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GUILHERME CAMPOS PIVA

IMPACTOS DO ROMPIMENTO DA BARRAGEM "FUNDÃO" SOBRE A FAUNA DE ARTRÓPODES NA BACIA DO RIO GUALAXO DO NORTE, MARIANA, MINAS GERAIS

VIÇOSA, MINAS GERAIS

2023

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Dissertação apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Ecologia, para a obtenção do título de *Magister Scientiae*

Orientador: Dr. Thiago Gechel Kloss

VIÇOSA, MINAS GERAIS

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Guilherme Campos Piva
Autor

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THIAGO GECHEL KLOSS
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Dr. Thiago Gechel Kloss
(Orientador)

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"Do rio que tudo arrasta, diz-se que é violento. Mas ninguém chama violentas às margens que o comprimem."

Bertolt Brech

RESUMO

PIVA, Guilherme Campos, MSc., Universidade Federal de Viçosa, dezembro de 2023. **Efeitos crônicos do rompimento da barragem "Fundão" sobre a fauna de artrópodes na bacia do Rio Gualaxo do Norte, Mariana, Minas Gerais.** Orientador: Dr. Thiago Gechel Kloss.

A atividade mineradora é uma das principais atividades econômicas no Brasil, sendo também uma significativa fonte de distúrbios ambientais advindos da ação antrópica. Nesse cenário, o rompimento da barragem da SAMARCO/BHP Billiton/Vale "Fundão", ocorrido em 2015 no município de Mariana (MG), é o maior desastre ambiental da história do Brasil. Esse evento teve papel estruturante na heterogeneidade ambiental, nas condições, recursos e dinâmicas das comunidades biológicas locais. Diante disso, este trabalho buscou compreender os efeitos remanescentes do rompimento da barragem de Fundão sobre a fauna de artrópodes após seis anos do rompimento. O estudo foi desenvolvido ao longo do primeiro afluente da bacia do Rio Doce que recebeu grande volume de rejeitos da barragem de Fundão, o Rio Gualaxo do Norte. Comparamos áreas não-afetadas e afetadas pelo rejeito, para avaliar possíveis efeitos remanescentes sobre a biomassa de insetos voadores e edáficos, e sobre riqueza, abundância e composição de espécies de aranhas. Nossos resultados apontaram que houve efeitos distintos entre grupos de artrópodes. Artrópodes voadores e edáficos sofreram alterações na biomassa em locais alterados pela passagem do rejeito, enquanto a comunidade de aranhas não sofreu alterações significativas. Observamos também que a altura da serapilheira foi maior nas áreas afetadas, o que sugere que a redução dos artrópodes edáficos pode afetar a ciclagem de nutrientes nos ambientes impactados. Por fim, sugerimos que a ausência de efeito sobre a comunidade de aranhas pode estar relacionada à resiliência dessa comunidade aos distúrbios.

Palavras-chave: Impacto ambiental. Barragens de rejeitos. Ecossistemas. Aranhas. Insetos. Artrópode.

ABSTRACT

PIVA, Guilherme Campos, MSc., Universidade Federal de Viçosa, December 2023. **Chronic effects of the "Fundão" dam failure on the arthropod fauna within the Gualaxo do Norte river basin, Mariana, Minas Gerais.** Advisor: Dr. Thiago Gechel Kloss.

Mining activity is one of the main economic activities in Brazil, being also a significant source of environmental disturbances coming from anthropogenic action. The failure of the SAMARCO/BHP Billiton/Vale's "Fundão" dam is known to be the greatest environmental disaster in Brazilian history. This event played a structuring role in environmental heterogeneity, conditions, resources and dynamics within local biological communities. Given that, this work aimed to understand reminiscent effects from Fundão dam breach unto the arthropod fauna after six years after such breach. The study was developed along the first tributary to the Doce river which received a high volume of tailings from the dam, the Gualaxo do Norte river. We compared areas not affected and affected by the tailings, to assess possible reminiscent impacts over biomass of flying and edaphic arthropods, and over spider abundance, richness and species composition. Our results point out that there were distinct effects among arthropod groups. Flying and edaphic arthropods suffered shifts in biomass at sites altered by the passage of tailings, while spider assemblage was not significantly affected. We observed greater leaf litter height in affected areas, which suggests that the reduction of edaphic arthropods may affect nutrient cycling at the impacted environments. Finally, we suggest that the absence of effect over spider assemblage may be related to resilience from this assemblage to disturbance.

Keywords: Environmental impact. Tailing dams. Ecosystems. Spiders. Insects.
Arthropod

SUMÁRIO

1. REFERENCIAL TEÓRICO

1.1. Impactos antrópicos

Os impactos antrópicos estão entre os fatores que afetam mais intensamente a vida na Terra (Barlow *et al.*, 2016), sendo significativas fontes de distúrbios ambientais e atualmente a maior ameaça à biodiversidade, especialmente na região Neotropical (Doré *et al.*, 2021). A região neotropical apresenta uma alta diversidade de espécies, abrigando mais de 6.000 espécies descritas de peixes de água doce (Pelicice *et al.*, 2021), 2.916 espécies nativas de anfíbios, e 13.519 espécies de aranhas (ArachnoTrAC, 2023). Em relação aos insetos, estima-se que a região concentre uma grande proporção da diversidade global (Stork 2018). Sendo assim, a região é considerada um *hotspot* de biodiversidade, com altos índices de diversidade e também de endemismo (Bolaños *et al.,* 2008).

Entretanto, esta região, tão importante para a biodiversidade mundial, se encontra ameaçada por diferentes distúrbios, como a mineração extrativista, agropecuária extensiva, e mudanças climáticas (Sonter *et al.*, 2017). Isto inspira preocupação com o conhecimento e a preservação da vida nos trópicos, em especial no Brasil (Correa 2020; Antonelli 2022). Nos últimos anos, estas atividades têm avançado em um ritmo acelerado em Minas Gerais (Menegassi 2024), tornando a situação ainda mais alarmante.

Os distúrbios atuam sobre uma série de fatores essenciais aos ecossistemas, homogenizando a estrutura de vegetação, alterando microhábitat e microclima, alterando as cadeias tróficas e as posições dos organismos nelas, e reduzindo a disponibilidade de recursos (Tews *et al.*, 2003; Hulton VanTassel *et al.*, 2015). Alterações nesses fatores, por sua vez, desestruturam comunidades biológicas, especialmente as mais sensíveis. Dessa forma, distúrbios podem promover alterações diretas na composição das comunidades biológicas, alterando de forma relevante as abundâncias das espécies, contribuindo também para a emergência de doenças e patógenos (Wolfe *et al.,* 2005; Schmeller *et al.*, 2020; Knaden *et al.*, 2022). Sendo assim, os distúrbios ameaçam as comunidades biológicas em vários níveis, podendo promover a perda de diversidade, funções ecossistêmicas, redes de interação e cadeias tróficas, e a extinção de espécies vegetais e animais (Ney-Nifle & Mangel 2000; Nakagiri *et al.*, 2001; Melián & Bascompte 2002; Seabloom *et al.*, 2002).

1.2 Impactos antrópicos sobre artrópodes

Os artrópodes constituem o grupo taxonômico mais diverso no planeta, englobando mais de 1,2 milhão de espécies descritas (Stork 2018) e a biomassa de artrópodes terrestres é similar à biomassa combinada de minhocas, entriqueias e nematoides (Rosenberg *et al.*, 2023). A produtividade primária das florestas apresenta relação positiva com a riqueza de distintas guildas de artrópodes (Li *et al.*, 2023), que são também essenciais na ciclagem de nutrientes, contribuindo para a fertilidade do solo, reciclagem de matéria orgânica (Culliney 2013; de Groot *et al.*, 2016), assim, os artrópodes são importantes no desempenho de funções ecossistêmicas distintas. Em regiões tropicais, o grupo apresenta maior riqueza de espécies (Jaffe *et al.*, 2008), o que resulta em interações ecológicas mais complexas (Privet & Pétillon, 2020). Em ecossistemas terrestres tropicais, os artrópodes atuam como herbívoros, polinizadores, dispersores de sementes, predadores, parasitas, engenheiros de ecossistema, ou detritívoros (Weisser & Siemann, 2008).

Os artrópodes são um grupo extremamente sensível a distúrbios, e podem sofrer impactos diretos e indiretos de distúrbios ambientais (Murphy *et al.*, 2020, Schowalter *et al.*, 2021). Bioindicadores são grupos cujas respostas a alterações ambientais súbitas e impactos de longo prazo fornecem pistas sobre as condições do ecossistema sob a interação de distintos fatores ambientais (Li *et al.*, 2010), podendo ser utilizados para o biomonitoramento desses ecossistemas (Li *et al.*, 2010). Por essas respostas e por sua grande diversidade, os artrópodes são bioindicadores úteis na avaliação dos ecossistemas (Madden & Fox, 1997; Hoffmann *et al.*, 2000; Holec & Frouz, 2005; Mannu *et al.*, 2020).

