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Seção de Artigos

RESILIENCE IN THE FACE OF DISASTER: ANALYZING THE TRANSFORMATION OF THE SOCIAL ECOLOGICAL SYSTEM OF THE QUILOMBOLA COMMUNITY OF DEGREDO AFTER THE FUNDÃO DAM FAILURE

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RESUMO

Em 5 de novembro de 2015, a barragem de Fundão, que pertencia à mineradora Samarco em Minas Gerais, Brasil, se rompeu e liberou rejeitos tóxicos de mineração que fluíram 660 quilômetros rio abaixo do rio Doce. Os rejeitos da mina destruíram assentamentos e ambientes locais rio abaixo, chegando ao Oceano Atlântico. A comunidade remanescente do Quilombo de Degredo, que faz fronteira com o Rio Doce e o Oceano, é um complexo sistema sócioecológico que foi diretamente impactado pelo desastre. Foi utilizado o referencial teórico de Elinor Ostrom (2009) para analisar os impactos do desastre nas questões sociais, ecológicas, econômicas, políticas e governamentais que ocorreram nesta comunidade após o desastre. Foram analisados fatores sociológicos do modo de vida da comunidade antes e depois do desastre, bem como características biofísicas do ambiente impactado pelo derramamento. Também avaliamos os efeitos da pesca de subsistência e na saúde humana, bem como quais medidas legais e reparadoras foram tomadas pelos órgãos responsáveis pelo desastre. Os impactos incluíram perdas no modo de vida ancestral da comunidade e nos costumes locais, dizimação da pesca e dos ecossistemas locais e impactos negativos duradouros na saúde humana.

Palavras Chaves: Sistemas Socioecológicos; Ostrom Framework; Rompimento da Barragem de Fundão; Comunidades tradicionais.

RESILIENCE IN THE FACE OF DISASTER: ANALYZING THE TRANSFORMATION OF THE SOCIAL ECOLOGICAL SYSTEM OF THE QUILOMBOLA COMMUNITY OF DEGREDO AFTER THE FUNDÃO DAM FAILURE

ABSTRACT

On November 5, 2015, the Fundão dam, which belonged to the mining company Samarco in Minas Gerais, Brazil, ruptured and released toxic mine tailings that flowed 660 kilometers down the Doce River. The mine tailings destroyed settlements and local environments down the river, eventually reaching the Atlantic Ocean. The remnant quilombo community of Degredo which borders the Doce River and the Ocean, is a complex socio-ecological system that was directly impacted by the disaster. The theoretical framework of Elinor Ostrom (2009) was used to analyze the impacts of the disaster on the social, ecological, economic, political, and governmental issues that occurred in this community after the disaster. Sociological factors of the community's way of life before and after the disaster were analyzed, as well as a biophysical characteristics of the environment impacted by the spill. We also evaluated the subsistence fishery and human health effects, as well as which legal and restorative measures were taken by the responsible bodies for the disaster. The impacts included losses in the community ancestral way of life and local customs, decimation of the fishery and local ecosystems, and lasting negative human health impacts.

Keywords: Socioecological Systems; Ostrom Framework; Failure of the Fundão Dam; Traditional Communities.

1 INTRODUCTION

According to Ailton Krenak, indigenous leader, environmentalist, philosopher, poet, and Brazilian writer from the Krenak indigenous ethnic group, his people live on the banks of the Doce River, which they call *Watú* (our grandfather). When Ailton was born, the river valley was beginning to be called the Steel Valley. "*That name was well suited because they contaminated the river with a toxic ore mud that, in addition to exploiting steel and other ores, poisoned the river and made it unviable for the families who live there"* (KRENAK, 2022).

