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SOCIOECONOMIC CHARACTERIZATION AND AQUACULTURE ANALYSIS ALONG THE DOCE RIVER BASIN, BRAZIL

CARACTERIZAÇÃO SOCIOECONÔMICA E ANÁLISE AQUÍCOLA NA BACIA DO RIO DOCE EM MINAS GERAIS (MG) E ESPÍRITO SANTO

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Abstract: Aquaculture is economically significant, contributing to healthy food production, income generation, and employment, while addressing poverty and hunger. However, this activity faces challenges from environmental disasters, such as the collapse of the Fundão dam on November 5, 2015, in Mariana, Minas Gerais (MG). This study investigates the disaster's impact and socioeconomically characterizes the region's aquaculture farmers and activities. Between June 2021 and April 2022, 82 closed questionnaires were conducted along a 5 km stretch of the Doce river. The data highlight key factors related to the activity, the production chain, and the role of formal and non-formal institutions. This study lays the groundwork for future research and identifies critical points of public interest, especially for public policy initiatives.

Keywords: Traditional communities; Socioeconomic impact; Public policies.

Resumo: A aquicultura tem grande destaque econômico e produtivo, decorrente da produção de alimentos saudáveis, geração de renda e emprego, além de contribuir no combate à pobreza e fome. No entanto, essa atividade vem sendo impactada por desastres ambientais, como o rompimento da barragem de Fundão em 5 de novembro de 2015, em Mariana, Minas Gerais (MG). Este estudo investigou os impactos desse desastre e caracterizou socioeconomicamente os aquicultores da região. Entre junho de 2021 e abril de 2022, foram aplicados 82 questionários em uma área de 5 km ao longo da calha do Rio Doce. Os dados analisados abordam os principais fatores da atividade, a cadeia produtiva, e as instituições atuantes. Assim, este estudo fornece bases para futuras pesquisas e apresenta pontos cruciais e de interesse público, especialmente para orientar políticas públicas.

Palavras-chave: Comunidades tradicionais; Impacto socioeconômico; Políticas públicas.

1 INTRODUCTION

Aquaculture can be defined as the activity in which the cultivation of aquatic organisms is practiced, normally in a confined and controlled space (Schulter; Filho, 2017). The concept differs from extractive fishing, in which fishing resources are removed from their natural environment. Furthermore, unlike populations exploited by fishing, the aquaculture product is not a collective good and must have an owner (Rana, 1997). Aquaculture production enterprises use natural, manufactured and human resources, such as water, feed, energy and labor. Aquaculture has three essential components for its longevity: profitable production, environmental conservation and social development (Valenti, 2002).

The natural conditions in Brazil are favorable to aquaculture activities, considering that the country holds approximately 13% of the total freshwater reserve available in the world (Rodrigues, 2012; Andrade, 2020; Leite *et al.*, 2024). According to the Ministry of Fisheries and Aquaculture, Brazil's total fish production increased by 6.2% in 2023, generating BRL 10.2 billion in revenue. Compared to 2022, production grew by 16.2%, reaching a total output of 655 thousand metric tons (Brazil, 2024). There are areas in the country where aquaculture activities are practiced on a small scale, as is the case in municipalities located along the Doce river channel.

Such activity is not free from environmental and social impacts, such as the introduction of non-native species, pollution, intensive use of feed and chemical products, medication and antibiotic residues, and the release of organic and inorganic waste. Aquaculture can generate conflicts over the use of land and water, disputes with other forms of land and water use, such as agriculture, traditional and sport fishing. (Pérez & Gómez, 2013; Franco, Araújo & Franke, 2018; de Paula, 2020; Fonseca *et al.,* 2021).

As it is an activity with a high degree of dependence on the good quality and availability of water resources, it is possible to consider that the collapse of the Fundão tailings dam caused direct impacts on the socioeconomic development of aquaculture farmers along the Doce river basin. The disaster occurred on November 5, 2015, and from then on, high levels of various ores were recorded both in the water and in sediments made up of the mud formed by the tailings (Viana, 2020).

Among the various impacts caused by the dam collapse is the disruption in the way of life of fishermen and aquaculturists, whose way of livelihood was lost or suddenly impacted, as well as the cultural relationship with the Doce river. In Espírito Santo (ES), for example, the negative impacts were enormous, as in the Minas Gerais region, causing problems in water supply, fishing activities, fish farming, among countless others (Silva, 2007; Organon, 2015). In addition to the incalculable destruction of aquatic life, the deaths of human beings stand out. In just eleven minutes the historical and cultural heritage was annihilated (Gonçalves; Vespa; Fusco, 2015). It is therefore possible to observe that what happened, which gained worldwide visibility, generated consequences of all kinds. The outcomes are quite significant and serious, particularly for riverside communities, populations that depended heavily on natural resources as a source of subsistence (food), supply (Sassine, 2015) and income. Catastrophic events such as the collapse of the Fundão dam, in 2015, and the Vale tailings dam failure in Brumadinho (2019), which caused hundreds of fatalities and widespread toxic exposure (Da Costa *et al.*, 2020), highlight the need for more rigorous management of associated environmental risks, ensuring the protection of aquatic ecosystems and the communities that depend on them.

In this context, the present study provides a socioeconomic characterization and analysis of the aquaculture activity of aquaculturists operating along the Doce river basin and on the coast of Espírito Santo, presenting information that could be used as a subsidy for the implementation of actions in the public and private sectors, contributing to the process of repair and development of aquaculture activity.