O declínio de artrópodes, como os insetos, constitui uma das maiores ameaças à biodiversidade (Lewinsohn *et al.*, 2022). Um estudo em áreas protegidas da Alemanha apontou um declínio de 76% na biomassa média de insetos voadores (Hallmann *et al.*, 2017). A expansão da agricultura e pecuária e o desmatamento podem ser fatores antrópicos responsáveis por esse fenômeno no Antropoceno (Uhler e*t al.*, 2021): As mudanças em temperatura e precipitação vêm afetando negativamente a riqueza de insetos e interações multitróficas associadas (Salcido *et al.*, 2020, Murphy *et al.*, 2020).

A mineração também reduz a diversidade taxonômica e a ocorrência de famílias de insetos (Stoll *et al*., 2022).

Insetos são também afetados severamente por substâncias tóxicas no ambiente, principalmente as relacionadas a olfato e respostas químicas. Mudanças induzidas por poluentes nos odores podem reduzir a polinização ao oxidar odores emitidos por plantas, e até mesmo a comunicação entre insetos – altamente relacionada a olfato e quimiorrecepção – gerando ainda efeitos diretos sobre o sistema olfatório destes animais (Knaden *et al*., 2022). Os insetos podem ser afetados também por modificações na paisagem, a exemplo do uso do solo. Deste modo, insetos são bioindicadores adequados para avaliação de impactos ambientais sobre os ecossistemas e as comunidades biológicas (Li *et al*., 2010).

Além dos insetos, as aranhas são artrópodes que também podem ser afetados direta e indiretamente por distúrbios antrópicos (Henschel *et al*., 2001). Este grupo apresenta grande diversidade, tanto taxonômica quanto trófica, constituindo o grupo mais diverso de predadores terrestres, com mais de 51 mil espécies descritas (World Spider Catalog, 2023). Estes animais apresentam plasticidade nas respostas a distúrbios, em escala de comunidade e também de comportamento, apresentando assim alterações na composição de espécies, na ocorrência de determinados grupos de acordo com a perturbação ambiental, além de modificações comportamentais. Distúrbios antrópicos afetam a comunidade de aranhas em florestas neotropicais, e diferentes guildas e famílias de aranhas exibem sensibilidades diferentes a mudanças nos gradientes de distúrbio (Gonzalez *et al*., 2021).

Por exemplo, evidências demonstram que aranhas de solo da família Lycosidae são sensíveis à poluição sonora (Bunkley *et al*., 2017) e a eventos de alagamento (Lambeets *et al*., 2008). Além disso, as aranhas podem ser indicadoras sensíveis de estresse químico, sendo reconhecidas como bons indicadores de poluição por metais pesados em ecossistemas ripários, o que torna o grupo um importante sentinela de contaminação por metais pesados (Migula *et al*., 2013; Wilczek *et al*., 2018; Beaubien *et al*., 2020; Hannappel *et al*., 2021; Chumchal *et al*., 2022; Drenner *et al*., 2022).

No que diz respeito aos efeitos dos minerais sobre estes animais, estudos realizados com *Steatoda grossa* (Araneae: Theridiidae) apontam que a intoxicação com metais pesados como Cádmio (Cd) ocasiona danos aos hemócitos dessa espécie através do consumo de presas contaminadas com esses minerais, com aumento significativo no número de células em apoptose e necrose ante a exposição (Stalmach *et al.*, 2015*a*; Wilczek *et al.*, 2018).

A ocorrência e eficiência de caça das aranhas em ambientes alterados por muitas contaminações antropogênicas, incluindo metais pesados, depende de sua capacidade de tolerar excesso de xenobióticos entrando no organismo prioritariamente através de alimento (Wilczek *et al.*, 2018). É conhecido que os níveis de tolerância e respostas são dependentes de espécie, de gênero e do metal pesado presente (Migula *et al.*, 2013), e a bioacumulação de metais varia ainda de acordo com o tamanho corporal (Hannappel *et al.*, 2021). Metais atacam as mitocôndrias e reduzem a energia disponível para os mecanismos de defesa das aranhas (Babczynska *et al.,* 2011*b*; Migula *et al.,* 2013). A bioacumulação de Mercúrio (Hg) está correlacionada com alterações na escolha de local das teias e mortalidade em aranhas (Liu *et al.*, 2013).

As aranhas, por sua vez, desenvolvem mecanismos de defesa que possibilitam a permanência em ambientes com presença de metais pesados, como o aumento na atividade de enzimas envolvidas em reações anaeróbias e aumento no *pool* de ADP em resposta a uma redução na disponibilidade de ATP, um dos principais efeitos negativos de metais pesados nas células (Migula *et al.*, 2013). Isto indica que aranhas respondem a efeitos associados à mineração. Ainda, aranhas respondem a impactos sobre o uso do solo. Tendo em vista as modificações significativas que a mineração provoca no uso do solo, isto indica que seja viável utilizá-las como modelo para estimar os efeitos do rompimento da barragem e sobre as condições pós-desastre nos ecossistemas deste local (Rosa *et al.*, 2019; Mannu *et al.*, 2020).

1.3 Impactos antrópicos em ecossistemas ripários

Uma série de distúrbios, entre mineração, barragens, represamento, afetam os ecossistemas aquáticos e ripários. A fauna ribeirinha fornece *feedbacks* importantes que podem influenciar as dinâmicas espaço-temporais da paisagem em períodos longos de tempo (Robinson *et al.,* 2002), respondendo a características relacionadas ao estágio sucessional, determinado pela frequência, duração e gravidade do distúrbio (Naiman *et al.*, 2000*a*). Por exemplo, os peixes neotropicais de água doce se encontram ameaçados por diversos fatores, principalmente drenagens, construção de barragens, e já se fala na erosão da diversidade do grupo, com mudanças em diferentes níveis de organização, padrões de diversidade, demografia, estrutura de comunidade, riqueza e extinção de espécies (Pelicice *et al*., 2021).

Um dos grupos mais abundantes em sistemas ripários são os artrópodes, que são impactados por essas atividades de distintas maneiras. Por exemplo, a concentração de diferentes metais pesados em área de mineração afeta a abundância e a composição da comunidade de Trichoptera e Plecoptera, duas ordens de insetos aquáticos (Lidman *et al*., 2020). Em outro exemplo, a concentração de Selênio (Se) em insetos aquáticos adultos em áreas de mineração de carvão foi cinco vezes maior que nas áreas não-mineradas, e excedeu os níveis tóxicos para aves, desencadeando assim impactos da mineração na cadeia trófica (Naslund *et al*., 2020).

De forma semelhante ao que ocorre com os insetos, as aranhas ocorrem amplamente em ecossistemas ripários (Henschel *et al*., 2001; Graf *et al*., 2019), e são importantes nas redes tróficas terrestres, tanto como predadores quanto presas (Poulin *et al*., 2010). Devido à sua diversidade de hábitos, aranhas podem se alimentar de diversos grupos de animais. Aranhas construtoras de teia podem predar insetos voadores aquáticos e terrestres (Roberts 1996; Graf *et al*., 2019), enquanto aranhas de solo que forrageiam ativamente podem predar animais terrestres e também aquáticos nas margens dos rios (Nyffeler & Pusey, 2014).

Os impactos presentes nestes sistemas ripários podem afetar diretamente as aranhas, variando desde ruídos sonoros dos rios até a presença de metais pesados (Gomes *et al*., 2020; Hannappel *et al*., 2020; Chumchal *et al*., 2022; Drenner *et al*., 2022). A contaminação das aranhas nestes ecossistemas ocorre principalmente pela proporção de insetos aquáticos e terrestres contaminados consumidos pelas aranhas. Estas respostas colocam as aranhas como boas indicadoras dos efeitos ecotoxicológicos da mineração, com robusta literatura. Além disso, aranhas apresentam grande diversidade taxonômica e trófica, forte associação do grupo com a vegetação e o estágio sucessional, e as respostas da comunidade de aranhas à sucessão ecológica e às alterações no ambiente ocasionadas pela mineração apontam que a comunidade de aranhas - assim como os demais artrópodes - constitui um excelente modelo para avaliar a presença de impactos da mineração sobre ambientes ripários (Madden & Fox, 1997; Mannu *et al*., 2020).

1.4 Impactos da mineração sobre a biodiversidade

Uma das principais atividades econômicas do Brasil, a mineração, representa uma das principais fontes de distúrbios antrópicos. A mineração a céu aberto, ao desmatar, retirar o solo fértil acumulado em pilhas de “estéreis”, escavar, perfurar blocos e detonar explosivos, modifica toda a paisagem, modificando com isso também o microclima, fauna, flora, dinâmica hidrológica (Milanez 2017). Deste modo, a mineração e os distúrbios ligados a ela atuam na estruturação da paisagem, da heterogeneidade espacial e ambiental e também na estruturação das comunidades.

Em especial, no estado de Minas Gerais, a mineração se estabelece como uma atividade que gera uma dependência econômica do estado, assim como das populações locais nos municípios onde se instalam estes empreendimentos (Bertollo 2021). O estado ainda hoje é o maior produtor do setor no Brasil (Alves 2008; Rezende 2016). A atividade está presente no estado desde o período colonial, estando ligada a processos socioeconômicos que vão desde urbanização até o trabalho e a formação da sociedade mineira.