The indigenous writer is referring to the environmental disaster that occurred in the city of Mariana, in the state of Minas Gerais, southeastern Brazil, resulting from the rupture of the retaining wall called Fundão, by the mining company Samarco, controlled by the company Vale and the Australian company BHP Billiton. The breach happened on November 5, 2015, releasing a slurry of mining waste that traveled for 660 kilometers down the Rio Doce, reaching the sea on November 22 in the village of Regência, state of Espirito Santo, affecting farmers, fishermen, indigenous peoples and quilombolas (SILVA, 2019). Perceived not only by the environmentalist Krenak, this disaster was one of the greatest environmental catastrophes related to large development projects in history. To mitigate and repair the damage caused by this disaster, it is necessary to prompt society and environmental entities about solutions. The environmental and social impacts caused by large projects in Brazil were justified by development policies, especially when related to energy demand and renewable energy, as in the case of hydroelectric plants (GOMES & SILVA, 2020). In the case of the mining industry, which creates the biggest environmental impacts in the state of Minas Gerais, the continuous demand for iron ore is still a reality because of the financial and social return, as well as being a large employer (LUCENA & SOUZA, 2021).

The Rio Doce region, due to its vast extent, contains numerous industrial development projects, for which social-ecological impacts can be examined. We identified the remnant quilombo community of Degredo as an example of a complex socio-ecological system that was directly impacted by the disaster. We seek to briefly describe socio-environmental aspects that configure the community as a region of transformation, adaptation, movements, organization, confrontations, and consequences in response to the disaster. Characterizing historical context, pre and post disaster way of life, biophysical characteristics, subsistence fishery impact, impacts on health and quality of life, in addition to the governance in the face of the historical scenario of post-disaster transformation in Mariana, allowed us to synthesize what previous studies and reports have produced through a holistic framework.

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Despite the specificity and historical context provided here, it is believed that Degredo is an example of hundreds of communities and territories (FUINI, 2015) who have already suffered damage and losses resulting from extractive industries in Brazil. Understanding these experiences can support new studies of environmental impacts.

2 METHODOLOGY

The methodology of this project is descriptive in nature, with a qualitative approach through the theoretical framework of Ostrom (2009). This framework identifies the actors involved and their interactions with the environment to characterize the socio ecological system. The Ostrom framework identifies the system's variables and conflicts of interest, and describes the data obtained, relating the different parts to each other. In addition to the identification of the actors, a document analysis will be carried out on the official documents made available by the Association of Fishermen and Extractivists and Remanescents of quilombo de Degredo (ASPERQD), in addition to other bibliographical references (VOLPATO, 2011; OSTROM, 2009).

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By reviewing the available literature, variables were chosen for the analysis of the socioecological system according to Ostrom (Table 1). An analysis was carried out to relate the variables to the framework theory by Elinor Ostrom (2009). In dealing with common-pool resources, or resources that are made available to all by consumption, there must be a framework to help analyze the interactions and sustainability of such interactions (Figure 1). The design principles developed by Ostrom (2007, 2009) can be very useful to describe and analyze these resources in a transdisciplinary way. Using the Ostrom framework we can organize social and ecological variables and describe the interactions and outcomes. "The framework serves two main aims: (a) to guide empirical data collection and analysis by pointing the analyst to those Social Ecological Systems (SES) variables that may be important for explaining self-organization and collective action, and (b) to provide a shared vocabulary (i.e. variables) to facilitate cross-case comparisons and support interdisciplinary collaboration" (BIGGS, 2022).

Table 1. Description of variables according to Ostrom (2009)

SES Subsystem	**Parts**
A. Resource Units (RU)	Fish, ore, trees, crops, farmland

B.Resource System (RS)	Inhabitants of the Rio Doce which were impacted by mine tailings after the Fundão dam ruptured (downstream of the dam). River, subsistence activities in the community of Degredo (fishing and extractivism)
C.Governance System (GS)	Brazilian Federal government, Government of Espírito Santo, Government of Minas Gerais, Public Ministry of both states, Renova Foundation (Samarco), Linhares City Hall
D.Users (U)	Citizens of Degredo, quilombola people, resource extraction companies (Samarco), fishers/fisherman (ASPERQD Association of Fisherman and Extractivists and Remainers of Quilombo de Degredo)
E. Interactions	Possible conflicts of interest; changes in the habits and ways of life of the community; fisheries and health
F.Outcomes	Ore tailings: from Rio Doce to the ocean Rio Doce water quality; the river receives waste from the pulp industry too, even before the disaster Characterization of the community; changes in the way of life of the community pre x post disaster; community health; fishing, fish and fishermen; conflict relationship between actors involved and damage repair.