2 METHODOLOGY

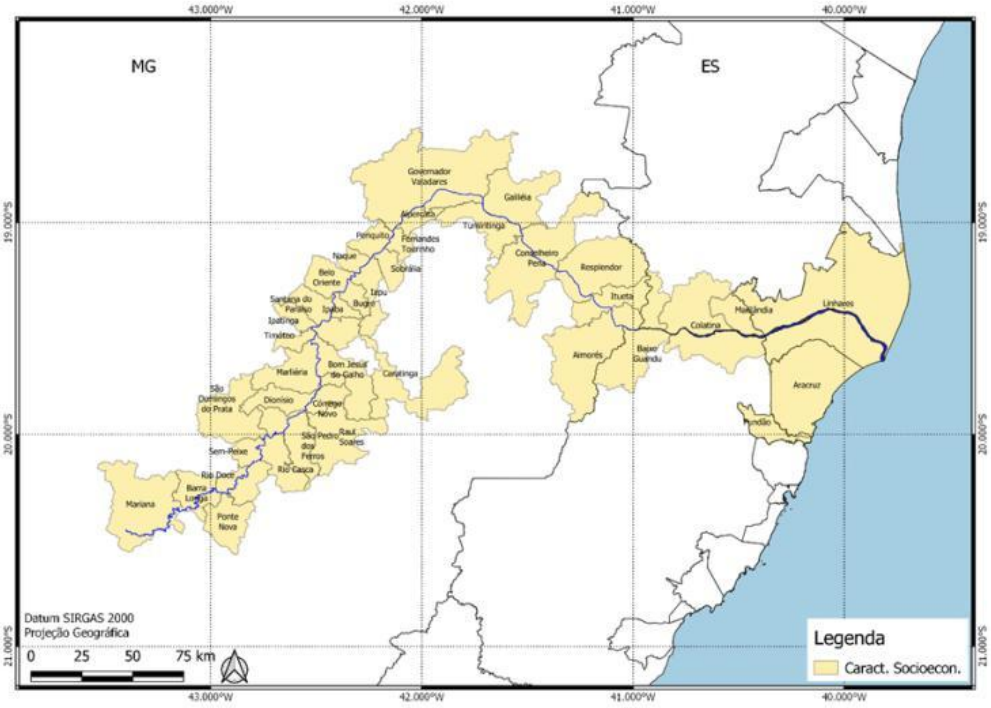
2.1. Study Area

The study was carried out in the Doce river basin, located in the Atlantic Forest biome, and recognized, in 2000, as a hotspot for environmental conservation in the world, due to high endemism, species richness and high degree of threat (Myers *et al.*, 2000). Among the main environmental attributes of the Doce river, the lagoon system stands out encouraging the creation of the Rio Doce State Park (PERD) (Brazil, 2020). However, the region came into the spotlight after the collapse

of the Fundão dam, in the municipality of Mariana-MG, in November 2015, resulting in an even greater need to carry out studies to analyze and characterize activities associated with the Doce river.

The total data collection area covered 42 municipalities, 36 of which were located in the state of Minas Gerais and 6 in the state of Espírito Santo (Figure 1). In these municipalities, priority was given to aquaculture farmers located at a distance of up to approximately 5 kilometers perpendicular to the Doce river channel, as well as those located in the coastal region of Linhares, Aracruz and Fundão, in Espírito Santo.

Figure 1 - Total data collection coverage area



Source: PMAP (2022).

Therefore, the basin area was divided into three regions: lower, middle and upper Doce river, with the lower Doce river region consisting of the six municipalities of Espírito Santo: Baixo Guandu, Colatina, Marilândia, Linhares, Aracruz and Fundão. On the middle Doce river are the municipalities of Aimorés, Itueta, Resplendor, Conselheiro Pena, Galiléia, Tumiritinga, Governador Valadares, Alpercata, Fernandes Tourinho, Periquito, Naque, Sobrália, Belo Oriente, Iapu, Bugre, Ipaba, Ipatinga, Santana do Paraíso, Caratinga, Timóteo, Marliéria, Bom Jesus do Galho, Pingo d'Água, Córrego Novo, Dionísio and São Domingos do Prata,

all located in the state of Minas Gerais. The upper Doce river region is made up of municipalities also belonging to the state of Minas Gerais, namely: Raul Soares, São José do Goiabal, São Pedro dos Ferros, Sem-Peixe, Rio Casca, Santa Cruz do Escalvado, Rio Doce, Ponte Nova, Barra Longa and Mariana.

2.2. Data Collection

Data collection took place between June 2021 and April 2022, and the method employed comprised the use of a closed-ended questionnaire, carried out through face-to-face interviews, preferably with the owner of the enterprise and, in their absence, the responsible person present. The research protocol and questionnaire used in this study were reviewed and approved by the Comitê de Ética em Pesquisa under Certificate of Ethical Assessment Presentation (CAAE) Nº 40221920.4.0000.5063 and Approval Opinion Nº 4.622.996, in full compliance with Brazilian National Health Council Resolution 510/2016.

The questionnaire addressed aspects related to the producer's socioeconomic profile, production, type of cultivation and destination of production. Potential interviewees were located using the snowball *or* information chain method (Biernacki; Waldorf, 1981): an individual indicated in the community for the interview will indicate the next ones, increasing the sample based on knowledge and recognition of peers. The sampling ends when there are no more indications of new names. For the socioeconomic profile, it is worth highlighting here that people recognized as aquaculturists those who still carry out production even after the collapse of the Fundão dam. In total, 82 interviews were carried out.

3 RESULTS AND DISCUSSION

3.1 Aquaculture and Socioeconomic Characterization of the Lower Doce river

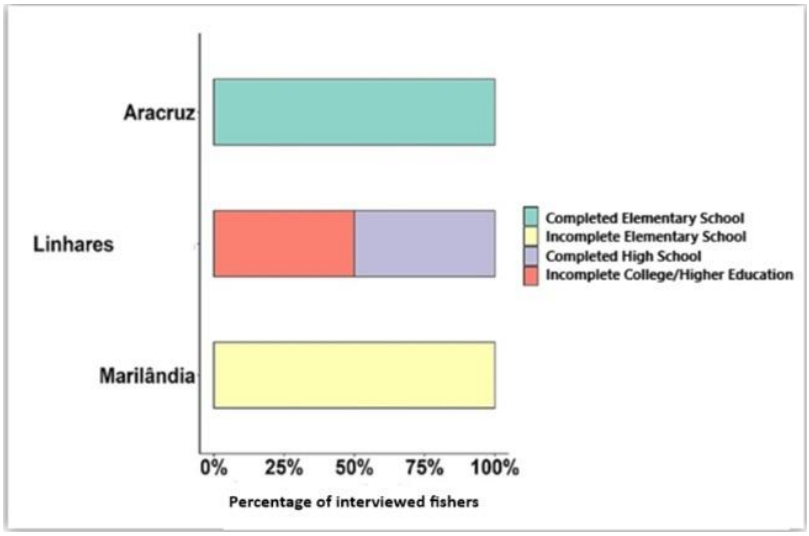
According to the data collected, in the lower Doce River, all fish farmers carry out cultivation in excavated pond-type structures, and ten categories of fish were mentioned and among the species, tilapia (*Oreochromis sp.*) is present in the four municipalities, being the only one identified in Marilândia and Aracruz. In the study

carried out by Oliveira *et al.* (2011) tilapia also appears in 100% of the fish farms interviewed.