Nos últimos anos, conflitos socioambientais têm se desencadeado com mais frequência e maior repercussão em torno da mineração no estado, envolvendo patrimônios naturais como a Serra do Curral[1] e a Serra da Moeda[2], em meio a um cenário de expansão de áreas de mineração. Além disso, nos últimos seis anos, Minas foi palco de dois grandes desastres relacionados à mineração, os rompimentos da Barragem Fundão (2015, em Mariana) e da Barragem Córrego do Feijão (2019, em Brumadinho). Exames toxicológicos após o rompimento da Barragem Córrego do Feijão, na bacia do Rio Paraopeba, demonstraram que a água e os sedimentos contendo minério têm potencial para induzir efeitos em diferentes níveis tróficos, desde produtores primários até consumidores primários e secundários (Vergilio *et al*., 2020). Um dos animais impactados por estas substâncias foi o microcrustáceo *Daphnia similis,* um consumidor primário, que apresentou imobilidade após exposição à água de Brumadinho, no ponto de amostragem imediatamente abaixo do local do rompimento (Vergilio *et al*., 2020). Também foi

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[1] “TRF-6 suspende licenças do projeto da Tamisa na Serra do Curral por falta de consulta ao quilombo Manzo Kaiango”, Observatório da Mineração, 16 dez 2022. Disponível em <https://observatoriodamineracao.com.br/trf-6-suspende-licencas-do-projeto-da-tamisa-na-serra-do-curral-por-falta-de-consulta-ao-quilombo-manzo-kaiango/>

[2] “Projeto que favorece a Gerdau e atinge Serra da Moeda escrito por deputado financiado por mineradoras é questionado em MG”, Observatório da Mineração, 24 nov 2021. Disponível em <https://observatoriodamineracao.com.br/projeto-que-favorece-a-gerdau-e-atinge-a-serra-da-moeda-escrito-por-deputado-financiado-por-mineradoras-e-questionado-em-mg/>

demonstrado que os rejeitos de minério de ferro liberados pelos rompimentos de Brumadinho e Mariana possuem características semelhantes, como material particulado fino, com predominância de Al, Fe e Mn (Vergilio *et al*., 2020).

O rompimento da barragem Fundão foi o maior impacto provocado pela mineração em ambientes tropicais, e afetou a maior bacia hidrográfica do sudeste brasileiro, a partir do Rio Gualaxo do Norte, em Mariana, Minas Gerais. O desastre liberou 43 milhões de m³ de rejeito na bacia do rio Doce (IBAMA, 2015; Vergilio *et al*., 2020), sendo 34 milhões imediatamente liberados no ambiente, e o restante carregado aos poucos em direção ao mar (IBAMA, 2015). A lama extrapolou a calha do rio, contaminando as florestas ripárias e as comunidades nelas presentes (Brito *et al*., 2020). Os rejeitos da barragem são compostos por material particulado fino, sendo majoritariamente partículas de silte-argila, e com predominância de Al, Fe e Mn (Vergilio *et al*., 2020). O rompimento aumentou as concentrações na água de mineiras como ferro (Fe), manganês (Mn), alumínio (Al), arsênio (As) e cádmio (Cd), apresentando um risco elevado de mobilidade de Mn (Santos *et al*., 2023).

No total, 98% da bacia do Rio Doce está situada na Mata Atlântica (IBAMA, 2015). O bioma é considerado um dos 25 hotspots mundiais, com altos índices de diversidade e endemismo, mas se encontra fortemente ameaçado e fragmentado (IBAMA, 2015). Neste cenário, um dano de tal magnitude sobre um bioma já tão fragilizado demanda trabalhos no sentido de conhecimento da biota e dos ecossistemas, justificando também trabalhos voltados ao impacto e à restauração da área atingida.

Na região de Mariana, trabalhos demonstraram que a deposição de rejeito alterou a comunidade microbiológica (Almeida *et al.*, 2023), o solo e processos biogeoquímicos (Silva *et al*, 2021). O desastre alterou os níveis de diversos metais no solo (Silva *et al.,* 2021) e na água. No Rio Gualaxo do Norte, as concentrações de Al e Fe dissolvidos na água, bem como os níveis totais de Ag, As, Cd, Cr, Cu, Mn, Ni, Pb e Zn excederam os níveis regulares, além de apresentar uma baixa absorção e alto risco de mobilidade de Mn (Santos *et al*, 2021; Santos *et al.*, 2023).

No que tange a artropodofauna da região atingida pelo desastre, Brito *et al*. (2020) demonstraram que as comunidades de formigas em ecossistemas ripários locais foram alteradas pelo dano ambiental, sendo a troca de espécies (*turnover*) um forte fator explicativo da β-diversidade. Além disso, outro trabalho encontrou redução da abundância de artrópodes de solo detritívoros e onívoros nas áreas afetadas pelos rejeitos, sem efeito significativo sobre os predadores e herbívoros (Ribeiro *et al*., 2023). Devido a sua diversidade de funções no ecossistema e forte relação com processos ecológicos e biogeoquímicos do ambiente, artrópodes em geral são importantes indicadores de impactos antrópicos, sucessão e restauração de ecossistemas, entretanto as respostas frente a esse distúrbio podem variar entre grupos de artrópodes. Sendo assim, faz-se importante conhecer mais a fundo as diferentes respostas a distintos distúrbios e sobre a comunidade de variados grupos do filo, alguns dos quais ainda pouco investigados neste aspecto, como as próprias aranhas.

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CHRONIC EFFECTS OF THE “FUNDÃO” DAM FAILURE ON THE ARTHROPOD FAUNA INDUCE DISSIMILAR RESPONSES

Paper to be submitted to Environmental Monitoring and Assessment

Chronic effects of the "Fundão" dam failure on the arthropod fauna induce dissimilar responses

Guilherme Campos Piva[1,2], Thiago Gechel Kloss[2]*

[1] Programa de Pós-graduação em Ecologia, Departamento de Biologia Geral, Universidade Federal de Viçosa, Av. P.H. Rolfs, s/n, Campus Universitário, 36570-900, Viçosa, MG, Brasil.

[2] Laboratório de Ecologia e Comportamento, Departamento de Biologia Geral, Universidade Federal de Viçosa, Av. P.H. Rolfs, s/n, Campus Universitário, 36570-900, Viçosa, MG, Brasil.

*Corresponding author: Thiago G. Kloss, Laboratório de Ecologia e Comportamento, Universidade Federal de Viçosa, Av. P.H. Rolfs, s/n, Campus Universitário, 36570-900, Viçosa, MG, Brasil. thiago.kloss@ufv.br

Abstract

Mining activity is nowadays one of the main economic activities in the world, and consequently, one of the main sources of environmental disturbances coming from anthropogenic action. The failure of the "Fundão" dam, occurred in 2015 in the city of Mariana, Minas Gerais state, is regarded as the greatest environmental disaster in Brazilian history, and the greatest mining disaster in world history. Since arthropods are usually good indicators for ecosystem health and there is a lack of knowledge about long-term effects unto these organisms, this investigation aims to understand how the dam failure affected the arthropod fauna associated with the more severely impacted tributary to the Doce river, the Gualaxo do Norte river. We performed a comparative analysis between affected and unaffected areas, estimating the impacts on spider richness, abundance, and species composition, as well as its effects on insect biomass. Our results showed that flying arthropod biomass was affected by the dam failure. Also, edaphic arthropod biomass was reduced in affected areas, showing a strong effect from the breach. Finally, we observed that spider abundance, richness and assemblage composition were not affected. These results indicate that there might be a distinct effect among arthropod groups. Also, we suggest that the identity of spider assemblage might be related to long-term exposure to disturbance in the Gualaxo do Norte river basin, thus leading to the occurrence of more generalist and tolerant *taxa* and therefore a more resilient spider assemblag*e*.

Keywords: Anthropogenic impact. Community dynamics. Spiders. Insects.

2.2 Introduction

Among the anthropogenic disturbances seen in tropical countries, mining constitutes one of the main activities, generating severe impacts on the landscape (Frouz *et al.*, 2011; Mannu *et al.*, 2020). The effects of contamination by toxic waste from mining occur at every level of biological organization (Peplow & Edmonds, 2005; Antunes *et al.*, 2013). These effects may be divided into immediate and long-term effects, given that mining sites even after abandoned may continue degrading the land, water bodies and the air (Mannu *et al.*, 2020). In addition, the range of the impact provided by mining is not restricted to exploration sites, and it may have effects along the environment, reaching rivers or riparian ecosystems. (Wohl 2005).