Source: Authors' own elaboration (2022)

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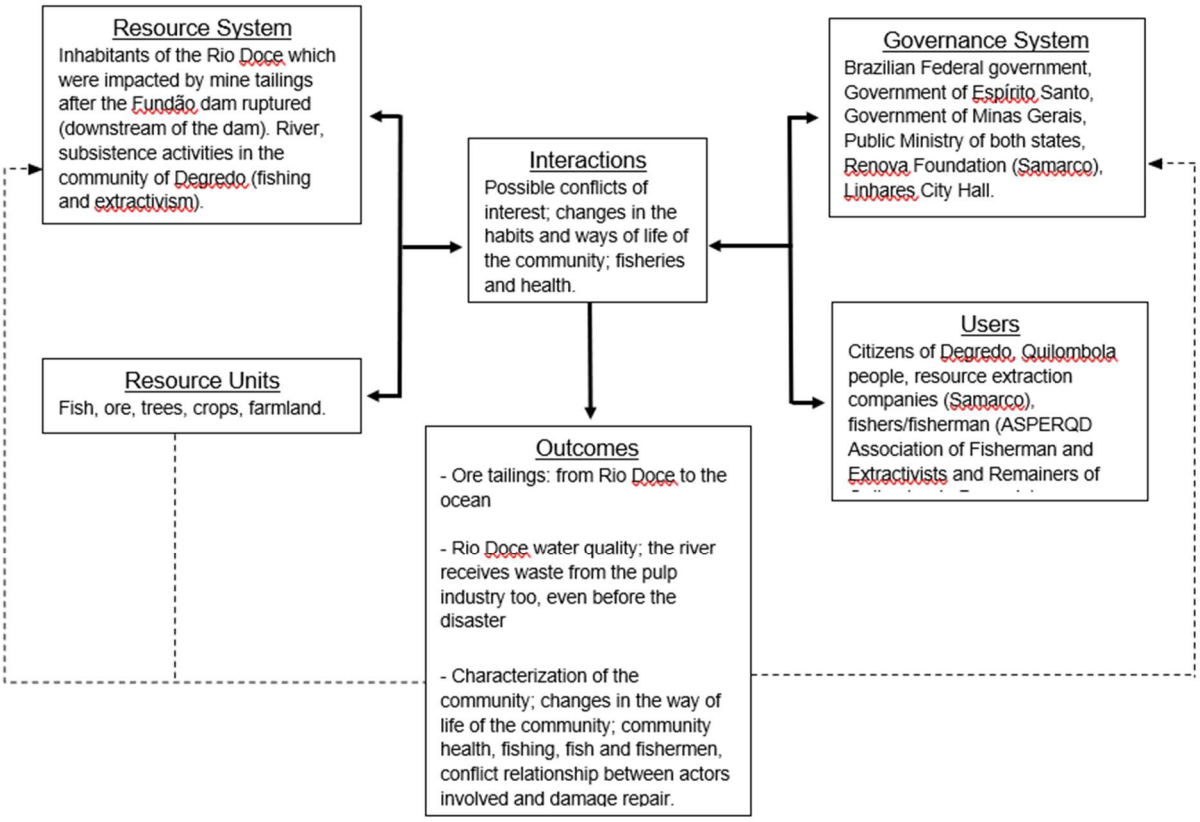

Figure 1. Diagram of the SES framework in the context of the quilombola community of Degredo after the Fundão dam failure. Source: Adapted from McGinnis and Ostrom (2014)

3 RESULTS AND DISCUSSION

Historic context and the quilombola's Degredo community

The quilombola community of Degredo is in the east of the municipality of Linhares, on the rural coastal coast of the District of Pontal do Ipiranga, in the state of Espírito Santo, Brazil, with coordinates 19°18'04"S 39°43'24" W, approximately 22 km from the mouth of the Doce River, in the north of Regência, Espírito Santo. Degredo is a community characterized by its substance activity of artisanal fishing and cassava cultivation. It was settled by family groups in collective and common use activities, which obtained certification as a remnant quilombo communities by the Palmares Cultural Foundation in 2016 (LINKS, 2021; FUNDO BRASIL, 2020; HERKENHOFF & PRATES, 2019).