The aquacultures of Aracruz and Marilândia at the time of the interview were partially abandoned. Respondents associate the abandonment of the activity with a series of problems, such as theft of production from nurseries, difficulty in marketing production, high consumption of electricity when used, lack of technical assistance, lack of access to financing, and especially the high cost of feed. The latter was also mentioned by interviewees in the studies by Zacardi *et al.* (2017), Almeida Júnior *et al.* (2012), Ferreira *et al.* (2013) and Lima *et al.* (2018). The high cost of inputs, among other challenges, slows down aquaculture development in a large part of the country, especially feed, which is the most expensive item in production (Ostrensky; Boeger, 2008).

The owners of aquacultures in the lower rio Doce area are exclusively male. Zacardi *et al.* (2017) found a similar situation in their studies. The average age indicates younger individuals, except in Marilândia. Looking at schooling (Figure 2), elementary education is the maximum level of education in Aracruz and Marilândia, which can be considered an obstacle to the development of activity in the region. Similar data were found by Silva (2023) in the state of Pará, where approximately 80% of the interviewed have completed or incomplete primary education. In Linhares, of those interviewed, the lowest level of education is complete secondary education and there is incomplete higher education, showing a higher level of education in this municipality.

Figure 2 - Education of interviewed in the Lower Doce river region



Source: Authors (2023).

Only in Linhares interviewed aquaculturists have an aquaculture registration. In the rest of the municipalities, they do not have registration, a situation that is similar to that recorded by Epamig (2009) in the Morada Nova de Minas region, where the majority of producers were not regularized. The results found by Oliveira *et al.* (2011) and Rotta (2003) indicate that more than 70% of those interviewed were registered to carry out the activity. At the same time, Linhares is also the only place where some interviewed aquaculturists participate in associations or entities aimed at defending their interests.

Reinforcing the small scale of the enterprises, when the importance of the aquaculture enterprise in terms of income generation was investigated, it was observed that none of the aquaculturists has the activity as their main source of income. In all municipalities, respondents have another income-generating activity, such as agriculture, commerce and extractive fishing. The same was observed in other studies in Mato Grosso do Sul and Pará, where aquaculture has almost zero importance in generating income for producers, compared to other activities developed, such as agriculture, livestock, pig farming, among others (Rotta, 2003; Silva, 2023).

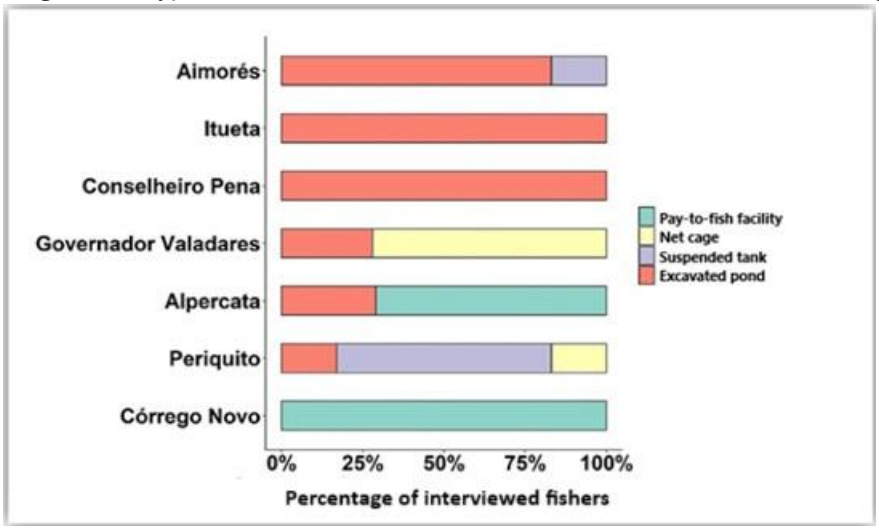
Interviewees report that even before the collapse of the Fundão dam aquaculture activity in the region was not significant due to the lack of incentives, actions and public policies in favor of producers. However, after the disaster it is even more difficult to maintain the activity as the main or only source of income due to the problems associated with the dam collapse. Among these problems, the most mentioned is consumer distrust, who often stops buying products because they do not differentiate between the fish produced in the enterprises and the fish from the Doce River. In the study by Mazzarino *et al.* (2020), one of the problems reported in relation to water would be pollution and its increasing contamination, causing its quality to decline.

3.2 Aquaculture and Socioeconomic Characterization of the Middle Doce River

According to the data collected, the majority of crops in the middle Doce river (Figure 3) are carried out in excavated nurseries (48%), followed by net ponds (37%). Fishing and suspended tanks were identified in a smaller proportion, with a frequency of 7.5% each. The excavated pond structure was also the most used by

aquaculturists in the studies of Zacardi *et al.* (2017), Silva (2023) and Lima *et al.* (2018). Twenty categories of fish were mentioned, including tilapia (*Oreochromis sp*.) that is the species present in the eight municipalities. According to Kubitza and Campos (2015), tilapia leads aquaculture production in Brazil and its commercial production occurs practically throughout the country, mainly in the Northeast, Southeast and South regions. The preference for the species may reflect its ease of management, as well such as its resistance to variations in temperature, in addition to commercial acceptance.