One of the most utilized models for understanding the effect of mining on environments are the arthropods (Medhi *et al.*, 2021). The impacts of mining on riparian arthropods can occur indirectly, usually through trophic interactions, and directly, through shifts in habitat and resources. Consequently, due to distinct *taxa* responding differently to resource, habitat and interactions or functions, this influences arthropod diversity and assemblage in regions affected by active mining or in areas where mining operations have ceased, leaving behind lasting remnants of this activity (Buchori *et al.*, 2018; Mannu *et al.*, 2020). The occurrence and abundance of arthropods in the environment reflects on shifts in arthropod biomass. Apart from insects, which currently suffer an acute decrease in biomass, the alterations caused by mining may also affect spiders. This is linked in some cases to the presence of anthropogenic contaminants found in their prey (Wilczek *et al.*, 2018). Therefore, these *taxa* represent a valuable model for assessing how disturbances affect community dynamics, due to their crucial ecological role and strong association both with habitat structure and anthropogenic impacts (Madden & Fox, 1997; Hoffmann *et al.*, 2000; Holec & Frouz, 2005; Mannu *et al.*, 2020).

One of the major impacts caused by mining activity in tropical regions was the failure of the "Fundão" Dam in the city of Mariana, Minas Gerais, Brazil in 2015 (Brito *et al.*, 2020). This disaster discharged 34 million m³ of tailings into the environment. These tailings were released into the Gualaxo do Norte river, running to the Doce river and spanning the entire basin, ultimately reaching the Atlantic Ocean (IBAMA, 2015). This damage immediately caused alterations in riparian environments. However, there is little evidence of the persistence of these damages in the long term, which could hide the real extent of this damage, and hinder its mitigation.

In this study, our objective was to assess whether this damage could persist after six years on the arthropod fauna community present in riparian environments, at the region where the environmental damage was most intense, the Gualaxo do Norte river, Mariana, Minas Gerais. We hypothesize that the damage reduced biomass, both for ground dwelling arthropods and flying insects. We also hypothesize that the damage shifted spider abundance, richness, and assemblage identity both directly, by changing environmental heterogeneity, and indirectly through impacts on resource availability. Therefore, we expect a lower insect biomass in affected sites, more acutely for ground dwelling arthropods, once the impact caused by the passing of the tailings at the ground level was more severe.

2.3 Materials and methods

2.3.1 Study area

The research was developed at the margins of the Gualaxo do Norte river, a tributary of the Doce river, located in the city of Mariana, Minas Gerais state (Figure 1). The river is a low depth river most of the year, acquiring greater water volume during the periods of intense rains. The river is characterized by the presence of bushy and arboreal vegetation near the riverbanks, where the Atlantic Forest biome predominates. We investigated how the failure of the Fundão dam may have affected the arthropod fauna in the Gualaxo do Norte river basin, once it was the more severely struck river within the Doce river basin, being the location where tailings have accumulated more intensely (Figure 1). Beyond that, the choice for this study site provided us with a good possibility to compare sites with and without tailings along the same river, thus reducing the effect of factors related to spatial variation throughout the Doce river basin.

2.3.2 Experimental design

With the aim of assessing insect biomass in both affected and unaffected areas, as well as spider richness, abundance, and assemblage composition six years after the disaster, we established seven sampling points in portions of the Gualaxo do Norte river not impacted by the tailings from the Fundão dam and nine points in areas affected by the tailings. The locations were initially established using satellite images from Google Earth, spaced at 1 km intervals in both areas impacted and unaffected by the tailings, taking into account the natural course of the Gualaxo do Norte river, rather than a linear distance (Figure 1). We placed them in the closest forest fragment at the margins of the Gualaxo do Norte river. In each point, we installed two 10x4m sampling plots, 50m distant from each other. We used a signaling tape to delimit the plot, attaching them to four irrigation pipes we put on the floor at the corners of the plot. The plots were installed during a previous expedition, conducted in the first week of December 2021, and sampling was carried out in a subsequent expedition, from March 23 to March 31, 2022. We set this 100-day interval between plot setup and the sampling to avoid the possible effect of environmental disturbance provoked by pitfall installation and plot delimitation over the arthropod community (Sperber *et al.*, 2007).

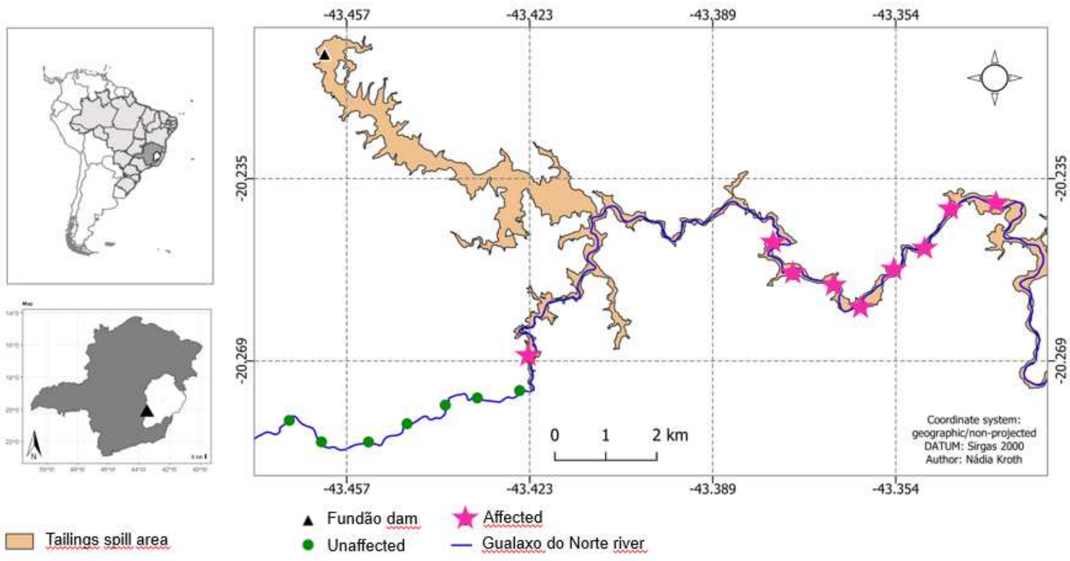

Figure 1. Map indicating the sampled points in the Gualaxo do Norte river, Mariana, Minas Gerais state, Brazil. In each point, two plots (10x4) were sampled. The white highlighted region in the Minas Gerais state map indicates the portion of this state occupied by the Doce river basin. The blue line indicates the course of the Gualaxo do

Norte river. Green dots indicate the unaffected points, and pink stars indicate the affected points.

2.3.3 Edaphic arthropod sampling with pitfall traps

We performed the collection of edaphic arthropods with pitfall traps between March 22 and March 25. We installed six traps in each plot, divided into 2 subsets of 3 pitfalls (Figure 2), each subset was 2m distant from each other. Pitfalls were made of 2L plastic recipients. These recipients had been installed in the previous expedition at each plot, and they remained closed - with their pot lids on them - and without any solution inside, to avoid undue sampling. In the second expedition, we took off the pot lids and filled these recipients with ethanol fuel (96ºGL), a financially accessible and easily available killing solution (Szinwelski *et al.*, 2012), then we left them on the field for 48h. At the end, all organisms captured by the traps were collected and stored in 80% ethanol. On the first day, we activated pitfalls at points 1-4 (unaffected) and 11-14 (affected). On the second day, we activated the pitfall traps at points 5-8 (unaffected) and 15-18 (affected).

To calculate the biomass of edaphic arthropods, we weighed the sample of each pitfall. Before weighing, we let the samples sit on a funnel for 3 minutes to allow for alcohol evaporation. We excluded butterflies from the biomass values because these few individuals were occasional unplanned samples, hence consider them would distort our data. Additionally, all vertebrates (n=5) were excluded from the analysis and were deposited in the collection of the Museu de Zoologia João Moojen at UFV.

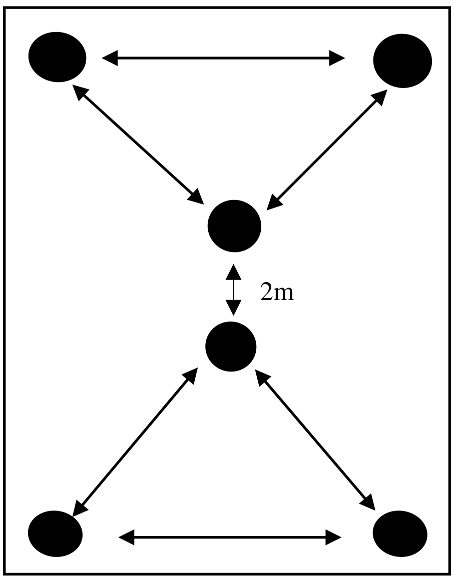

Figure 2. Scheme of a plot (10x4m). Each circle represents a pitfall trap, constituting two sets of 3 pitfalls. Arrows indicate the distance between each pitfall.