The name "quilombola" describes a social group whose traditional population are descendants of enslaved people during the colonial era in Brazil, who fled from their masters and built their refuge themselves. The "quilombo" is the physical place they live in and has a distinct quilombola culture associated with it. The quilombolas have traditions built from the resistance to the adversity they have faced through many years, and are intrinsic to the trajectory of their social, political, cultural and economic response to the disaster. This resistance was built on their ancestry and kinship relationships, as well as the persistence to maintain their own traditions, knowledge and cultural practices in a deep relationship with the territory, common in the historical political resistance of Afro-Brazilian peoples in the country (HERKENHOFF & PRATES, 2019).

According to Herkenhoff and Prates (2019), the quilombola community of quilombo de Degredo has approximately 437 people, composed of rural agglomerations that were and still are impacted by the activities of oil companies who practice coastal strip mining. The pipelines of oil companies pass through the backyards of the families' houses in the community and impede agriculture. This causes significant harm to the families, who frequently grow crops for subsistence, in addition to negatively impacting on the quilombola way of life (LINS, 2021). Most people in the population of Degredo identify as fishermen and/or shellfish gatherers, followed by rural workers, and other occupations, such as family farming. The community's economic activities are mainly focused on artisanal fishing, coconut and cassava plantation, cattle raising, and honey production (JESUS, 2012; HERKENHOFF & PRATES, 2019).

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Pre disaster Livelihood

According to Herkenhoff and Prates (2019). The affected region was full of lakes with a large biodiversity of fish and caiman, which provided plenty of food to feed the population and sell commercially. River and sea fishing was the primary economic driver and promoted social interaction among the locals. There was also pig farming, where the surplus was taken to nearby locations where it was sold and products were exchanged between and within communities (LINS, 2021).

In the period prior to the dam failure, according to data collected by Herkenhoff and Prates (2019), about 95.2% of respondents had at least one member in their family who engaged in fishing. In quilombola communities, artisanal fishing is practiced and learned through ancestral knowledge passed down through generations. In addition to this, before the dam breach, it was common to have socialization and bathing in the river, lakes, and sea as well as small cassava plantations, backyard gardens, artisanal pig and chicken farming, that relied on clean water and well-tended soil.

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Before the disaster, the ecology and economy of the region was already impacted by industrialization and anthropogenic processes. Landfills, river channels, monoculture, high earthquake activity, ranching, pipeline construction, and other activities of exploration and expropriation of the territory caused conflicts and environmental degradation in the region. These environmental impacts have forced the quilombolas to fight for their rights and for the maintenance of their ancestral practices and ways of life (LINS, 2021).

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Biophysical characteristics

The territory of the Degredo community is in the Atlantic Forest biome, with restinga (coastal broadleaf forest) as the predominant vegetation but having a range of ecosystem types in its landscape. The community is in a coastal region, close to the mouth of the Doce River, which contributes to local biodiversity of its fauna and flora (HERKENHOFF & PRATES, 2019). In addition, in the region there are mangroves, wetlands, and seasonal tropical forests (AB'SABER, 2003). The forests of the basin have been largely cut down, with the remaining forests present mostly in the steepest and most elevated terrain. In the lower areas, the vegetation was replaced by pastures, leading to soil erosion and transport of sediments to water courses in the basin (LINS, 2021). Degredo is dominated by sand substrate due to the constant flooding of the region from the rain and tides. Sand dunes have formed over time as the sea level decreased in relation to the coastline. Flooding causes the depletion and weakening of the vegetation, with the presence of shrub species being noticeable in the higher

portion of Degredo (HERKENHOFF & PRATES, 2019; LINS, 2021). The landscape biodiversity supports the regional economy and development of Degredo (HERKENHOFF & PRATES, 2019; AB'SABER, 2003).

The community of Degredo is located within the Rio Doce Hydrographic Basin, in the southeast region of Brazil, between the parallels 17°45' and 21°15' S and the meridians 39°30' and 43°45' W, integrating the hydrographic region of the Southeast Atlantic and between the states of Minas Gerais and Espírito Santo (MARCUZZO, 2011).