Figure 3 - Types of cultivation structure found in the middle Doce river region

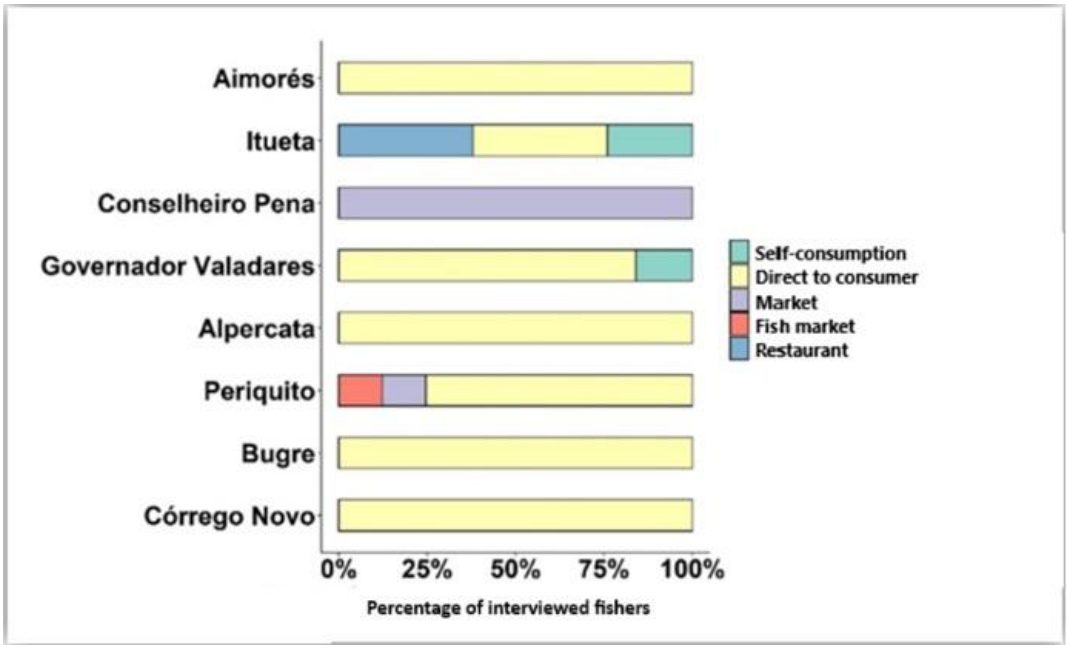


Source: Authors (2023).

When interviewed about how the product is sold, 96% reported that it is sold *fresh*. Only in Governador Valadares is fish processed before commercialization. Similar results were found by Rezende *et al.* (2008), Silva (2010) and Almeida Júnior *et al.* (2012), showing that most producers sold live fish, without processing them. Oliveira *et al.* (2011) found the opposite in their study, with most businesses processing fish. It was also possible to observe (Figure 4) that fish are sold directly to the consumer (77.78%), with no large production chain involved in the commercialization of fish, by the interviewed aquaculturists. According to the data collection carried out, Conselheiro Pena had 100% of sales at fairs, and there is also this option in Periquito. Own consumption was recorded in Governador Valadares and Itueta, but at a low rate. In addition, sales to restaurants in Itueta and fishmongers in Periquito were also recorded, both in small proportions. These data

are close to the records of Oliveira *et al.* (2011) which showed that all aquacultures have commercial purposes.

Figure 4 - Destination of fish production from aquaculture in the middle region of the Doce river

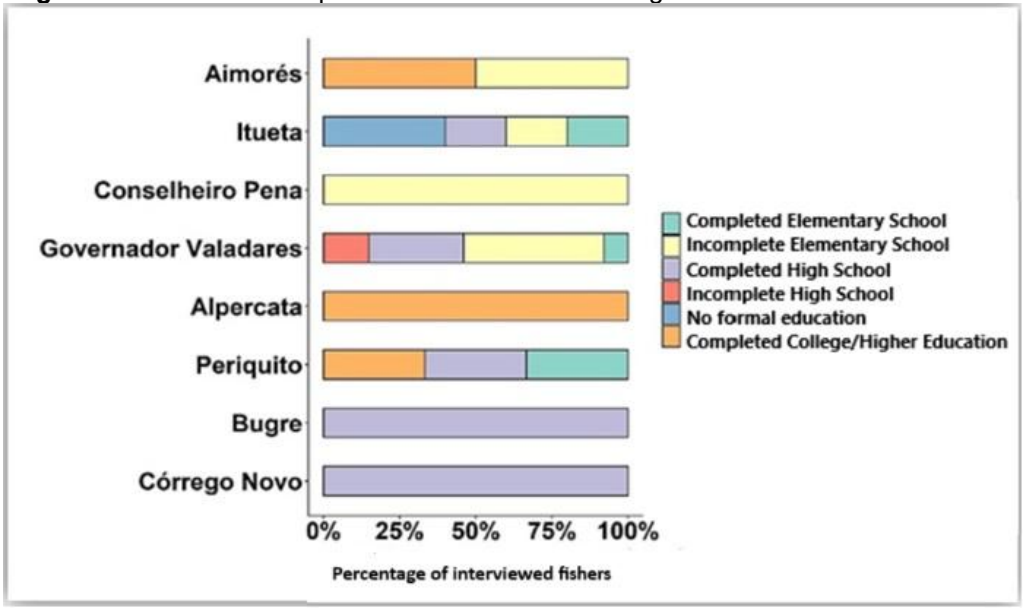


Source: Authors (2023).

The enterprises are predominantly male, with a female presence in only 11.11% of the enterprises. Around half of the enterprises rely on hired labor (48.15%). In relation to the average age, it varies greatly between municipalities and between enterprises, with the youngest women being 32 years old, and the oldest men being 66 years old.

Looking at education, around a third (33.33%) of those interviewed had incomplete primary education, and 29.63% had completed secondary education, with a considerable percentage having completed higher education (11.11%). Similar results were found by Almeida Júnior *et al.* (2012) in Pará and Lima *et al.* (2018) in Amazonas, where approximately a third of those interviewed have primary education. Incomplete primary education corresponds to 100% of those interviewed only in Conselheiro Pena. In the other municipalities there is an increase in education, especially in Alpercata, where 100% of those interviewed have completed higher education. In Bugre and Córrego Novo, all interviewees had completed secondary education (Figure 5).

Figure 5 - Education of aquaculturists in the Middle region of the Doce river



Source: Authors (2023).

Only in Córrego Novo and Conselheiro Pena interviewed producers do have aquaculture registration; in the rest of the municipalities the majority of aquaculturists do not have registration. Obtaining an aquaculture registration and regularizing fish farming involves bureaucratic processes, as well as the need to carry out technical training for the operation, which are some of the factors that discourage producers from seeking to regularize their activity. Participation in associations or entities aimed at representing aquaculturists occurred only in Governador Valadares and Periquito; in other municipalities interviewed aquaculturists do not participate in any form of organization. Similar results were found by Zacardi *et al.* (2017) where few interviewees stated that they participate in organizations related to aquaculture.

