Fronteiras: Journal of Social, Technological and Environmental Science
http://periodicos.unievangelica.edu.br/fronteiras/
ISSN 2238-8869

Article

Fundão Dam Disaster's Consequences: A Characterization Study of Fishery Communities and Their Current Challenges on Rio Doce

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RESUMO

O trabalho caracterizou o perfil da pesca e das comunidades pesqueiras, bem como consequências que o rompimento da barragem de Fundão, Mariana, Minas Gerais, teve sobre a pesca artesanal na bacia do Rio Doce. Para tanto foram aplicados 1.998 questionários semiestruturados em 42 municípios ao longo do Rio Doce e sua foz, utilizando o método bola-de-neve e entrevistando ao menos 20% do total de pescadores e pescadoras nas comunidades pesqueiras. Os questionários abordaram questões socioeconômicas e as mudanças na atividade pesqueira, e buscaram trazer informações sobre os impactos sofridos e eventuais mudanças no perfil socioeconômico. Como resultado, o perfil dos pescadores indica a predominância de homens, com idade média de 49 anos, com grande experiência na atividade pesqueira e com ensino fundamental. Ocorre a pesca de pequena escala, muitas vezes desembarcada, especialmente no alto e médio Rio Doce. Quanto as principais consequências do rompimento, nota-se o abandono da atividade, especialmente no alto e médio Rio Doce e redução da renda. A contaminação e a redução do estoque pesqueiro aparecem como um dos principais problemas, e entre as expectativas dos atores locais há o desejo de retornar à atividade. Percebe-se, por fim, que seis anos após o ocorrido as comunidades pesqueiras ainda sofrem com as consequências do rompimento e não houve recuperação da atividade. Esses resultados são importantes para ações de reparação atingirem seu objetivo.
Palavras-chave: perfil socioeconômico, impacto, pesca de pequena escala, desterritorialização, vulnerabilidade

ABSTRACT

This study characterized the profile of fishing and fishing communities, as well as the consequences that the Fundão dam break disaster in Mariana, Minas Gerais, had on artisanal fishing in the Rio Doce Basin. A total of 1,998 semi-structured questionnaires were applied in 42 municipalities along the Rio Doce, using the snowball sampling method and interviewing at least 20% of the total number of fishers in the fishing communities. The questionnaires addressed socioeconomic issues and changes in fishing activity, aiming to gather information on the impacts experienced and possible changes in the socioeconomic profile. As a result,

Submissão: 15/10/2023 Aceite: 22/07/2025 Publicação: 04/09/2025

v.14, n.3, 2025 • p. 42-56. • DOI http://dx.doi.org/10.21664/2238-8869.2025v14i3.7122

the profile indicates the predominance of men, with an average age of 49 years, with extensive experience in fishing activities and primary education level. Small-scale fishery often occurs onshore, especially in the upper and middle reaches of the Rio Doce. Regarding the main consequences of the disaster, there is evidence of abandonment of fishing activities, especially in the upper and middle reaches of the Rio Doce, and a reduction in income. Pollution and reduction of fish stocks appear as some of the main problems, and among the expectations of local actors is the desire to return to fishing activities. Finally, it is evident that until now, fishing communities still suffer from its consequences, and there has been no recovery from fishing activities. These results are important for reparation actions to achieve their goal.
Keywords: socioeconomic profile, impact, small-scale fishery, deterritorialization, vulnerability.

Introduction

Artisanal fishing is one of humanity's oldest activities (Oliveira et al. 2017, Zacardi 2015, Santos et al. 2012) and currently represents around 40% of world fishing production, generating around 37 million tons of fish, of which marine fishing is responsible for 68% of production and continental fishing 32%. Furthermore, it directly employs 60 million people throughout its production chain (FAO 2020).

In Brazil, according to fishing registration data in 2015 (last survey), the number of artisanal fishers corresponds to around 99% or 1.077 million workers in the fishing sector, 43% of which are coastal and 57% continental (Cunha-Lignon et al. 2022). Among artisanal fishers, the majority are professionals (70.2%), but there is still a significant portion of 29.8% subsistence fishers, that is, they fish for their own consumption (Campos & Chaves 2016).

Despite the countless transformations in society over time (Pacheco & Mendonça 2012, Weiss 2019, Kooiman et al. 2008, Dowbor 2014), some of the difficulties encountered in the fisher's life remain: low profitability at the time of commercialization (Behrmann 2017); exclusionary legislation, due to low education and difficulty in accessing information by fishers (Amanajás 2018); lack of installed physical structure; ineffective union support (Silva et al. 2015); disputes over fishing territory caused by conflicts or anthropogenic impacts (Paula & Silva 2020).