From its source, the Doce River travels 853 km until it reaches its mouth, in Linhares, where it flows into the Atlantic Ocean (HERKENHOFF & PRATES, 2019). In terms of hydrology, the basin has a drainage area of 86,715km² and with a total of 269 municipalities, being 86% of this area in Minas Gerais territory and 14% in Espírito Santo. It has irregular physiognomy due to the presence of the relief known as "sea of hills" that limits the practice of economic activities as well as human occupation in urban agglomerations. Because of this, populations are concentrated along the water courses of the Basin where floods tend to occur (ANA, 2017).

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SES TRANSFORMATION

The failure of the Fundão dam

On November 5, 2015, the Fundão tailings dam, located between the mining municipalities of Mariana and Ouro Preto, broke. The dam spilled approximately 50 million m³ of tailings, most of them sand and silica, with high levels of iron and manganese. This spill covered 600 km crossing the Gualaxo do Norte River, the Carmo river, and the Doce river until it reached the ocean in Linhares, Espírito Santo on November 22, 2015 (HERKENHOFF & PRATES, 2019). Along this path, many communities, such as Bento Rodrigues and Paracatu de Baixo were completely destroyed by the tailings. The spill caused extensive damage to fauna, flora, water quality, biodiversity, local cultures and ways of life of various populations. Much of this damage has not yet been repaired (HERKENHOFF & PRATES, 2019).

The ore tailings arrived on the beaches of Degredo and caused panic among residents, who feared contamination of seawater and fish, their main source of income and subsistence, in addition to being part of their culture. Fishing was prohibited after the event and caused fear in the quilombolas, who were afraid to eat and sell the fish due to potential health risks. In addition to this, many had doubts about the future of the community and the lives of the

local people who depended on the sea and the river for livelihoods. The disaster brought new perceptions of reality and family relationships in Degredo because the cohesion of the community was increasingly important at this time (LINS, 2021).

Post disaster livelihood

The arrival of the mine tailings in Degredo caused an irreparable loss in the local habits due to the impacts on the community's way of life, customs, and ancestral fishing activity that were modified. In addition to this, the toxic mine tailings caused the death of fish, other fauna, and vegetation, and negatively impacted the health of residents (LINS, 2021). Contamination of water and wells used by the residents made it impossible to continue the traditional activities that were carried out in the community's day-to-day life including fishing, bathing, farming, commerce, and animal rearing. On top of this, leisure and beach activities, considered by the community to be important, were now impossible, causing sadness in the community (LINS, 2021; HERKENHOFF & PRATES, 2019).

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Due to the toxic waste in the river, there was a ban on fishing activity and an interruption of small-scale agriculture. The damage went beyond environmental losses, generating a series of conflicts in the community, health problems, and ultimately the migration of residents. Residents who had been in Degredo for many generations left the community in search of jobs and a better quality of life, deterred by fear and uncertainty of the future to remain in the community (LINS, 2021).

In addition, there was a climate of constant conflict with the Renova Foundation - the entity that represents the mining company Samarco in terms of guaranteeing the supply of potable water to the community, as well as mitigation and containment of damage (LINS, 2021). Faced with this conflict scenario, the Degredo community began to meet to discuss and fight in political confrontations for the guarantee of their rights in relation to the use of their waters and distribution of potable water (ASPERQD, 2018; HERKENHOFF AND PRATES, 2019; LINS, 2021).

Fishery

The fishery is not only important for subsistence, commerce, livelihood, and culture, but is also an important hotspot for global biodiversity, boasting an extremely high fish species richness (>100 species), with 6 species considered at risk of extinction and many species unknown to science prior to the dam breach (MYERS *et al*., 2000; VIEIRA, 2009; MINISTÉRIO DO MEIO AMBIENTE, 2014; GRUPO DA FORÇA-TAREFA, 2015;

NEVES et al., 2016). According to the Brazilian Ministry of Environment, the ecoregions which are directly adjacent to the Doce River delta are of "very high" biological importance for marine conservation (ROSA *et al*., 2007). This ecosystem's resilience was already weakened before the breach of the dam however, due to historic anthropogenic degradation in the form of water pollution, development, and the introduction of invasive species (FERNANDES *et al.*, 2016).