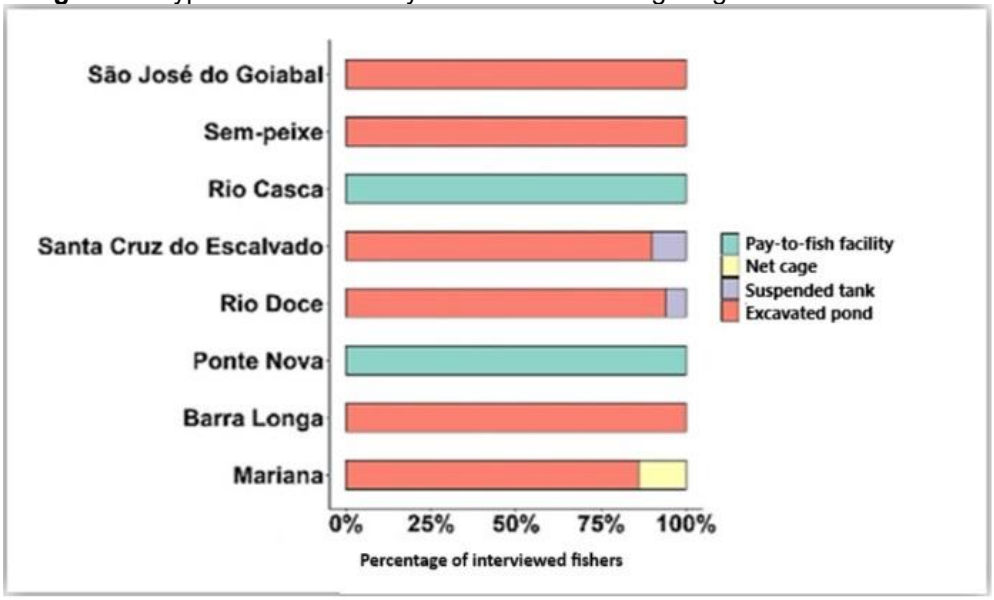
It was observed that in the municipalities of Conselheiro Pena, Governador Valadares, Periquito and Córrego Novo interviewed aquaculturists have the activity as their main source of income. However, even though this is the main income-generating activity, only in Governador Valadares and Córrego Novo the majority of interviewees did declare aquaculture as the only source of income. In the other municipalities, the majority of interviewees declared that they have another income-generating activity besides aquaculture. In studies carried out by Viana et. al (2022), it was shown that the activity generates income for families who use it for survival. Already carried out by Cardoso *et al.* (2012), a greater balance was pointed out in the

“Zona da Mata Mineira” region, where in all the municipalities surveyed, aquaculture activity has a greater share in family income. This same research showed that there is a large concentration of producers whose only source of income is aquaculture, a characteristic that differs from crops along the Doce river channel.

3.3 Aquaculture and Socioeconomic Characterization of the Upper Doce River

Most of the crops are grown in excavated nurseries (85.10%) followed by tanks suspended on land (8.5%). Panga fishing and net tanks were located to a lesser extent in the upper Doce river, 4.2% and 2.1% respectively (Figure 6). The predominance of excavated ponds is thus noted, although this is not a reality in all municipalities, with pay-fishing being exclusive in Rio Casca and Ponte Nova. Eighteen categories of fish were mentioned. Among the common species, tilapia (*Oreochromis sp.*) is the species present in the eight municipalities where fish farmers were found.

Figure 6 - Types of cultivation system found in the high region of the Doce river

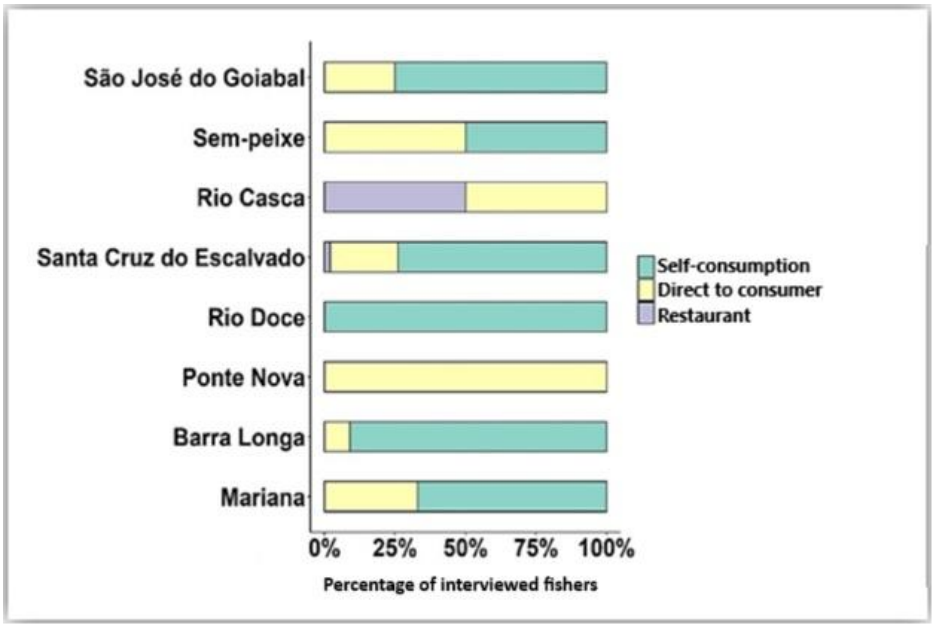


Source: Authors (2023).

As for how it is sold, the vast majority of the product is sold *fresh* (90.91%). Only in Sem Peixe and Mariana fish is processed before commercialization. In addition to the lack of processing in most cases, it was also possible to observe that the majority of fish farming (69.61%) is intended for consumption (Figure 7), as

observed by Zacardi *et al.* (2017) and Silva (2023), who in their studies point to the practice of family fish farming, where only surplus production is sold. There are those who sell directly to the consumer (27.45%), and there is no large production chain involved in the sale of fish.

Figure 7 - Destination of fish production from aquaculture in the upper region of the Doce river



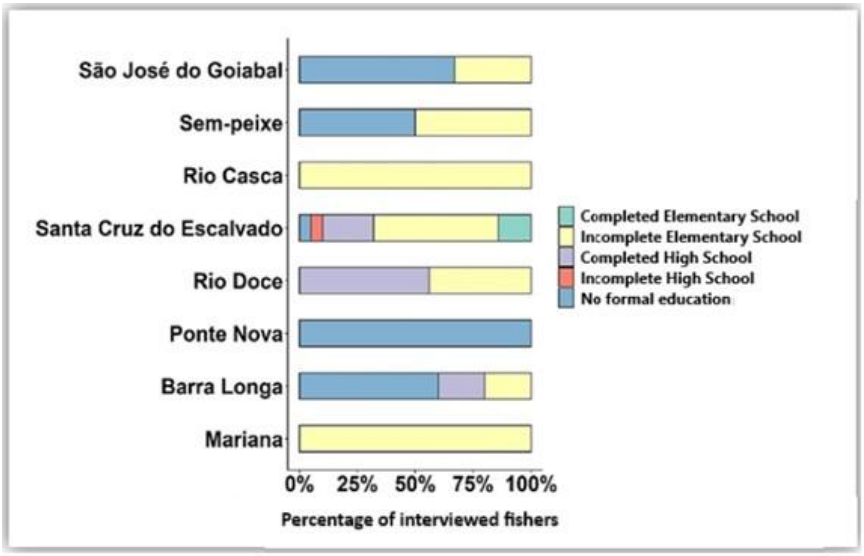
Source: Authors (2023).