Considering the manifold disruptions to the activities and traditional ways of life of local communities, it is worth noting the impact stemming from the breach of the Fundão mining tailings dam (20°12'30.7"S 43°27'43.8"W), located in the municipality of Mariana, state of Minas Gerais (05/11/2015). One of the largest recorded anthropogenic disasters that has ever occurred in the world, and certainly the largest ever observed in the country (Hatje et al. 2017, Lima et al. 2020). Data released by the Brazilian Institute of Environment and Natural Resources (IBAMA, 2015) showed a negative impact on ecosystems, affecting fauna and flora, in addition to having an impact on the socioeconomic aspects of the regions that were struck (Ribeiro et al. 2019). In this way, it caused enormous losses to riverside communities that depend on the river for water supply, irrigation, fishing, tourism, sport, or leisure.

The mud released by the collapse of the Fundão dam caused a trail of destruction across collective territories occupied by rural and riverside populations in the Rio Doce Valley and its tributaries. Thus, the living and working conditions of the populations were compromised, limiting local sources of income generation and threatening the material and immaterial conditions for the survival of these individuals (Wanderley et al. 2016).

Following the collapse of the Fundão tailings dam, the ichthyofauna of the Doce River basin experienced drastic and persistent impacts. Studies indicate a significant reduction in trophic diversity and ecological stability in the affected stretches, especially in areas closest to the dam breach (Fráguas et al. 2025). The disaster also caused mass fish mortality and a partial replacement of native species by exotic ones, which began to occupy broader trophic niches—possibly due to their greater ability to exploit resources released by environmental degradation (da Silva et al. 2024). Fish populations started to exhibit signs of physiological stress and bioaccumulation of heavy metals in their tissues, such as iron, cadmium, copper, and manganese (Maraschi et

al. 2022), compromising not only the health of the organisms but also the food security of human communities that rely on these resources.

Regarding fishing, traditional communities along the river basin and in the estuarine region were deeply affected. The suspension of fishing activities, fish contamination, and the loss of market value of the catch severely impacted artisanal fishers (Oliveira et al. 2020, Jankowsky et al. 2024, Dadalto et al. 2020).

As already reported, the Rio Doce basin serves as the main means of subsistence for fishers, as it is through fishing that these individuals earn a living for their families. The socioeconomic and environmental consequences generated by the disaster brought significant changes to fishers who depended on natural resources (Viana 2017), and affected the various dimensions linked to fishing activity, from obtaining food to collective leisure activities (Ibrahin 2021). However, even though the region is recognized for its fish fauna diversity, there are few studies on fishing activity in the continental area, which is better characterized in the coastal zone of the river basin (Jankowsky et al. 2021).

Thus, given the relevance of fishing activity and the need to understand the socioeconomic situation of fishers after the environmental disaster, resulting from the collapse of the Fundão dam in Mariana/MG, the present study aimed to present the current socioeconomic profile of the actors involved, a characterization of fishing activity and the changes that have occurred, as well as the main problems and expectations of the sector.

Materials and Methods

Between May 2021 and April 2022, 1,998 semi-structured questionnaires were administered to fishermen and fisherwomen in 42 municipalities along the Rio Doce channel and at its mouth (Figure 1). To facilitate analysis, the municipalities were divided into 1) upper Rio Doce: Mariana; Barra Longa; Ponte Nova; Rio Doce; Santa Cruz do Escalvado; Sem-Peixe; Rio Casca; São José do Goiabal; São Pedro dos Ferros e Raul Soares; 2) middle Rio Doce: São Domingos do Prata; Dionísio; Córrego Novo; Pingo D'água; Marliéria; Bom Jesus do Galho; Timóteo; Caratinga; Ipatinga; Santana do Paraíso; Ipaba; Belo Oriente; Bugre; Iapu; Naque; Periquito; Sobrália; Fernandes Tourinho; Alpercata; Governador Valadares; Tumiritinga; Galiléia; Conselheiro Pena; Resplendor; Itueta; e Aimorés; 3) lower Rio Doce: Baixo Guandu; Colatina; Marilândia; Linhares; Aracruz; e Fundão (Figure 1). In the coastal region of Linhares and Aracruz, the fishing exclusion area explained above is present (MPF, 2016).