The impacts on the fishery following the breach of the Fundão dam had immediate and long-term impacts on the fishery the people of Degredo relied on. These effects spanned a massive downstream area, affecting riverine, estuarine, and marine environments (COSTA *et al.*, 2022). The toxicants released into the ecosystem biomagnified through the food chain from the bottom up, and negatively affected the health of the fish. Fish caught from the areas downstream of the dam breach contain toxicants in their tissues rendering them unsafe for consumption (DOS SANTOS VERGILIO, *et al.*, 2021; PAULELLI, *et al.*, 2022). Biodiversity of this ecosystem was severely affected, and may never fully recover (FERNANDES, *et al.*, 2016).

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The toxic sludge from the mining tailings released into the watershed immediately decimated the fishery of the Rio Doce and its estuary. The initial wave of tailings wiped out entire populations of fish by burying them and clogging their gills. The immediate harmful effect was worsened because it occurred during an important fish spawning season called *defeso*. Fishing during *defeso* is outlawed because impacts to fish stocks during this time hurt the recruitment of fish populations needed to sustain the fishery. Furthering the long-term recruitment impacts, the spill harmed 1469 hectares of vegetation and 90% of riparian habitats of the North Gualaxo, Fundão, and Carmelo Rivers, thus stunting long-term recovery of fish stocks by burying aquatic and riparian nursery habitats (FERNANDES, *et al.*, 2016). Toxicants continue to contaminate the ecosystem because the rainy season continually stirs up the mine tailings in the sediments, resuspending metals in the water column (AGUIAR *et al.*, 2020; ANDRADES *et al.*, 2021).

The breach of the dam and subsequent release of mine tailings impacted freshwater, coastal, and marine ecosystems through water, sediment, and biota (COSTA, *et al.,* 2022). A study by Magris *et al.*, (2019) modeled sediment transport, and discovered that the intensity of the contamination may decrease over time, but the area impacted would probably increase. Sediments spread from the river through marine habitats up the Brazilian coast up to 200km into the ocean. (BIANCHINI, 2016).

Polluted water downstream of the dam breach had negative repercussions for aquatic food webs. Suspended particulate matter contained high concentrations of heavy metals which biomagnified up the food chain from plankton to macroinvertebrates and fish (VIEIRA *et al.,* 2022). These changes continue to cause long term trophic depletion as sediments are resuspended seasonally (ANDRADES *et al.*, 2021). After the dam breach, trophic groups of macroinvertebrates such as plankton and crabs were negatively impacted, and displayed high concentrations of mercury, lead, copper, and iron (GOMES *et al.*, 2017; COSTA, *et al.*, 2022). Fish sampled downstream of the dam breach have accumulated lead, aluminum, iron, manganese, and zinc in their muscle tissue from consuming lower trophic organisms that absorb toxicants from the mining tailings directly (DOS SANTOS VERGILIO, *et al.,* 2021; COSTA, *et al.,* 2022).

Over five years after the disaster, Vieira *et al.,* (2022) determined that fish had been altered physiologically due to exposure to heavy metals. Physiological alterations to fish included DNA damage, lipid peroxidation, oxidative damage in proteins, metallothionein concentrations and activity of superoxide dismutase in the gills. Weber *et al.,* (2020) concluded that contaminated fish displayed bodily reactions consistent with fighting off metal toxicity and are under significant oxidative stress due to lowered levels of O_2 in the water. Bonecker *et al.,* (2022) found that the dam tailings had a negative effect on larval fish, fish eggs, and ichthyoplankton abundance and detected deformations in the digestive tracts of larval fish.

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Human Health

The rupture of the Fundão Dam has a wide range of socio-ecological impacts, including the damage and risk of damage to human health. Despite the massive environmental impact of the dam breach, the toll on human health has been minimally described. The community relies heavily on the Rio Doce for crop irrigation, subsistence fishing, and well water for consumption. Impacts to the watershed from mining and development pre-disaster laid the foundation to a polluted system. Once the Fundão Dam ruptured, it only amplified the toxicity of the watershed.