2.3.4 Flying arthropod sampling with luminous traps

We collected flying arthropods through Pennsylvania luminous traps, installed at the border of each plot, considering the border closer to the river. Luminous traps were fixed to a wooden support (2m) and plugged into a 12-volt battery. The trap consists of a lamp with a wooden support at the top and a pot at the bottom. The insects are attracted by the light and fall into the pot, which is filled with a liquid for collection, in this case we used 80% alcohol. We turned the traps on at the beginning of twilight (around 6:00p.m.), leaving them lit for one night, turning them off and removing them the morning after. Flying arthropod sampling was carried out after the end of pitfall sampling in each plot, which prevented the effect of researchers' locomotion within the plot on the arthropod capture rate in soil traps. We lit luminous traps in four sampling points a day, switching between affected and unaffected points. Traps were lit at points 11-14 (affected) on March 26, at points 1-4 (unaffected) on March 27, at points 5-8 (unaffected) on March 28, and at points 15-18 (affected) on March 29. The arthropods from these samples were kept in 80% alcohol and deposited at the collection of the Museu de Entomologia da UFV (Frederico Falcão Salles curator). Lamps from the traps within three plots, 5B, 7B (unaffected area) and 8B (affected area), turned off sometime between installment and removal. Therefore, data from these traps were excluded from the analysis to avoid bias.

The assessment of flying arthropod biomass comprised two distinct steps. Initially, we utilized a beaker to measure the weight of each sample. Prior to weighing, the samples were placed on a funnel for 3 minutes to facilitate the evaporation of alcohol. Subsequently, each sample was put into the beaker and weighed.

2.3.5 Spider sampling

From March 24th to March 27th, 2022, we collected spiders through active sampling during nighttime, as it is the period of higher activity both to insects and spiders (Williams 2009; Pinto-Leite & Rocha, 2012), always starting at 7 p.m. In each sampling point, two pairs of researchers simultaneously collected all visually detected spiders within the plot for 25 minutes, sampling two plots at the same time. Each researcher collected with the use of a plastic pot containing 300ml ethanol. Each night, we carried out the sampling in eight plots in four sampling points. Sampling at the points within affected and unaffected areas was carried out alternately. Also, spider sampling was always carried out after the end of pitfall collections in each plot. Spiders were determined to family level following Brescovit *et al.* (2002), and then determined to species or morphospecies level. Then they were stored in 80% alcohol and deposited in the arachnological collection at Universidade Federal de Minas Gerais (Adalberto José dos Santos curator).

2.3.6 Environmental variables

To control potential effects of environmental variables on insect biomass (edaphic and flying), we measured the distance of each plot from the river and canopy coverage percentage. Also, we assessed the effects of litter height to control a possible effect on biomass of edaphic insects. Distance to the river may influence arthropods through resource availability, plant composition, humidity, predators, and susceptibility to flooding events for ground dwelling arthropods (Ellis *et al*., 2001; Achury *et al*., 2023). Canopy coverage is important both for insects and spiders. Insects may use vegetation as a resource, shelter or for predator avoidance through camouflage (Björklund 2008; Duarte *et al.*, 2017). Spiders use them either for foraging, as anchorage points for web building, shelter, or to foil both predators and prey, hiding at the abaxial surface of the leaves, or even through visual camouflage in the leaves or tree trunks (Manicom *et al*., 2008; Théry & Casas, 2009). Litter height is associated with edaphic arthropod assemblage and their ecosystem functions, providing them with valuable resources (Gonzalez & Seastedt, 2001; Myer & Forschler, 2019).

To measure the distance to the river, one of the researchers conducted the tip of a 50m measuring tape until the nearest river margin to the plot, while other researcher held the measuring tape, situated at the border of the plot. To measure mean litter height, we used a ruler, positioned at the border of each pitfall. Finally, to measure canopy coverage percentage, we used a concave densimeter, counting the number of quadrants occupied by canopy, later calculating the cover percentage. This metric was calculated based on the number of quadrants occupied by canopy vegetation, multiplying them by the total number of quadrants of the equipment (17), and dividing by 100. The concave densimeter consists of a wooden square with a concave mirror at the center, and a compass at the border.

Finally, to address potential impacts of resource availability on the spiders, alongside assessing the proximity of each plot to the river and the percentage of canopy coverage, we considered information on the biomass of arthropods smaller than 3cm within the samples from luminous traps. Our focus was specifically on prey insects that were up to 3cm in size, as larger insects are typically less susceptible to becoming trapped in spider webs (Xavier *et al*., 2021).

2.3.7 Statistical analyses

To analyze the potential impact of the environmental changes resulting from the Fundão dam breach, we employed linear mixed models (LMM) for each dependent variable: (i) total biomass of flying insects, (ii) biomass of edaphic arthropods, (iii) spider abundance, (iv) local spider richness, and (v) evenness (Pielou index). We fitted models with the natural logarithm of biomass of edaphic arthropods, to assess the effect of the independent variable (affected or unaffected by the tailings) on this dependent variable. Also, we fitted models with Gaussian distribution to assess the effect of the independent variable (affected or unaffected by the tailings) on total biomass of flying insects, spider abundance, local spider richness and Pielou evenness index.

Furthermore, in the models aimed at assessing the potential effect on the biomass of soil-dwelling arthropods, we considered the additive effect of the covariables, (i) distance of each plot to the river, (ii) canopy coverage, and (iii) litter height in each sample unit (set of pitfall traps). The sampling point, as well as the identity of each plot, were considered as a random factor. To assess the potential effects of environmental change on the community of flying insects (total, smaller and larger than 3cm), we included the predictor variables (i) distance of each plot to the river and (ii) canopy coverage in the models. Sampling points were considered as a random effect in these models.

To assess the effect of environmental change driven by the tailings on spider abundance, local richness and evenness, we considered additional covariables, such as the distance from the river and the availability of flying insects up to 3cm in total length. Each sampling point was also considered as a random variable. Prior to the following analyses, spider community data were Hellinger transformed as per Legendre and Gallagher (2001) using the *decostand* function in '*vegan*' (Oksanen *et al*., 2022).

Finally, to assess the effect of environmental changes on spider species composition, we conducted a permutational multivariate analysis of variance (PERMANOVA) using the Bray-Curtis dissimilarity index. We performed a Non-metric Multidimensional Scaling (NMDS), creating a distance matrix for species ordination with *Vegan* package (Oksanen *et al*., 2022). We conducted the PERMANOVA test using a presence/absence matrix.

We tested the assumptions of both linear mixed models using the *simulateResiduals* function within DHARMa package (Hartig 2022). All additive predictor variables were scaled using the *'scale'* function. To compare the effects in the best fitted model, we used type III Anova with *car* package (Fox & Weisberg 2019). We performed all analyses in R version 4.2.3 (R Core Team 2023).

2.4 Results

2.4.1 Flying arthropods biomass

We observed that the total biomass of flying arthropods was 22.7g (±2.82) in areas affected by the tailings and 28.8g (±2.57) in areas without the presence of the tailings. We found that the total biomass of arthropods is lower in areas where the presence of tailings from the Fundão dam breach remains (χ^2_1=4.28, p=0.03, Figure 3). Furthermore, we did not observe any differences related to the distance to the riverbank (χ^2_1=2.52, p=0.11), nor to the forest canopy coverage of each plot (χ^2_1=0.002, p=0.98) (Figure 3), indicating that it is reasonable to affirm that this result is related to the reminiscent effects from the tailings at the environment.

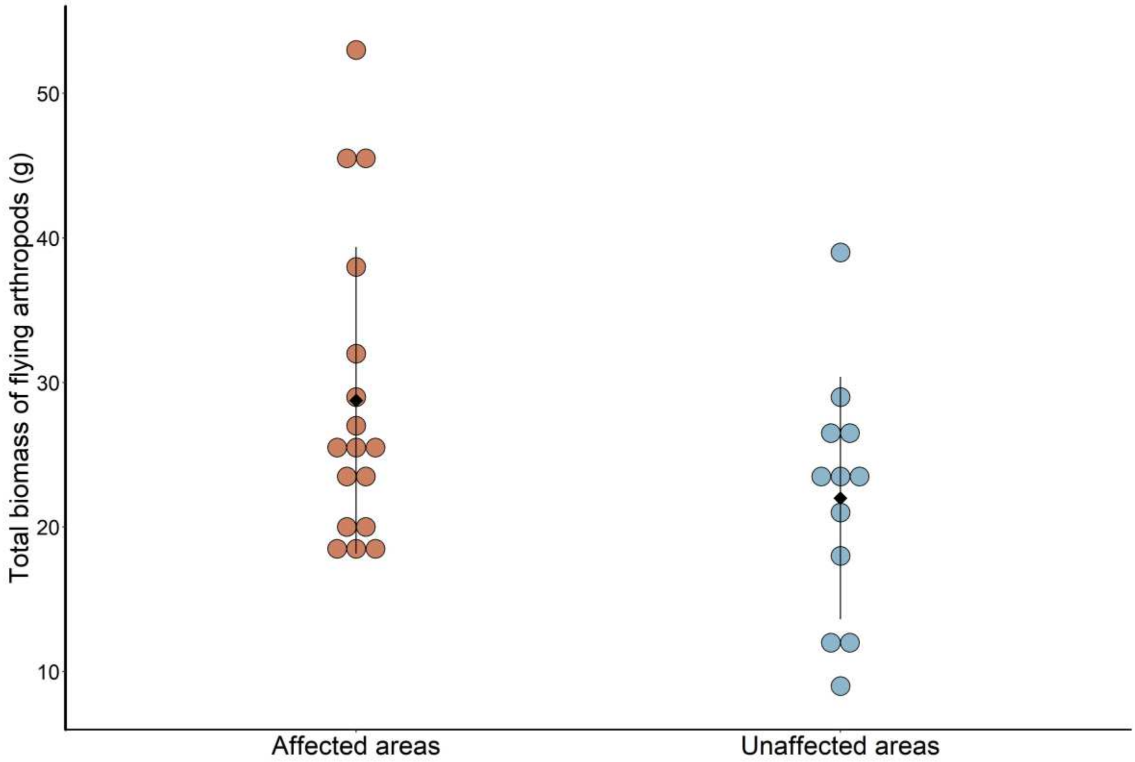

Figure 3. Total biomass of flying arthropods collected in areas affected and unaffected by the Fundão dam breach along the Gualaxo do Norte river, Mariana, Minas Gerais, Brazil. Each dot represents the biomass obtained in each plot. Black diamonds (♦) represent the mean biomass of flying arthropods in areas affected or unaffected by the Fundão dam. The lines represent the standard deviation.