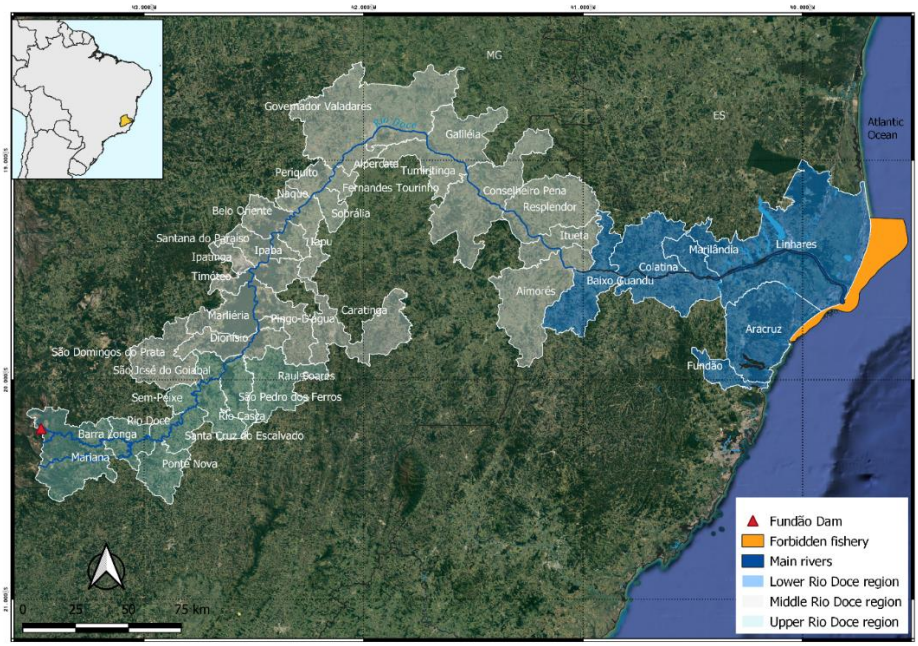

Figure 1. Study area showing the upper and middle Rio Doce region in Minas Gerais and lower Rio Doce in Espírito Santo. Source: Authors (2025).

Aiming for a significant sampling, we sought to achieve a minimum random sample of 20% of the total number of fishers in fishing communities, covering both genders. In communities where the number of fishers was less than 30 individuals, 100% of the community was interviewed (Barbetta 2007). The minimum number of fishers to be interviewed in each community was calculated from the total number of fishers obtained from the most experienced fishers and local entities. The location of fishers was done using the snowball method or chain of informants, in which, from one individual, others are indicated, increasing the sample based on knowledge and recognition of peers (Biernacki & Waldorf 1981).

For the interviews, people recognized as fishers were considered even if, after the dam broke, they stopped fishing or selling their products. In data collection, a semi-structured questionnaire was used, addressing questions about socioeconomics, and changes in fishing activity. All information was analyzed using descriptive statistics, and to present the main problems and expectations, Wordcloud was used, since these questions were opening questions, capturing the speech of the people interviewed.

This study is part of the "Socioeconomic Characterization of Fishing and Aquaculture Activity in the Rio Doce and the coast of Espírito Santo Project" and is carried out in conjunction with the Federal University of Espírito Santo and the Fisheries Institute of the State of São Paulo. It was approved by the Ethics Committee of the Federal University of Espírito Santo (authorization 4,622,996) and registered in the National System for Management of Genetic Heritage and Associated Traditional Knowledge (registration A3803D3).

Results and Discussion

Profile of people involved in fishing activity

As observed in other studies on the profile of people involved in fishing activities (Mendonça et al. 2017, Oliveira et al. 2020, Rabelo et al. 2017), fishers are mostly men (65.71%), aged average of 49.18 years (DV=15.37 years), primary education level (65.56%). However, in each region there is variation around this general picture (Figure 2 A, B, C).

Corroborating the above, studies in the north and south of Brazil also address the predominance of adults and/or elderly people in artisanal fishery; the analyzes carried out in this research showed similar results, suggesting that more and more young people are seeking other means of subsistence aside from fishing (Harayashiki et al. 2011, Santos et al. 2011). For example, a study carried out with young fishers reported that 39% of those interviewed admitted to having abandoned their studies due to incompatibility between fishing and school schedules. This is because, from a very early age, they need to contribute to the family income (Vieira et al. 2013). The results of the low education level of those interviewed in this study corroborate this statement, suggesting that although the participation of individuals aged between 12 and 28 years in fishing is low, it is still present, and may be one of the factors in school dropout.

Regarding the younger age group, it is noteworthy that the upper Rio Doce region showed the almost absence of fishers up to 20 years of age. This is the region with the average number of older people and the lowest participation of young people (Figure 2 C). When comparing with a previous study, carried out in 2009 in the middle Rio Doce region (Lima et al. 2010), it is possible to observe increase of the average age of fishers; previously it was close to 35 years old, and in the present study it is close to 49 years old (Figure 2 C).

The length of experience in the activity was 31.19 years (DV= 16.24 years) in average, although this value is influenced especially by the upper Rio Doce region, which has a length of experience close to 35 years (Figure 2 D). The length of experience above 30 was also observed in studies in the north of the country (Rabelo et al. 2017, Zacardi et al. 2017, Nascimento et al. 2020). These profile data show the presence of older and more

experienced fishers in the upper Rio Doce region, with a decreasing gradient in the middle and lower Rio Doce, the latter being the region with younger fishers and those with less experience in the activity.