Paulelli *et al.,* (2022) conducted human blood biomonitoring on 313 volunteers living in communities surrounding the Rio Doce up to 600 km away. They analyzed blood samples and measured for eleven elements (Al, As, Cd, Cu, Hg, Mn, Ni, Pb, Se, and Zn). Authors compared the blood chemistry reports to other baseline Brazilian population averages. Several elements with extremely high levels in the impacted population were arsenic, mercury, and

lead. Within the study group, lead was significantly higher in groups that reported eating seafood. Even in those that reported not eating seafood or fish, the mean levels of arsenic were high compared to baseline averages. This led the authors to explore the volunteers' sources of freshwater (for consumption). Those reported to drink water from a well or tap had higher levels of arsenic, nickel, manganese, and zinc than those drinking mineral water. After the tailings dam failure, many families drilled artesian (deep) wells in hopes of securing safe freshwater for consumption. Paulelli *et al.,* (2022) demonstrated that water was an important source of exposure to these heavy metals and that a closer study on water quality is warranted.

In the area of Degredo specifically, the quilombolas have subsisted off the land and water for many years, often curing ailments with medicinal herbs from the forest called "forest remedies". These practices were interrupted when the mining tailings arrived. Their nutrition was replaced with donated food from outside the region. The restrictions implemented on fishing, farming, and gathering further displaced the traditions of the Degredo community. In addition to being impacted physically, experiencing nausea, vomiting, diarrhea, itchy skin, dermatitis, and anemia (unpublished, but community reported), the quilombolas experienced severe mental health issues. Many of their daily tasks were community driven, but after the "arrival of the mud" they returned to their homes and were isolated, which led to severe depression in the community (ASPERQD, 2018).

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Governance

Literature states that it is important for governments that control complex social ecological systems to use methodologically-sound scientific approaches to implementation of solutions (MARQUES *et al.,* 2020). That is, authors argue that the resilience and production capacity of an ecological system depends on the interaction networks between community, market, government, and their forms of interlocution (DELGADO, 2019). This section seeks to understand the relationships of governance in Degredo by analyzing the organizations and their efforts, identifying their constituents, and understanding the connections among mining companies and foundations, state and municipal governments and the networks created for management and development.

The Quilombola Commission of Degredo (CQD) was initially organized in the fight for the recognition of the quilombola territory by the Brazilian authority. This organization works in partnership with the Association of Fishermen and Extractivists and Remnant Quilombo of Degredo (ASPERQD) through multidisciplinary technical assistance (ATI), in the fight for reparations for the damage caused (LINS, 2021). As part of the process of

managing the territory of Degredo, associations with legal representations were identified, namely the ASPERQD, the Association of Residents, Rural Producers and Quilombolas of Degredo (AMPROD), and the Association of Women of Degredo (LOIOLA, 2022).

According to our literature review and the websites of the mentioned organizations, there seems to be consistent activity and persistence from these organizations towards reclaiming rights and securing reparations for the people they represent. However, the performative nature of the RENOVA foundation is clear, and because of this, reparations for the community of Degredo have been slow. The claims and news from ASPERQD corroborate the finding that RENOVA is using representation of the affected peoples as a tool to mask the fact that little work has been done to repair this complex social ecological system.

RENOVA Foundation: the avatar of the repair project

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The RENOVA Foundation was established in 2016 through a Transaction and Conduct Adjustment Term (TTAC), signed by Samarco, their shareholders Vale and BHP Billington, Federal Governments, the states of Minas Gerais and Espírito Santo, Instituto Brasileiro do Meio Environment and Renewable Natural Resources (IBAMA), Chico Mendes Institute for Biodiversity Conservation (ICMBio), National Water and Basic Sanitation Agency (ANA), State Institute of Forests, National Indian Foundation (FUNAI), and environmental agencies. A Interfederative Committee (CIF) was established to guide and validate the RENOVA's acts, so it is important that civil society and the affected population must closely monitor the actions and development of RENOVA’s projects through a participatory governance system (BRASIL, 2016).

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According to the Foundation, 42 programs (including programs focused on environmental repair, promotion and stimulation of agriculture, professional training etc.) are under development and being implemented along the impacted area of the Rio Doce and its tributaries. In 2018, the Governance Conduct Adjustment Term was signed, which incorporates the participation of those affected in the reparations decision-making process. The term establishes the creation of regional and local chambers supported by technical advisors. The Foundation also receives expert recommendations from the Rio Doce Panel, managed by the International Union for the Conservation of Nature and Natural Resources (IUCN), ensuring positive impacts on the reparations process (RENOVA, 2022a).