2.4.2 Edaphic arthropods biomass

The biomass of arthropods in the areas affected by the Fundão dam failure (0.54±0.06g) was lower than the biomass recorded in areas unaffected by the tailings (0.88±0.11g; χ^2_1=9.23, p=0.002; Figure 4). We observed that, unlike flying individuals, edaphic arthropods rarely exceeded 3cm in body length. Therefore, it was not possible to measure the effect for large edaphic arthropods. Also, we found that this lower biomass in the affected areas was not affected by differences in canopy coverage (χ^2_1=0.07, p=0.78) or distance from the river (χ^2_1=1.74, p=0.18). However, we observed that leaf litter height was greater in the impacted sites (2.67±0.20 cm), surpassing the average height recorded in areas unaffected by the Fundão dam breach (1.98±0.19 cm) (χ^2_1=6.08, p=0.013).

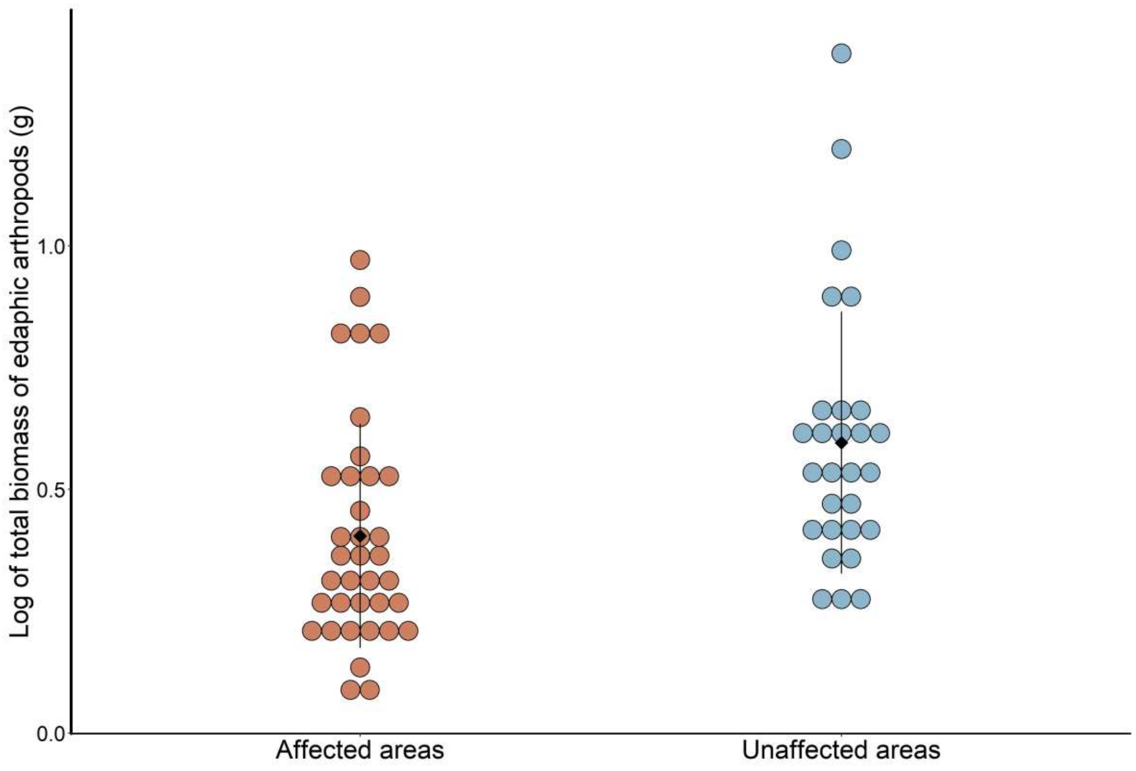

Figure 4. Log (ln) of total biomass of edaphic arthropods sampled in areas affected and unaffected by the Fundão dam breach along the Gualaxo do Norte river, Mariana, Minas Gerais. Each dot represents the biomass obtained in each set of pitfall traps. Black diamonds (♦) represent the mean biomass of edaphic arthropods. Black lines represent the standard deviation.

2.4.3 Spider assemblage

We collected 1.551 spiders, with 443 being adult spiders, representing 32 species and 89 morphospecies. Theridiidae was the most frequent family, comprising 65.01% (288) of adult individuals, followed by Thomisidae with 8.57% (38). We observed an abundance of 14.7(±1.91) individuals at unaffected sites and 13.11(±1.45) at affected sites, meaning similar abundances (χ^2_1=0.04, p=0.83, Figure 5). Furthermore, we observed that spider abundance was not influenced by the distance from the river (χ^2_1=0.32, p=0.56), canopy coverage (χ^2_1=0.02, p=0.88) or availability of flying insects up to 3cm in size (χ^2_1=1.76, p=0.18).

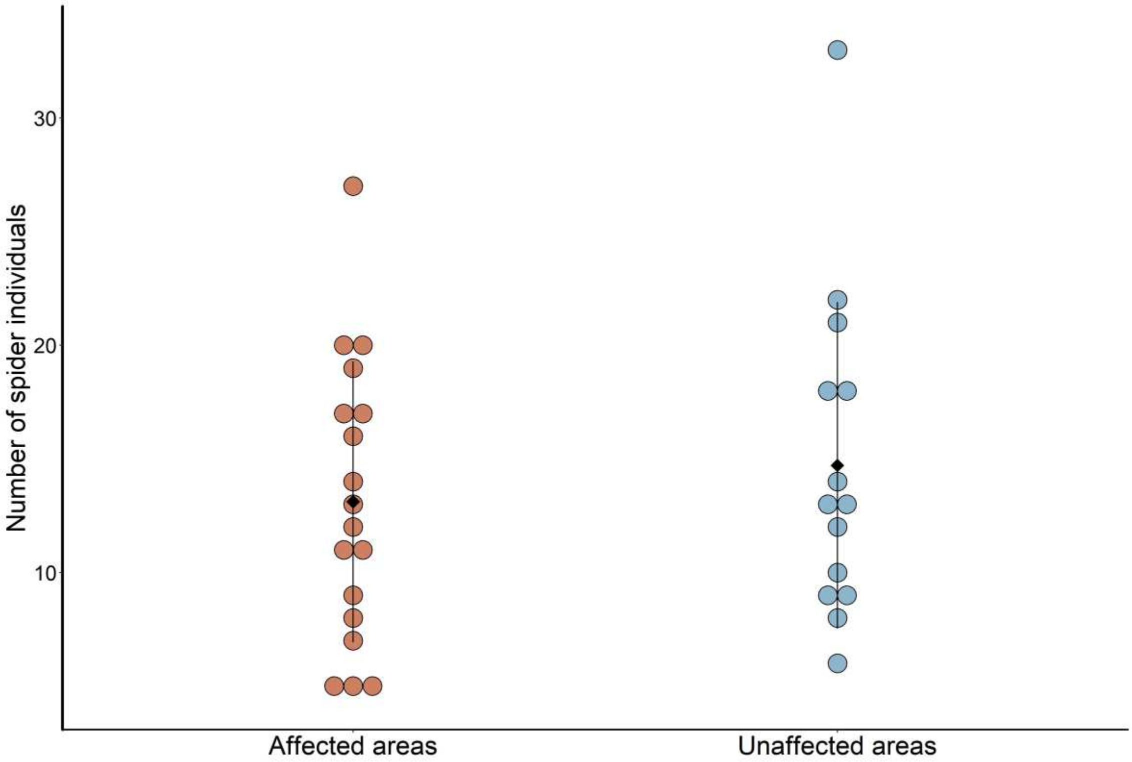

Figure 5. Number of spider individuals collected in areas affected and unaffected by the Fundão dam breach along the Gualaxo do Norte river, Mariana, Minas Gerais. Each dot represents the number of spider individuals in each plot. Black diamonds (♦) represent the mean of number of spider individuals in areas affected or unaffected by the Fundão dam. The lines represent the standard deviation.