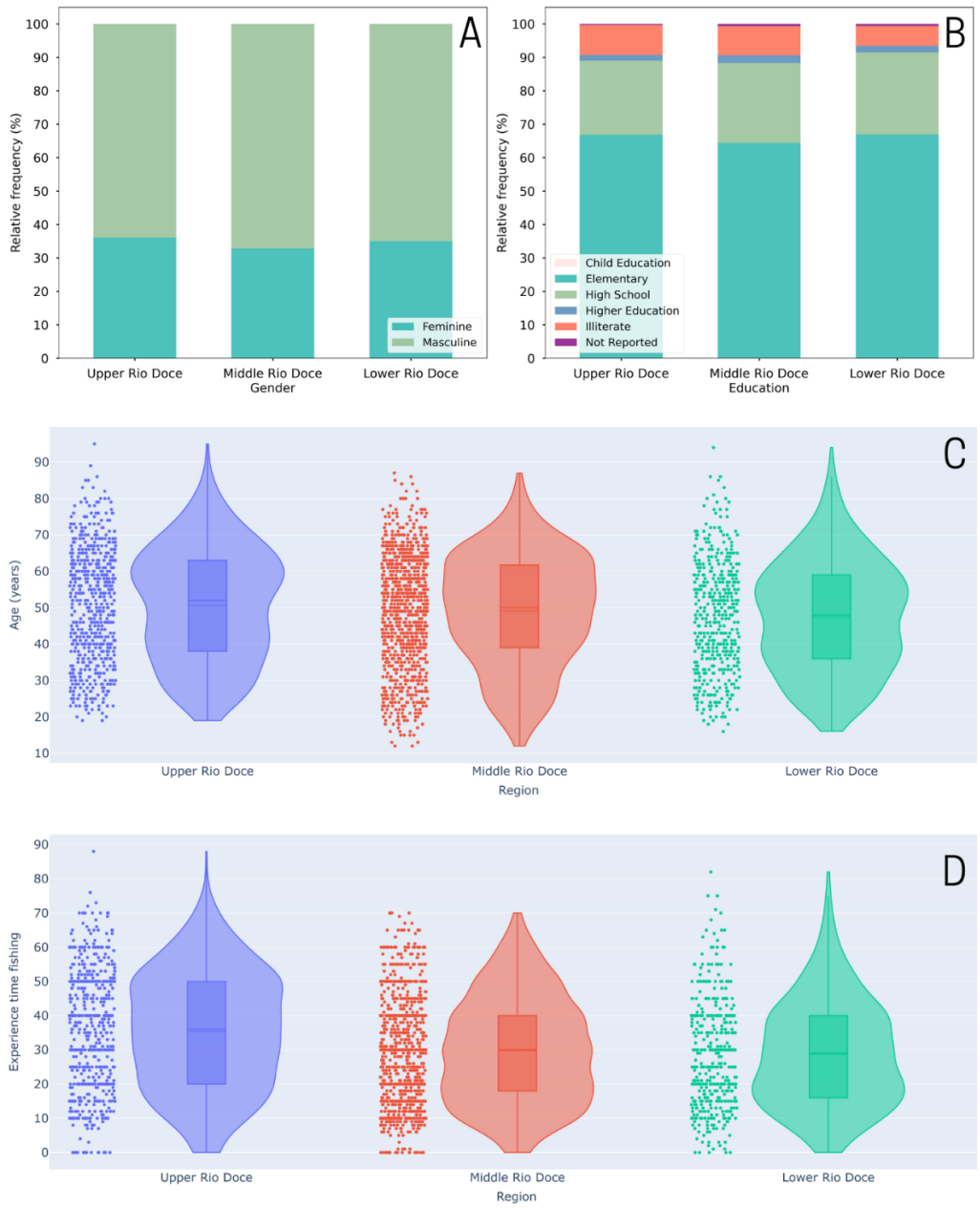

Figure 2. Summary of the characteristics of artisanal fishers from the upper, middle, and lower Rio Doce. Figure (A) relative frequency of genres; (B) relative frequency regarding level of education; (C) violin graph and the dispersion of responses regarding the age of the interviewees; (D) violin graph and the dispersion of responses regarding time of experience in fishing activity. Source: Authors (2025).

Fishing activity

A significant portion of fishers from the upper and middle Rio Doce practiced landed fishing, 91% and 72%, respectively. In both regions, the equipment "bamboo pole", "reel" and "casting net" were the most cited, although with different relative frequencies of citations: 34.70%; 20.69% and 7.90% at the upper Rio Doce and 19.13%; 15.44% and 12.97% in the middle Rio Doce.

