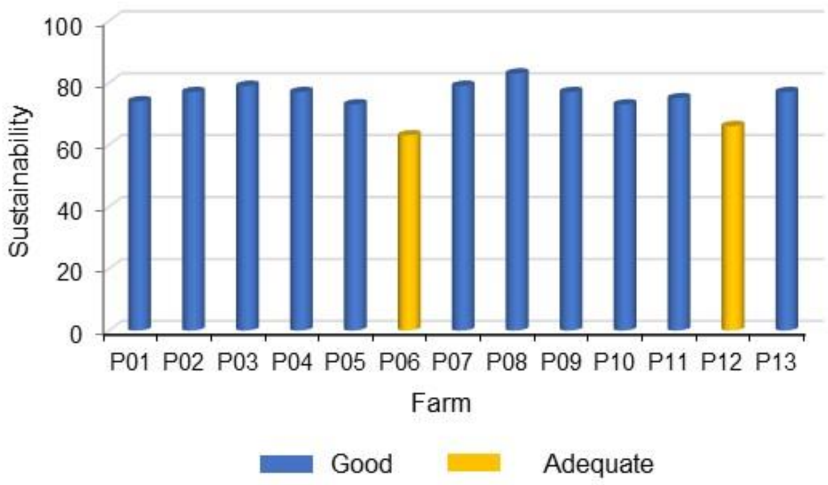

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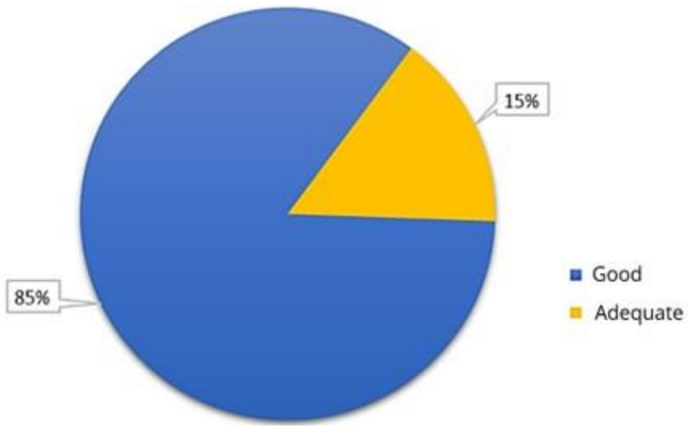
Figure 4. Sustainability classification according to the model proposed by Leripio (2001)



Oliveira (2012) reported disparate results regarding the conservation of permanent preservation areas (PPAs) in fish farms. Although all were aware of the importance of protecting these areas, 100% of the responses were negative regarding the recovery and mitigation measures required by law for occupied areas. Coelho (2018) highlighted that investing in PPA conservation brings benefits that extend beyond these areas. Regarding water and soil conservation, most fish farms (84.6%) monitored their water and effluents; however, 38.5% did not take measures to prevent soil degradation. The application of lime was a common practice in 84.6% of fish farms, but care must be taken, as intense liming can have serious consequences for water quality and fish (Fortunato, Melo & Mendes, 2020; Massago, Silva & Marchiori, 2018).

Regarding the species used, most fish farms (69.2%) bred native species such as tambatinga and curimatá, whereas tilapia, an exotic species, was bred by 30.8% of fish farms. Although 76.9% of fish farms claimed to have no record of exotic species escape, it is necessary to implement tools that guarantee effective containment because the introduction of exotic species can have significant negative impacts on the environment (Santos, 2021; Pozzetti & Gasparini, 2018).

Regarding the storage of inputs, most fish farms (69.2%) stored fuels, lubricants, and agrochemicals in appropriate places, but only 23.1% used antibiotics only after a correct

diagnosis, and 30.8% used mixed medications in the feed. It is important to follow regulatory norms and manufacturer recommendations to ensure the safety of employees and their property (Marek, 2019). Appropriate feed storage is essential to ensure the quality of the final product (Senar, 2018).

To prevent disease, 76.9% of fish farms adopted adequate feeding, correct pond management, and stress reduction, but 46.2% used antibiotics without verification or indication by a qualified professional. It is important to emphasize the need for the sustainable management of fish farming with natural predator control and the adoption of practices that minimize environmental impacts.

The study revealed that most fish farmers were unaware of the list of prohibited medications and chemicals in the country, and many did not use the minimum necessary dose when administering antibiotics. In addition, the lack of adequate biosafety practices can lead to disease spread and the excessive use of antibiotics can lead to cross-resistance. Fish companies must follow the norms established by the Ministry of Agriculture and perform proper cleaning and disinfection to ensure fish health and final product quality.

Disinfecting tanks after handling is essential to prevent the presence of microorganisms, and periodic tank cleaning is a common practice among fish farmers. Additionally, the amount of feed offered should be based on periodic fish biometry to ensure healthy growth.

Fish farmers must be aware of the environmental risks associated with the use of chemical products in aquaculture, including toxicity to flora and fauna and the development of resistance in pathogenic organisms. The use of ecological methods for predator control is a common practice among fish farmers. However, it is important to implement safer practices to prevent the spread of disease and reduce the excessive use of antibiotics.

FINAL CONSIDERATIONS

This study found that the fish farms evaluated had a satisfactory level of concern for environmental and natural resource conservation, indicating a good level of sustainability. Fish farmers demonstrated knowledge of the environmental and social impacts associated with fish production and showed an intention to minimize negative impacts and maximize positive impacts. To achieve an even higher level of sustainability, the following actions are suggested:

- reforest the PPAs of the Mearim River to protect and maintain the quality of water used in fish farming, avoiding fines and administrative sanctions by competent environmental agencies.
- maintain or implement the control and treatment of effluents generated by fish farming and use these to irrigate fruits, vegetables, and animals.
- provide training for fish farmers on management, work safety, and first aid, improving knowledge of various aspects related to the activity.
- create quality seals to value fish farms and the fish produced.
- invest in protection and/or drainage structures, such as monks and elbows, to prevent the escape of exotic species into the river.
- encourage the construction of a processing factory to serve fish farms for the sale of fish fillets.

With the implementation of these actions, it will be possible to achieve a high level of sustainability, contributing to the preservation of the environment and improving the quality of life of the local community.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships.

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