We observed that local spider richness was 10.9(±1.30) at unaffected sites and 9.38 (±0.86) at affected sites, thus not showing significant differences between these areas (χ^2_1=0.45, p=0.49, Figure 6). Also, we observed that the number of species was not influenced by the distance from the river (χ^2_1=0.58, p=0.44), canopy vegetation coverage (χ^2_1=0.97, p=0.32), or the availability of insect prey up to 3cm (χ^2_1=0.16, p=0.68).

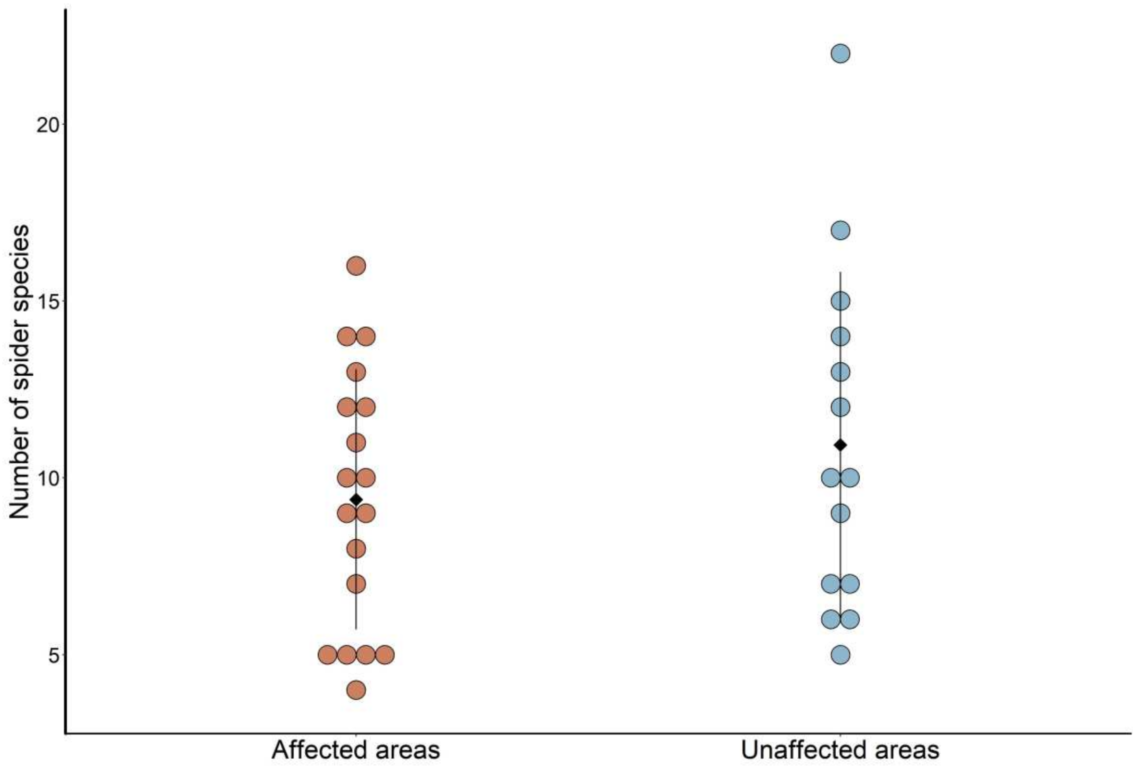

Figure 6. Number of spider species collected in areas affected and unaffected by the Fundão dam breach along the Gualaxo do Norte river, Mariana, Minas Gerais. Each dot represents the number of spider species in each plot. Black diamonds (♦) represent the mean of number of spider species in areas affected or unaffected by the Fundão dam. The lines represent the standard deviation.

In addition, we observed that the evenness in the distribution of species abundance in a community (Pielou index) was 0.27 (±0.02) in areas affected by mining tailings and 0.29 (±0.01) in unaffected areas, indicating that spider assemblage was similar between these areas (χ^2_1=0.27, p=0.59, Figure 7). Additionally, the index was not influenced by the distance from the river (χ^2_1=0.41, p=0.52) or the availability of insect prey up to 3cm (χ^2_1=2.77, p=0.09). However, we noted differences associated with canopy vegetation coverage (χ^2_1=6.33, p=0.01) between affected and unaffected areas.

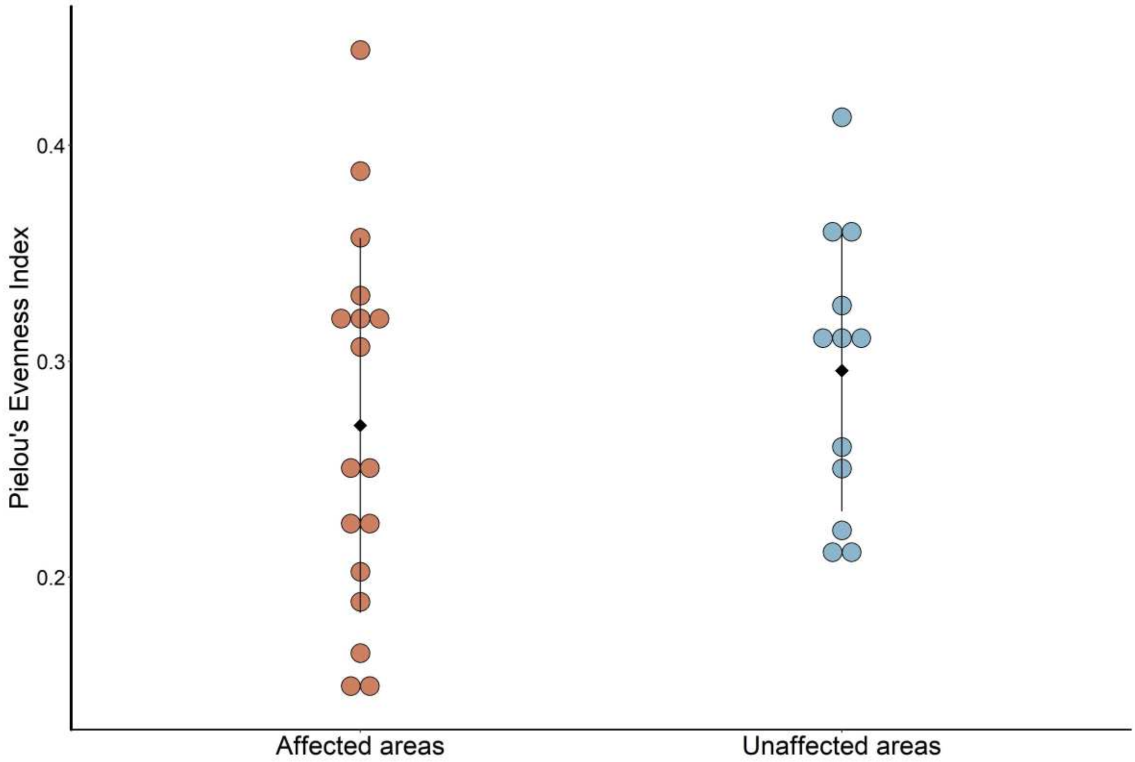

Figure 7. Pielou evenness index of spider species collected in areas affected and unaffected by the Fundão dam breach along the Gualaxo do Norte river, Mariana, Minas Gerais. Each dot represents Pielou evenness index in each plot. Black diamonds (♦) represent the mean of Pielou evenness index in areas affected or unaffected by the Fundão dam. The lines represent the standard deviation.

Finally, we observed that there were no differences between the structures of the spider cluster communities (Figure 8). Affected and unaffected areas did not show significant differences ($p = 0.14$), with a classification percentage $R^2 = 0.05$ and stress = 0.27.