As for the vessels used, they can be characterized in the upper Rio Doce with an average length of 3.60 ± 1.14 meters, being made of aluminum (36.67%), fiber (26.67%) and wood (13.33%), 100 % single, full beam,

with gross tonnage of up to 5 AB, and crew ranging from 2 to 4 people (78.38%). Regarding the power of the engines, it was possible to identify that the average of the engines is equivalent to 12.25 ± 9.05 HP. Furthermore, regarding load capacity, there is a variation from 120 kg to 1200 kg.

In the region of the middle Rio Doce, it was found that the vessels have an average length of 4.83 ± 1.70 meters, being made of aluminum (29.91%), fiber (11.21%) and wood (57.01%); 99.53% without superstructure, a full beam, with a gross tonnage of up to 5 AB, and a crew of 2 to 4 people (74.91%). The power of the engines has an average of 16.60 ± 37.35 HP. This high standard deviation is because in the municipality of Governador Valadares there is an engine with a power of 160 HP, higher than the others identified in this study. Furthermore, the load capacity of vessels in this region usually varies from 100 kg to 1500 kg.

Conversely, in the lower Rio Doce region, most of the activity is shipped (79%). It was found that the vessels are slightly larger, with an average length of 6.44 ± 2.20 meters, being made of aluminum (31.79%), fiber (4.05%) and wood (64.16%); 82, 69% without superstructure, full beam (82.69%), with a gross tonnage of up to 5 AB (76.92%) and a crew of 2 to 3 people (72.12%). There are some variations in the type of vessels between municipalities, with the fleet with the largest number of large vessels, with cabins and closed decks, being in Aracruz, mainly present in the community of Santa Cruz. The engine power has an average of 27.67 ± 45.24 HP. Here again the high standard deviation occurs due to differences in fleets, especially in Aracruz.

Furthermore, the load capacity of vessels in this region usually varies from 80 kg to 10,000 kg. Regarding the devices used in this region, it was found that the most used equipment are "gillnets" (46.90%) and various lines (26.86%), having been registered in all municipalities, as well as "longlines". In a study with the fishing community of Linhares, also observed the predominance of wooden vessels (Oliveira et al. 2020). However, they recorded vessels that were slightly larger than those found in the present study.

It was possible to notice, when comparing the characteristics related to the typology of the vessels, among the three regions, that the vessels have similar characteristics, as they are small. But there are exceptions with the fleet in Aracruz, where there is a community with vessels with greater engine power, length, deck, and hold, differing from the other vessels. In relation to fishing equipment, the continental area of the upper and middle Rio Doce shows similarity, as the main devices used by fishers are the "bamboo rod", "reel" and "net". In a study carried out in 2008, the introduction of "gillnets" and "longlines" in the region of the middle Rio Doce was seen as a threat to the conservation of the species, clashing with the commonly practiced line fishing (Lima et al. 2010). In the lower Rio Doce, in the coastal region, "gillnets" and "lines" are more present, which had already been reported by studies in Linhares, where gillnets were the most common devices (Pinheiro & Joyeux 2007).

Changes occurred

Comparing the data on the changes that occurred before and after the collapse of the Fundão dam (Figure 3 A and B) it is possible to note that until 2015 there were few notable changes in fishing, with an emphasis on changes in fishing areas in the lower Rio Doce. It is known that the Rio Doce basin, despite being important for conservation (Marchese, 2015; Myers et al., 2000) was already an anthropic river basin before the rupture, highlighting the occupation of river banks, dams (Carvalho et al. 2021) and the presence of species exotic to the ichthyofauna (Lima et al. 2010, Jankowsky et al. 2021, Fragoso-Moura et al. 2016). In this context, changes to target species and gear would be plausible. However, there was little record of changes during this period, the most cited being the change of fishing area in the lower Rio Doce region, where other studies already pointed to the pressure on artisanal fishing exerted by population density in the coastal zone, tourism, increase in fishing effort, presence of industrial and port activities (Knox & Trigueiro 2014).

Conversely, after the collapse of the Fundão dam, the regions of the upper and middle Rio Doce showed that most interviewees abandoned fishing activities. The total number of individuals who still carry out some activity related to fishing and have this activity as their main source of income, represents around 3.4% of the total number of interviewees, pointing out the impact that the rupture disaster had on the lives of these people, where approximately 96.6% of those interviewed ended up abandoning the connection they had with fishing as their main source of income.

The impact on the fish fauna immediately after the rupture in the Rio Doce was drastic, with high fish mortality (Viana 2017). Subsequently, studies have pointed to fish contamination years after the rupture (Vieira et al. 2022, Bonecker et al. 2022, Mourão et al. 2023, Fráguas et al. 2025), and the consequences of this loss of biodiversity need to be better studied. As a result, the marketing of fish began to face a lack of confidence on the part of the consumer in purchasing the product (Ribeiro et al. 2019). One justification that can confirm why income from fishing has a low percentage of participation in occupations is that the disaster that occurred in Mariana/MG, brought a loss of a dimension that was difficult to measure for families who had fishing as a source of income and survival (Ribeiro et al. 2019, Jankowsky et al. 2024). Thus, these individuals had to adapt to the new reality, seeking new means to survive, replacing fishing, which was previously their main occupation, and entering new activities in the job market.