In the identified enterprises, the work is predominantly male, with a female presence in only 10.64% of them. Similar frequencies were found by Silva (2023) in the mesoregions of Marajó and Northeast Pará, where around 90% of enterprises are run by men. Lima *et al.* (2018) found a frequency of approximately 80% male participation in the enterprises interviewed. The average age varies greatly among municipalities and among enterprises, with the youngest women being 43 years old, and the oldest men being 69 years old.

Looking at schooling, almost half of those interviewed have incomplete primary education (47.73%), and the percentage of people without formal education (18.18%) draws attention. Unlike other regions, in the upper Doce river no fish farmer has higher education. The predominance of aquaculturists without formal education was higher in São José do Goiabal, Ponte Nova and Barra Longa, while incomplete primary education was predominant in Rio Casca, Santa Cruz do Escalvado and Mariana. Only in Rio Doce the percentage of aquaculturists with completed

secondary education does represent just over half of those interviewed (Figure 8). Rotta (2003) points out a different situation in a study carried out in Alto Taquari, Mato Grosso do Sul, whose results indicate fish farmers with a high level of education. This difference may be related to the sociocultural characteristics of the regions.

Figure 8 - Education of aquaculturists in the upper Doce river region



Source: Authors (2023).

Only in the municipality of Rio Doce there were interviewed aquaculturists with aquaculture registration; in the rest of the municipalities all have no registration. It is observed that in only two municipalities – Rio Casca and Ponte Nova – aquaculturists have aquaculture activity as their main source of income. However, even though this is the main income-generating activity, only in Rio Casca aquaculture is the only source of income. In the other municipalities, interviewees declared that they have another income-generating activity in addition to aquaculture. Oliveira *et al.* (2011) found similar results in the municipality of Guapé, also in Minas Gerais, where 60% of those interviewed said they did not depend on this activity to generate income. In the state of Amazonas, Lima *et al.* (2018) recorded a frequency of more than 80% of interviewees who responded that they did not depend exclusively on fish farming.

3.4. Support the Activity

Currently, in the Espírito Santo region, the activity has the support of institutions, such as the Capixaba Institute of Research, Technical Assistance and Rural Extension (Incaper), with the aim of enhancing the activity, working together with the producing communities, through actions of extension and research aimed at surveying suitable regions; development of actions with the purpose of implementing and adapting the techniques of the cultivation structure, such as the use of net tanks and/or nurseries excavated in the ground, so that the capacity to produce can be promoted with the aim of developing the state of Espírito Santo (INCAPER, [sd]).

It is noteworthy that aquaculture has limited support in credit projects, marketing of the product in its final state and organization of producers. Some actions are mentioned, such as the cooperation of the Espírito Santo Agricultural Development Foundation (Fundagres) and Brazilian XX of Support to Micro and Small Enterprises (Sebrae) (2017), which carried out training for producers, students and technicians in various areas of aquaculture and the Aquaculture and Fisheries Operational Project (2019), which aimed to improve productivity and income through training (INCAPER, [sd]). Also noteworthy is the support from the Agriculture, Supply, Aquaculture and Fisheries Secretariat (SEAG) with the aim of structuring and motivating research programs, studies, surveys and data analysis; control, inspection and health protection policy for products of animal origin; and conservation and recovery of renewable resources, within the areas of competence (INCAPER, [sd]).

Despite the active institutions, greater technical support is evident and necessary for the emergence of new enterprises, since according to many aquaculturists, they need this support in order to obtain the technical knowledge necessary for the viability of the enterprise, because, spite of several initiatives, the activity does not prosper, with cultivated products perishing, profitability not sufficient to cover production costs and ultimately resulting in the closure of the business.

It is worth noting that in the Minas Gerais region there is Piscicultura AquaMinas, which has a laboratory for the production of native fish with production and sale of fingerlings of the most varied species, such as tilapia, carp, lambari, pacu and other species (AQUAMINAS, [sd]). There is also the Association of Aquaculturists and Specialized Companies of the State of Minas Gerais, that

collaborates in the sector's production chain, providing expansion and technical assistance and encouraging the development of sustainable, rational and modern activities throughout the state's production chain.

Finally, even with the reports above, it is clear that there is a lack of institutions and technical assistance, and also market limitations that result in the non-expansion of fish farming (Brandão, 2018). The lack of specific public policies aimed at the sector, high production costs, particularly feed, and insufficient access to available technologies limit the expansion of the activity throughout the national territory (Kubitza, 2015; Casotti, Batista & Freitas, 2017). Therefore, to promote the expected expansion, it is crucial to promote actions that would boost aquaculture, through more affordable prices and highlighting its importance and advantages (Brandão, 2018).

4 CONCLUSIONS

By reason of the disaster that occurred in the Espírito Santo and Minas Gerais regions as consequence of human action, this study brought important data on the current situation of aquaculture farmers, addressing economic, social, production and installed infrastructure issues. From the present study, it was found that among the most commonly bred types of fish, tilapia has the greatest prominence due to its ease of reproduction, adaptability and survival, being cultivated mostly in nurseries, due to the advantages it provides, such as food and observation of fish and lower labor costs. It is noteworthy that 85% of the aquaculturists consider carrying out the process *in natura*, that is, it corresponds to food that has not undergone any industrial process.

In general, the majority of aquaculturists have a low level of education, with primary education being the predominant maximum level of education in the three regions. As in other locations in Brazil, tilapia (*Oreochromis sp*.) accounts for the majority of crop production, being a species with wide adaptability to temperature variations, facilitating management, in addition to being able to be produced in different structures and systems. It is worth remembering that tilapia is an invasive exotic species, which reinforces the need for precautions regarding the escape of

individuals in non-confined environments, in order to avoid future environmental problems. Production is predominantly intended for commercialization, which occurs without being associated with an adequate production chain, with the fish being sold most of the time without any type of processing. In general, aquaculturists in the Doce river channel reported the need to carry out another income-generating activity due to the challenges faced in aquaculture, especially after the collapse of the Fundão dam. Among the challenges mentioned are the scarcity of good quality water resources, the high cost of inputs and electricity, as well as the lack of reliability among consumers in relation to fish, who often associate fish produced in fish farms with those found in the Doce river and they end up not consuming for fear of contamination.