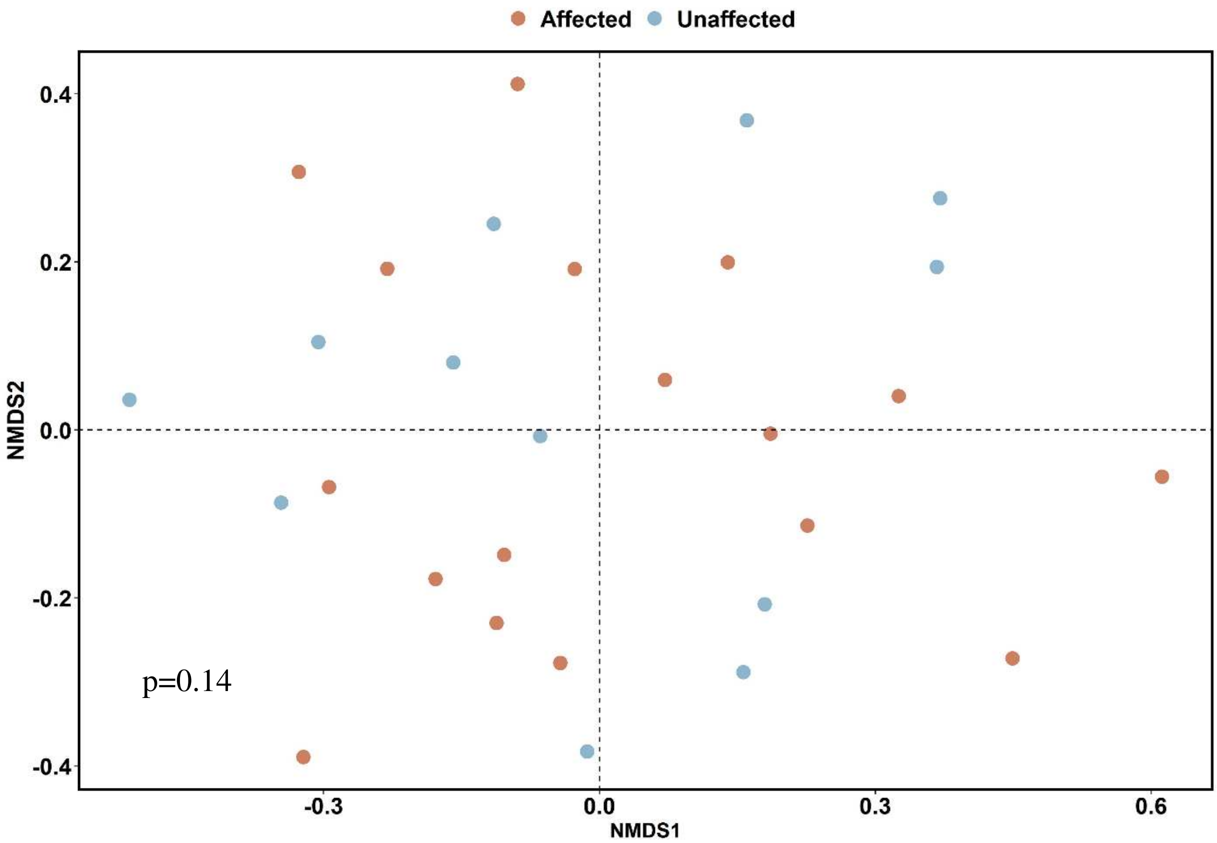

Figure 8. Non-metric Multidimensional Scaling (NMDS) of spider species composition among the affected and unaffected sites. Each dot represents a spider community in a plot. Red dots represent affected sites, while blue dots represent unaffected sites.

2.5 Discussion

We observed that even six years after the rupture of the Fundão dam, the total biomass of insects in the riparian vegetation of the Gualaxo do Norte river continues to be influenced by the alterations caused by environmental damage. We observed that areas with the presence of tailings have a higher biomass of flying insects. We also observed lower biomass of soil arthropods in the affected areas. This may indicate that some groups of flying insects may be less prone to decline because of the environmental change, while others are being harmed, indicating also that arthropod groups that have direct contact with the tailings in the soil are being severely harmed. However, the effects were not observed for bushy spiders, suggesting that the effects of environmental alteration are less intense for generalist predators, such as spiders, in these riparian environments.

In forest gaps, animal communities present a relation with plant successional patterns (Achury *et al.*, 2023). Since the affected areas exhibit a more open structure, this could favor flying arthropods, which are probably habitat generalists (Achury *et al.*, 2023) through changes in the climatic conditions of these locations, as well as through differences in individuals' dispersal ability.

Edaphic arthropods presented a significant reduction in biomass in affected environments. This reduction was not influenced by distance to the riverbank, and it showed no effect from canopy coverage either. The impact on edaphic arthropods may be linked to the presence of tailings in the environment, as tailings are still visible in all affected points except for one point. The effect over soil arthropods biomass was affected by leaf litter height. In tropical ecosystems, biological regulation by soil macrofauna is important for plant litter decomposition (Gonzalez & Seastedt, 2001). Leaf litter was higher at affected sites, probably because a decrease in arthropod biomass, induced by lower nutrient availability and organic matter at this soil, leads to lower decomposition rates. In fact, another study performed at the Gualaxo do Norte river basin found higher abundance of detritivore edaphic arthropods in unaffected areas (Ribeiro *et al.*, 2023). Therefore, the lower abundance and biomass of detritivore arthropods might lead to slower nutrient cycling at this environment, consequently slowing restoration, mainly since these insects are important restoration indicators (Mertl *et al.*, 2009; Lafage *et al.*, 2015; Lawes *et al.*, 2017). Thus, this result might suggest that environmental restoration at the ground in this region is slower than at forest canopy height. Also, previous studies showed that some chemicals – like lead, manganese, and phosphorus – were higher in affected areas, with Chromium and Lead being above the soil quality guideline values (Silva *et al.*, 2021). This could induce harsher conditions for these organisms, as well as trophic effects within this community, consequently simplifying terrestrial food webs (Morales-Silva *et al.*, 2023).

The persistence of tailings at the impacted environment did not change spider assemblage significantly. However, as spider abundance and richness indexes were low, conditions for their occurrence may be harsh in these environments. On the other hand, spiders respond strongly to disturbance, so it is possible that the *taxa* within this assemblage are more resistant to environmental change (Samu *et al.*, 2021). Since the environmental change induced relevant shifts in the biomass of potential insect prey, it is possible that the identity of this assemblage is composed by more generalist families and species, which are less prone to be affected by impacts over the food web. This is in line with previous studies involving edaphic arthropods (spiders included), which also found no significant effects over the abundance of predators between affected and unaffected areas (Ribeiro *et al*., 2023).

The high frequency of Theridiidae within this assemblage might indicate that this taxon might be more tolerant or easily adapted to these environmental changes than other families, probably because they might be more habitat and resource generalist compared to other families. Theridiidae is the third family in species number for Brazil (ArachnoTrAC, 2023). Although the great diversity could help explain why this family was by far the most frequent in our study, Araneidae, the second species-richest family in Brazil (ArachnoTrAC, 2023), was far less frequent. Given that both Theridiidae and Araneidae share the same foraging strategy – web-building – this could indicate that the prevalence of Theridiids could be explained by some aspects in their life history, such as higher plasticity or lesser specificity in their interaction with plants.

Our results indicate that, even though a few parameters we assessed were not severely affected by the presence of tailings from the Fundão dam breach, there were still relevant long-term impacts to the environment associated with it, even after six years. There are documented community effects for arthropods, soil microbial community (Almeida *et al*., 2023), arbuscular fungi (Prado *et al*., 2023), as well as a diversity of impacts over fish (Weber *et al*., 2020; Petesse *et al*., 2023). For instance, in a previous work with the community of edaphic arthropods within the same river basin, areas impacted by the disturbance showed reduced estimated species richness (Ribeiro *et al*., 2023), decreasing also the abundances of omnivore and detritivore arthropods, while not affecting herbivores or predators (Ribeiro *et al.,* 2023). Since our data indicates that the impact significantly reduced the biomass of edaphic arthropods, this could suggest that omnivores and detritivores may represent a big portion of edaphic arthropods at this region. Thus, their response to the presence of tailings at the soil leads to the hardening of the restoration process at this level, indicating also that these groups, mainly detritivores, may play a key role in the restoration of this environment. Also, our result for edaphic arthropods reinforces that the response varies among groups, as it has already been shown for functional guilds of soil arthropods (Ribeiro *et al*., 2023), being now demonstrated also for flying insects. Therefore, in the current context of a decline of arthropods and a trend towards increase in mining activity within the state of Minas

Gerais, our data show environmental restoration after the impact still demands high attention, mainly for soil fauna. In addition, our results for edaphic arthropod fauna help to broaden the comprehension of the magnitude of these impacts for the ecosystems struck by the Fundão dam failure, complementing previous studies regarding arthropod responses after the disaster, also showing the effects over understory invertebrate fauna.

Many factors influence the restoration rates in this environment, so there are key actions that can be carried out to help increase the velocity of environmental restoration. In the areas affected by the damage, we observed the presence of tailings deposited on the ground, as well as the presence of a population of buffaloes, contributing to slower ecological succession in the context of restoration. Therefore, we suggest that the removal of tailings from the banks of the Gualaxo do Norte river may be important factors in enabling the proper restoration of the environment. Our work points to varied responses of riparian arthropod groups within the Gualaxo do Norte river basin to reminiscent effects from the Fundão Dam breach, as certain groups of flying insects may be favored by shifts in understory vegetal community (Ribeiro *et al.*, 2023) as well as plant succession patterns (Achury *et al.*, 2023; Ribeiro *et al.*, 2023), also because they might provide relevant functions to these environments in the context of the stage of ecological succession, while edaphic insects are being harmed at the current state of the regeneration process. Also, the composition of the spider assemblage may be a response to the impacts over understory vegetation as well, composed by generalist and more tolerant *taxa*. Therefore, this suggests that the impacts of the dam breach go way beyond the presence of tailings, constituting long-term effects to biological communities. This effect seems to be more severe for edaphic arthropods and flying insects than for predators, which highlight that the restoration at this environment still requires much attention, demanding more consistent and effective actions. Hence, we suggest that future works should aim at understanding the responses of other arthropod groups not included in this study, as well as following how the responses from these groups change over time.

2.6 References

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