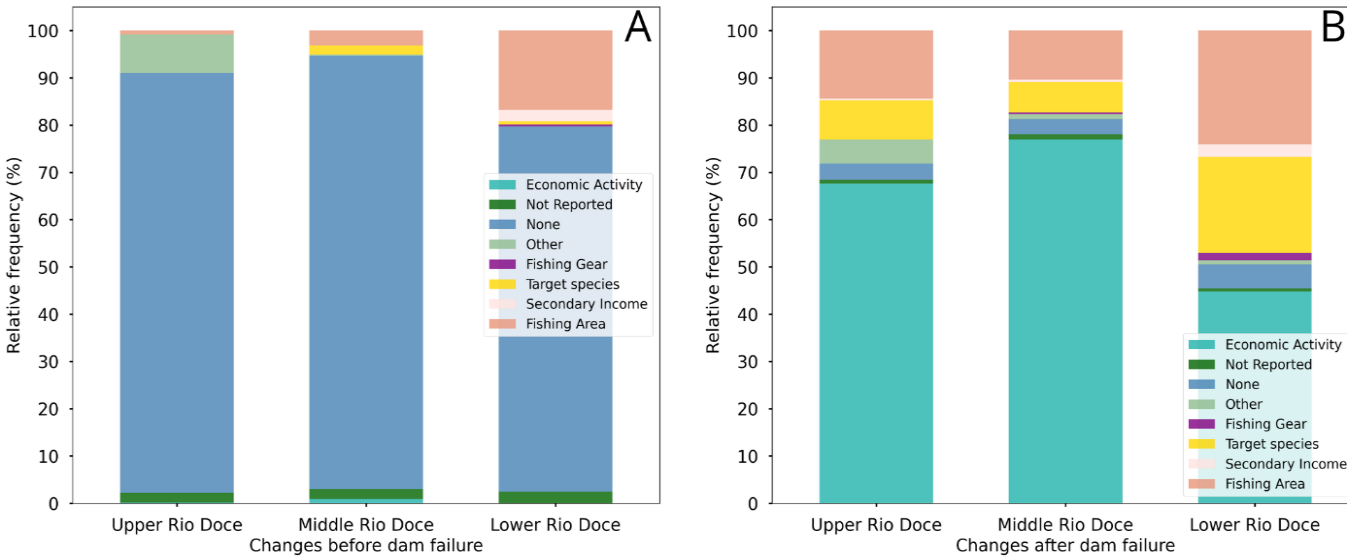

Figure 3. Changes in fishing activity occurring in the upper, middle and lower Rio Doce. Figure (A) relative frequency of changes that occurred before the collapse of the Fundão dam; (B) relative frequency of changes that occurred after the collapse of the Fundão dam. Source: Authors (2025).

In the lower Rio Doce region, 44.81% of those interviewed abandoned fishing, and 49.42% adopted some strategy to remain in the activity, such as adopting a second economic activity or changing: 1) the area of fishing, 2) of the gear and/or 3) of the target products (Figure 3 B). The presence of large lakes in the lower Rio Doce region stands out, with the passage of water from the Rio Doce isolated, seeking to avoid contamination. Thus, there are still some "available" fishing areas, and in the coastal region there are fishers with boats that manage to leave the fishing prohibition area, adopting fishing territory beyond the area at the mouth of the Rio Doce.

Looking at the region, the process of deterritorialization is noticeable, with the consequent loss of economic activities and subsistence. When fishing activity is maintained, it often requires the adoption of a low-specialized secondary source of income such as assisting in construction, delivery services, gardening

(Jankowsky et al. 2024). This process has been analyzed in other studies as a consequence of other projects that affect coastal and riverside communities (Silva & Cavalcante 2019, Paula & Silva 2020).

Another consequence to be analyzed in this context is the monthly income of what was once the fishing community. Even adopting other activities, in the middle and upper Rio Doce region the average monthly income was close to the minimum wage (considering the value of R$ 1,100.00 during the interview period). The few people who continued fishing have a lower income than those who managed to adopt another source of income, the most drastic situation being in the upper Rio Doce, where the average income of those who continued fishing was R$ 450.00 (Figure 4). Ribeiro et al. (2019) observed in Governador Valadares, in the middle of Rio Doce, the reduction in the income of fishers, who previously received between four and five minimum wages. In the present study, the income observed in this region was less than the Brazilian minimum wage (R$ 1,100), R$ 833.33. The lower Rio Doce shows a different scenario, with the average income exceeding one minimum wage – R$ 1,463.98 – and with fishers earning slightly higher income than those who abandoned the activity (Figure 4).