It is important to highlight that aquaculture activity is not just a form of production, but is also part of rural development, in addition to being directly associated with cultural aspects of the municipalities located in the Doce river basin. In this context, intervention for the benefit of aquaculturists through public policies and actions by the public and private sectors is essential, given the current state of the activity.

Although the research focuses on the socioeconomic characterization of communities affected by the environmental disaster in the Doce River Basin, it correlates with Production Engineering by analyzing data that helps identify production bottlenecks, inefficiencies, and improvement opportunities through mapping the fish production structure, including its distribution and commercialization. The study further contributes by identifying environmental challenges, providing subsidies for public policies and efficient management models. Additionally, the research demonstrates how an environmental disaster can directly impact a production chain that sustains local populations.

REFERENCES

ALMEIDA JÚNIOR, C. A. M. d. **A aquicultura nas microrregiões Bragantina e do Salgado Paraense, Amazônia Oriental (Pará, Brasil)**. 2012. Dissertação (Mestrado) – Universidade Federal Rural da Amazônia, Belém, 2012. Disponível em: https://repositorio.ufra.edu.br/jspui/handle/123456789/333. Acesso em: 21 ago. 2024.

ANDRADE, A. S. Aquicultura Brasileira: A visão do Ministério da Agricultura, Pecuária e Abastecimento a partir do Sistema de Registro Geral da Pesca e Aquicultura. **Research, Society and Development**, v. 9, n. 10, p. e2759108398, 26 set. 2020. DOI: http://dx.doi.org/10.33448/rsd-v9i10.8398.

AQUAMINAS**. Produção e venda de alevinos**. Disponível em: http://pisciculturaaquaminas.com.br/. Acesso em: 26 ago. 2024.

BIERNACKI, P.; WALDORF, D. Snowball Sampling: Problems and Techniques of Chain Referral Sampling. ***Sociological Methods & Research****,* v. 10, n. 2, p. 141-163, 1981. DOI: https://doi.org/10.1177/004912418101000205.

BRANDÃO, C. d. S. **Perspectivas do desenvolvimento da piscicultura no Brasil: Um enfoque na produção de tilápias nos últimos dez anos**. 2018. Trabalho de Conclusão de Curso (Bacharelado) – Universidade Federal da Bahia, Salvador, 2018. Disponível em: https://repositorio.ufba.br/handle/ri/25945. Acesso em: 17 ago. 2024.

BRASIL**.** Ministério da Pesca e Aquicultura. **Balança Comercial do Pescado**. Ministério da Pesca e Aquicultura, 2009. Disponível em: https://www.pesca.sp.gov.br/. Acesso em: 17 ago. 2024.

BRASIL**.** Ministério da Pesca e Aquicultura. **Aquicultura brasileira cresce 6,2% em 2023 e alcança 655 mil toneladas**.. Ministério da Pesca e Aquicultura, 2024. Disponível em: https://www.gov.br/mpa/pt-br/assuntos/noticias/producao-aquicola-aumenta-16-no-brasil-e-gera-r-10-2-bilhoes-em-2023. Acesso em: 10 out. 2024.

BRASIL**.** Ministério da Pesca e Aquicultura. **Boletim estatístico de pesca e aquicultura do Brasil**. Ministério da Pesca e Aquicultura, 2024. Disponível em: https://www.gov.br/mpa/pt-br. Acesso em: 17 ago. 2024.

BRAZIL**. Funai Geoprocessamento**. Disponível em: http://www.funai.gov.br/index.php/shape. Acesso em: 26 ago. 2024.

CARDOSO, R. S. Caracterização socioeconômica da aquicultura ornamental na região da Zona da Mata Mineira. ***Boletim do Instituto da Pesca****,* v. 38, n. 1, p. 89-96, 2012. Disponível em: https://institutodepesca.org/index.php/bip/article/view/947/927. Acesso em: 09 set. 2024.

CASOTTI, R. F.; BATISTA, B. C.; FREITAS, R. R. de. Análise dos elos produtivos e aplicação do método de análise dos modos e efeitos de falhas (FMEA) na pesca artesanal no norte do Espírito Santo, Brasil. **Revista Produção Online**, *[S. l.]*, v. 17, n. 4, p. 1111–1133, 2017. DOI: 10.14488/1676-1901.v17i4.2407.

COSTA, G. B. R. DA *et al.* Rompimento da barragem em Brumadinho: um relato de experiência sobre os debates no processo de desastres. **Saúde em Debate**, v. 44, p. 377–387, 2020. DOI: https://doi.org/10.1590/0103-11042020E226

DE PAULA, C. Q. Conflitos por território na pesca artesanal brasileira. **Revista NERA,** v. 23, n. 51, p. 180-204, abr. 2020. DOI: https://doi.org/10.47946/rnera.v0i51.6453

EPAMIG. Empresa de Pesquisa Agropecuária de Minas Gerais. **Diagnóstico da piscicultura na região de Morada Nova de Minas**. Belo Horizonte, 2009. Disponível em: https://livrariaepamig.com.br/wp-content/uploads/2023/02/diag_da_piscicultura_na_reg_de_morada_nova_de_minas.pdf. Acesso em: 17 ago. 2024.

FONSECA, R. A. *et al.* Aquicultura: Impactos ambientais negativos e a mitigação com práticas agroecológicas. **Tópicos em recuperação de áreas degradadas**, 2021. DOI: https://doi.org/10.4322/mp.978-65-991393-6-9.c2

FRANCO, I.; ARAÚJO, A. R. D. R.; FRANKE, C. R. Aspectos Socioambientais da Aquicultura na Região do Baixo São Francisco, Sergipe, Brasil. **Revista Meio Ambiente e Sustentabilidade**, v. 14, n. 7, 1 out. 2018. DOI: https://doi.org/10.22292/mas.v14i7.824.

GONÇALVES, E.; VESPA, T.; FUSCO, N. Tragédia Evitável. ***Revista Veja****,* v. 48, n. 46, p. 70-71, 2015.

INCAPER. Instituto Capixaba de Pesquisa, **Assistência Técnica e Extensão Rural**. Aquicultura. Disponível em: https://incaper.es.gov.br/aquicultura. Acesso em: 26 ago. 2024.