On the RENOVA website there are versions of annual reports from 2016 to 2021. The Foundation identifies several programs, projects, actions, partnerships and reparations activities that have been taking place since its conception. As published, until now, 24.73

billion reais have been invested in reparation and compensation actions, 11.5 billion reais have been paid in indemnities and emergency financial aid for more than 403,800 people, in addition to contracts and loans with local and regional communities. There are more than 70 entities involved in the governance system, 9.300 employees and third parties, 25 universities and 40 partner NGOs in the repair. Information is also available on reforestation programs and environmental monitoring, including analysis of water and soil for planting and consumption (RENOVA, 2022b).

4 CONCLUSIONS

Quantifying and understanding the full impacts of the breach of the Fundão dam on the quilombola people of Degredo is a complex task. Many of the impacts of the dam manifest themselves as non-tangible, but negative externalities such as generational trauma, depression, and a lack of community closeness. Using the Ostrom framework, we can analyze social, ecological, cultural, economic, and governmental factors that may be otherwise overlooked when considering the aftermath of a catastrophic ecological event. However, when a people live a way of life that is traditionally close with, and reliant on, natural resources such as the quilombo people, ecological degradation impacts the community in an observably negative way.

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As Degredo is a coastal fishing town, the impact of the dam breach on the fishery cannot be overstated for this community. Many scientific studies have come to the general conclusion that the fishery was completely decimated by the disaster and needed to be restored from the bottom up. Even several years after the disaster, fish and other aquatic life still contain dangerously high amounts of heavy metals deemed too toxic for human consumption. It is unclear when these heavy metals will eventually be dispersed and diluted enough for the fishery to be safe again, or if the fishery will ever return to the quality of before the disaster. Fishing represented a great cultural and social resource for the town, in addition to feeding people. How to replace the resource that artisanal fishing represented for Degredo may not have a straightforward answer, but as of now, more research could be allocated to learning about the health effects of consumption of food from the aquatic ecosystems around Degredo, and what the total cost of replacing or repairing this resource is.

One of the most obvious and pressing externalities of the disaster is the human health impact. The dam breach ultimately has been linked to physical ailments through increased levels of toxicants, as well as an overall drop in mental health due to a complete ending to the usual way of life of the community. Because the mine tailings have contaminated the water

source of the surrounding area, virtually all aspects of life have been impacted. Dealing with traumatic events and struggling for their way of life is not new to the quilombola people and is woven into their traditions. Because they are a people of traditional knowledge, partaking in activities that subside directly from the land such as artisanal fishing, family farming, and community gardening, this community is probably more acutely impacted by such a catastrophic change than societies that are more removed from where their food and water come from. Their way of life today is similar to how it has been for many generations and they have not lost their connectivity with their natural resources as other communities across the world have through globalized industrialization. This unique, and simple way of life is threatened by globalized extractive industries such as mining, deforestation, and oil and gas, which seek to maximize profits no matter what the long-term cost, or non-monetary externalities may be.

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Within the community, grassroots organizations such as ASPERQD have proven to be the solution for providing representation for the quilombo people of Degredo throughout this struggle. Organizations funded and driven by those with profit incentives like RENOVA seem to provide help but are mostly performative in nature with respect to providing representation to the impacted people. Even with all the restoration efforts in place, the community of Degredo will never be the same.

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Because this disaster affected a complex social ecological system, the governance solution requires many different forms of representation. Vulnerable groups such as the quilombo people of Degredo should be included in the process of reparations and restoration for their region to ensure their survival as a community. Current projects and initiatives are working towards restoring the environment from the damage caused by this disaster, but how much can and will be done to fix the many problems is yet to be seen. This disaster represents an environmental justice case study for how marginalized groups receive disproportionate repercussions for the negative externalities of resource extraction industries. Degredo is one of many such cases, which is unique in that it has received international attention, while many other communities around the globe are impacted by extractive industries with little attention or efforts to repay those affected.

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