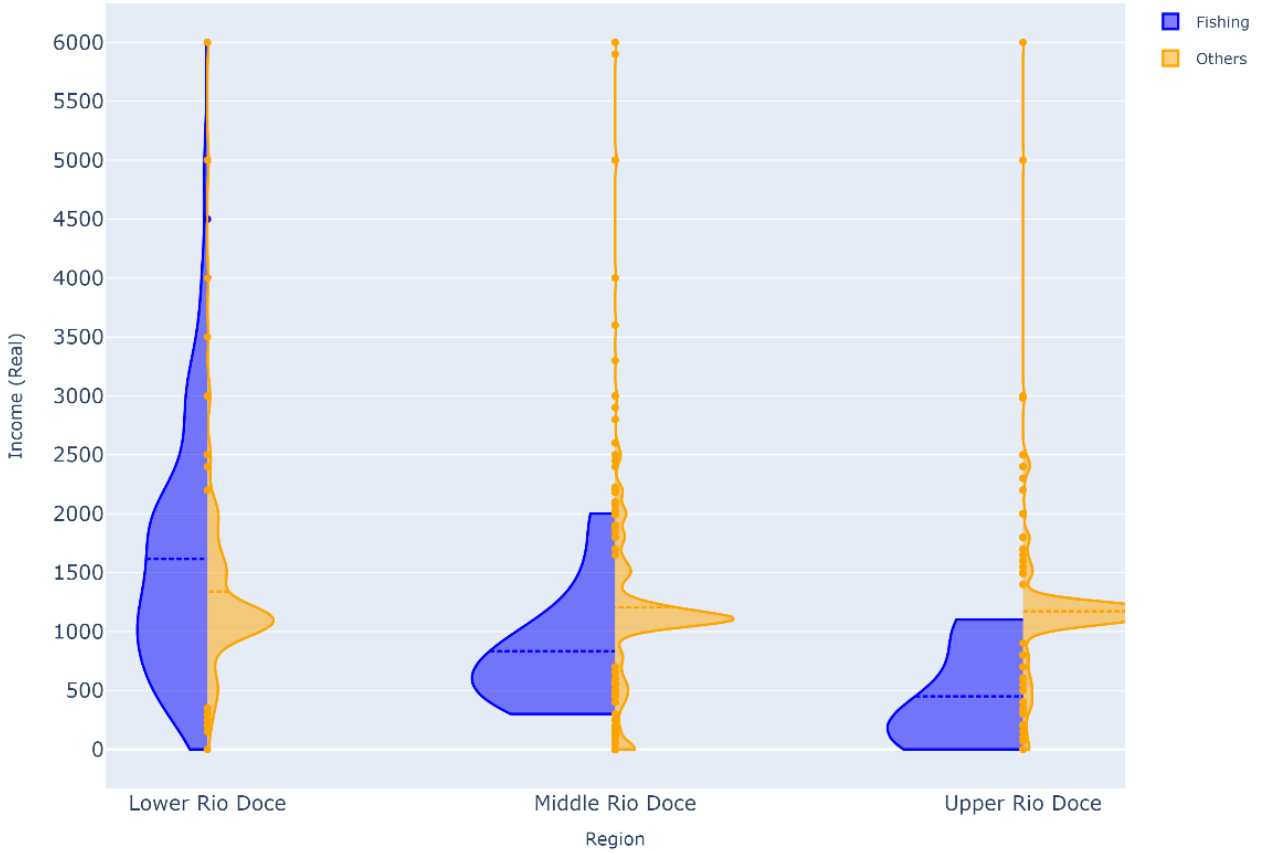

Figure 4. Violin graph with the monthly income reported by respondents in different regions. In each region, orange represents the income of people who stopped fishing and sought to adopt another activity and in green the income of people who continued fishing. Source: Authors (2025).

Problems and expectations

When asked about the main problems affecting fishing activity, the answers generated clouds of similar words, with the common and prominent words in the three regions being: fish, mud, contaminated, quantity, decreased, eat and income (Figure 5). This contributed to the qualification of the problem experienced, today resulting from the collapse of the Fundão dam, and it can be understood as the perception of a reduction in

the quantity of fish and income, risk of contamination and compromised fish consumption. The difficulty of commercialization, the risk of contamination and the reduction in income was also analyzed in the municipality of Linhares, in the lower Rio Doce region (Oliveira et al. 2020), which led many fishers to adopt a second economic activity, similar to the results found here (Figure 3 B).

Figure 5. Wordcloud about the problems related to fishing experienced by fishing communities in the different regions of the Rio Doce.