KUBITZA, F.; CAMPOS, J. L. Aquicultura no Brasil: Conquistas e Desafios. ***Panorama da Aquicultura****,* v. 25, n. 150, p. 11-13, 2015.

LIMA, C. A. S. **Caracterização e diagnóstico do perfil socioeconômico da piscicultura no estado do Amazonas**. 2018. Dissertação (Mestrado) – Universidade Federal do Amazonas, Manaus, 2018. Disponível em: https://tede.ufam.edu.br/handle/tede/6231. Acesso em: 10 fev. 2024.

MAZZARINO, J. M. *et al.* Governança e gestão comunitária das águas. ***Ciência E Natura****,* v. 42, p. e59, 2020. DOI: https://doi.org/10.5902/2179460X36394.

MYERS, N. *et al.* Biodiversity hotspots for conservation priorities. ***Nature****,* v. 403, p. 853-858, 2000. DOI: https://doi.org/10.1038/35002501.

OLIVEIRA, A. S. **Caracterização socio-ambiental da piscicultura em tanques-rede no município de Guapé**. 2011. Dissertação (Mestrado) – Universidade Jose do Rosario Vellano, Belo Horizonte, 2011. Disponível em:

ORGANON. **Núcleo de Estudo, Pesquisa e Extensão em Mobilizações Sociais.** Impactos socioambientais da ruptura da barragem de rejeitos da Samarco no Espírito Santo**,** 2015**.** Disponível em: https://www.ufes.br/sites/default/files/anexo/relatorio_de_impactos_organon.asd_.pdf . Acesso em: 06 mai. 2024.

OSTRENSKY, A.; BOEGER, W. A. Principais problemas enfrentados atualmente pela aquicultura brasileira. **Organização das Nações Unidas para Agricultura e Alimentação**, p. 135-158, 2008. Disponível em: https://www.fao.org/fishery/docs/DOCUMENT/aquaculture/sect_study_brazil.pdf. Acesso em: 06 mai. 2024.

PÉREZ, M. S.; GÓMEZ, J. R. M. Políticas de desenvolvimento da pesca e aquicultura: Conflitos e resistências nos territórios dos pescadores e pescadoras artesanais da vila do Superagüi, Paraná, Brasil. **Sociedade & Natureza**, v. 26, n. 1, p. 35–47, jan. 2014. DOI: 10.1590/1982-451320140103.

RANA, K. J. Guidelines on the collection of structural aquaculture statistics: Supplement to the Program for the world census of agriculture 2000. 1. ed., v. 1. **FAO**, 1997. Disponível em: https://openknowledge.fao.org/server/api/core/bitstreams/98e54c40-4b37-42d6-927f-cd7150bc1ba2/content. Acesso em: 05 mai. 2024.

REZENDE, F. J. W. Perfil da aquicultura no Estado do Acre. ***Amazônia: Desenvolvimento***, v. 4, n. 7, p. 167-180, 2008. Disponível em: https://www.bancoamazonia.com.br/component/edocman/revista-amazonia-ciencia-e-desenvolvimento-edicao-07/viewdocument/1862. Acesso em: 10 abr. 2024.

RODRIGUES, L. S. *et al.* Panorama da aquicultura no Brasil: desafios e oportunidades. **Banco Nacional de Desenvolvimento Econômico e Social**, 2012. Disponível: https://web.bndes.gov.br/bib/jspui/handle/1408/1524. Acesso em: 10 abr. 2024.

ROTTA, M. A. Diagnóstico da piscicultura na Bacia do Alto Taquari-MS. ***Embrapa Pantanal-Boletim de Pesquisa e Desenvolvimento (INFOTECA-E)***, 2003. Disponível em: https://www.infoteca.cnptia.embrapa.br/bitstream/doc/786918/1/BP40.pdf. Acesso em: 10 abr. 2024.

SASSINE, V**.** Laudo aponta que o rio Doce estará sujeito a condições imprevisíveis. ***O Globo***, 2015. Disponível em: http://oglobo.globo.com/brasil/laudo-aponta-que-rio-doce-estara-sujeito-danos-imprevisiveis-18378346. Acesso em: 26 ago. 2024.

SCHULTER, E. P.; FILHO, J. E. R. V. Evolução da piscicultura no Brasil: Diagnóstico e desenvolvimento da cadeia produtiva de tilápia. ***RePEc: Research Papers in Economics***, 2017. Disponível em: https://www.econstor.eu/bitstream/10419/177544/1/td_2328.pdf. Acesso em: 26 ago. 2024.

SILVA, J. P. S. Impactos ambientais causados por mineração. ***Revista Espaço da Sophia***, v. 8, n. 1, p. 1-13, 2007. Disponível em: https://doi.org/10.5902/2236130841705.

SILVA, J. A. **Caracterização da aquicultura familiar nas mesorregiões: Marajó e nordeste paraense, Amazônia oriental-Brasil.** 2023. Dissertação (Mestrado) – Universidade Federal Rural da Amazônia, Belém, 2023. Disponível em:

https://repositorio.ufra.edu.br/jspui/handle/123456789/1839. Acesso em: 05 mai. 2024.

VALENTI, W. C. Aquicultura sustentável. In: ***12º Congresso de Zootecnia da Associação Portuguesa dos Engenheiros Zootécnicos,*** Vila Real, Portugal, p. 111-118, 2002. Disponível em: https://www.caunesp.unesp.br/Home/publicacoes/cpil_valenti_aquicultura-sustentavel.pdf. Acesso em: 09 abr. 2024.

VIANA, D. C. *et al.* Pisciculture productive chain in the state of Maranhão. ***Ciência E Natura,*** v. 44, p. e39, 2022. DOI: https://doi.org/10.5902/2179460X64832.

VIANA, J. P. Teria a produção da aquicultura na Bacia do Rio Doce sido impactada pelo rompimento da Barragem de Fundão em Mariana (Minas Gerais)? ***IPEA,*** v. 1, n. 1, p. 131-142, 2020. Disponível em: https://repositorio.ipea.gov.br/server/api/core/bitstreams/1fe0744e-a93a-47ae-85b3-ab6e023d5944/content. Acesso em: 17 ago. 2024.

ZACARDI, D. *et al.* Caracterização socioeconômica e produtiva da aquicultura desenvolvida em Santarém, Pará. ***Acta of Fisheries and Aquatic Resources,*** p. 102-112, 2017. DOI: https://doi.org/10.46732/actafish.2017.5.3.102-112

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