As for the expectations of those interviewed, they are largely focused on returning to fishing activities, hoping for the recovery of the river and the fish (Figure 6). The desire to return to fishing may be linked to the degree of satisfaction with the fishing activity carried out, a fact that has been pointed out in some studies, where the majority of interviewees are satisfied with the profession (Durgun et al. 2021, Seara et al. 2017). However, expressions "Has No Expectation", "Doesn´t have" or "None" also appears as a result in this study, showing the lack of perspective of returning to the old way of life. The perception that the environment will continue to be contaminated has already been analyzed in the lower Rio Doce region, four years after the collapse of the Fundão dam (Oliveira et al. 2020).

Figure 6. Wordcloud about expectations related to fishing reported by fishing communities in different regions of the Rio Doce.

Reflections on the Vulnerabilities of Fishing Communities

The testimonies of riverside communities regarding the abandonment of artisanal fisheries, the drastic drop in income, fish contamination, the collective sense of hopelessness about the future, and, in many cases, the complete abandonment of the activity, point to a perspective that goes beyond environmental impacts and reveals a process of social, economic, and cultural vulnerabilities.

Vulnerabilities is not merely exposure to risks, but the intensification of inequalities and the obstruction of the affected actors' capacities for resistance and reorganization (Acselrad et al. 2011). It can thus be associated with both structural factors (such as low levels of formal education) and contextual factors, such as the disaster itself (O'Brien et al. 2007). The environmental contamination and collapse of fish stocks disrupted local livelihoods—conditions compounded by the absence of institutional guarantees for rebuilding life and activity, or opportunities for territorial governance—thus revealing elements of dispossession (Bavinck et al. 2017).

The absence or sluggishness of public policies aimed at the effective reconstruction of fisheries has exacerbated this situation. The literature shows that, even after the disaster, the actions of public authorities remained fragmented, overly bureaucratic, and often insensitive to local realities (Jankowsky et al. 2021, Lyra 2019, Smith & Val 2020). Reparation processes were marked by conflict, generating widespread mistrust among those affected (Lyra 2019). The promise of a transparent and multilateral governance model often resulted in opacity, fragmentation, and exhaustion within the communities, further deepening institutional discredit and the sense of abandonment (Milanez et al. 2021). Despite the creation of structures such as the Renova Foundation, participation mechanisms were co-opted by corporate interests and shaped by a technocratic logic disconnected from the knowledge and needs of those affected.

The accounts gathered in this study must be understood as part of a broader process of systemic vulnerabilities, in which the damage extends beyond ecological concerns (O'Brien et al. 2007). The disruption of artisanal fishing undermines the material subsistence of families and the continuity of sociocultural practices essential to collective identity, requiring public responses that go beyond assistance and promote environmental justice, territorial equity, and effective reparation.

As Milanez et al. (2021) suggest, post-disaster reconstruction processes must be designed based on genuinely participatory practices, with mechanisms for active listening, recognition of local knowledge, and the strengthening of territorial governance.

Final Considerations

It was clear that the disaster of the Fundão dam collapse had a significant impact on the communities in this region in various social spheres.

Regarding the education factor, it is possible to note that most of the people submitted to the questionnaire have primary education, a situation that can be explained by a possible school dropout when they are younger. This would justify the fact that adult and elderly individuals predominate in fishing work.

Unquestionably, the disaster that occurred caused losses to families who had fishing as their main source of income and survival. This situation worsened in a post-disruption scenario since these individuals had to look for new means of support. They still have the income, but it is often less than the minimum wage.

Considering the results obtained through the questionnaires, it can be concluded that, based on this socioeconomic characterization carried out, it is possible to understand the situation of these communities that were affected. Therefore, we can say that the social sphere of these people was compromised, both in economic areas and in their quality of life.

Acknowledgements

To the fishers who voluntarily collaborate with this research. To the PMAP team for their work and dedication. The present work was carried out with funding from the Renova Foundation, as part of the fulfillment of the Conduct Adjustment Transaction Term (TTAC), through the Project for Fishery Monitoring Program, contract number 8600002299, developed by the Fisheries Institute and Federal University of Espírito Santo. The Renova Foundation is the entity responsible for the reparation of the damages caused by the collapse of the Fundão dam in Mariana (MG, Brazil). It is a non-profit organization, the result of a legal commitment called Transaction and Conduct Adjustment Term (TTAC); it did not play any role in the interpretation of the results or preparation of the manuscript. The content, analyses, and conclusions presented here are the sole responsibility of the authors. We also thank FAPES (Research Support Foundation of Espírito Santo), through the Researcher Capixaba Fellowship – EDITAL FAPES No. 06/2021, for the grant awarded to Prof. Dr. Rodrigo R. de Freitas.

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