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A cross-sectional ecological study of the impact of sand mining on biodiversity in the Umdloti River, KwaZulu-Natal – A qualitative study.

Sibonelo Thanda Mbanjwa
Mangosuthu University of Technology P.O. Box 12363 Jacobs 4026 Durban, South Africa

Abstract

Background
Sand mining is an escalating threat to riverine ecosystems, especially in developing regions where construction demands are high. In KwaZulu-Natal, the Umdloti River has seen a surge in sand mining, raising concerns about its impact on biodiversity and habitat integrity. This study investigates the ecological effects of sand mining along the Umdloti River, focusing on macroinvertebrate diversity, vegetation cover, and habitat condition.

Methods
A cross-sectional ecological assessment was conducted in April 2024 across three zones: an active sand mining site, an upstream control site, and a downstream recovery site. Macroinvertebrates were sampled using the South African Scoring System (SASS5), while aquatic and riparian vegetation was surveyed using species richness transects. Habitat condition was evaluated based on channel morphology, substrate type, bank stability, and turbidity. Comparative analysis employed descriptive statistics and ANOVA.

Results
Macroinvertebrate diversity and SASS5 scores were significantly lower in the mining zone, with sensitive taxa absent and pollution-tolerant species dominating. Vegetation cover was reduced, with indigenous species displaced by invasive colonizers. Habitat assessments indicated degraded conditions, including unstable banks, altered channel structure, and elevated turbidity. The control zone exhibited greater biodiversity and intact habitats, while the downstream zone showed signs of partial recovery but remained impacted.

Conclusion
Sand mining along the Umdloti River has led to measurable biodiversity loss and ecological degradation, disrupting both aquatic and riparian systems.

Recommendations
Immediate regulatory interventions are needed, including buffer zone enforcement, rehabilitation of mined areas, and stricter permitting controls. Long-term ecological monitoring should be implemented to assess recovery trends. Engaging local communities and stakeholders in sustainable alternatives to unregulated sand extraction is critical to safeguarding the river's ecological integrity.

Keywords: *Sand mining, Riverine biodiversity, Macroinvertebrates, Habitat degradation, Umdloti River, Riparian vegetation, Ecological assessment, SASS5, Sedimentation, Environmental regulation*
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Corresponding Author: *Sibonelo Thanda Mbanjwa*
Email: *mbanjwa.sibonelo@mut.ac.za* *ORCHID 0000000319417669*
Mangosuthu University of Technology P.O. Box 12363 Jacobs 4026 Durban, South Africa

Background information

Sand mining refers to the removal or extraction of sand directly from its natural environment, typically using heavy machinery such as excavators or front-end loaders. This process often involves clearing natural vegetation, constructing gravel access roads, and transporting sand, primarily sourced from riverbeds, although occasionally from banks and beaches, and rarely from the seabed. Such activities result in the destruction of ecologically sensitive areas and significant harm to local biodiversity. De Villiers (2016) noted that in KwaZulu-Natal, the City of Durban commissioned the Council for Scientific and Industrial Research (CSIR) to conduct a cost-benefit assessment of sand mining across 18 rivers within its

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jurisdiction, including the Tongaat, Amahlongwa, and Umvoti Rivers. The Sand Budget Analysis revealed that extraction rates surpassed the natural sediment yield of these river systems, resulting in a net loss of sand. The report further indicated that illegal upstream mining activities had removed approximately one-third of all sediment within the affected rivers.

A 2014 investigation by the United Nations Environment Programme (UNEP) identified illegal sand mining as a major component of the $200 billion global environmental crime sector. Driven largely by financial gain, this practice leads to the degradation of natural habitats and a decline in biodiversity. It also facilitates the spread of alien invasive species, significantly altering local ecosystems. The health impacts are equally concerning noise and dust pollution from mining operations directly affect human well-being (ScienceDirect, 2022), while the transport of sand via uncovered trucks on both national and rural roads poses safety risks to commuters and damages private vehicles. Waters (1995**)** reported that globally, between 47 and 59 billion tons of material are mined annually, underscoring the scale of the problem.

Sand mining also has direct consequences for both terrestrial and aquatic flora and fauna. It disrupts recreational fishing and small-scale agriculture and contributes to the broader challenges of climate change (Frontiers Editorial Team, 2024). Additionally, mining interferes with natural waste disposal processes, causing domestic waste to be carried further downstream (Haslam, 1990). While sand is essential for the construction of infrastructure such as roads, bridges, and buildings (Kondoly, 1994; Pallin et al., 1994), unsustainable mining practices risk irreversible ecological damage. Without proper safeguards, sand mining promotes the loss of biodiversity and the proliferation of invasive species Waters, 1995**)**. Waters (1995**)** found that upstream erosion caused by mining leads to riverbank failure and loss of riparian vegetation, severely impacting fish habitats and destabilizing spawning and nursery grounds. According to Waters (1995), the resulting impact on fish populations is immeasurable.

Beyond environmental concerns, sand mining poses substantial social and economic challenges for indigenous and rural communities. Ecologically, it causes erosion, landscape degradation, biodiversity loss, and grazing land depletion, while socially, it leads to increased dust pollution and the development of mosquito-infested pits, heightening the risk of waterborne diseases (Zema & Lucas-Borja, 2025**)**. According to the National Environmental Management Act (NEMA, 2004), sand mining has also contributed to local economic development by generating employment opportunities. Small-scale vendors often benefit by selling food and goods at mining sites, using this income to support their families. However, these sites have also attracted negative social consequences, including increased prostitution, school dropouts seeking income, and a rise in alcohol and drug abuse. While sand mining cannot be eliminated, there is an urgent need for stronger regulatory frameworks. Government and stakeholders must implement effective policies and enforce compliance to balance development with environmental conservation. The primary objectives of this study are to assess the impact of sand mining on aquatic macroinvertebrate diversity in the Umdloti River using the South African Scoring System (SASS5) as a biomonitoring tool and to evaluate changes in riparian and aquatic vegetation cover and species composition in areas affected by sand mining compared to undisturbed zones. Additionally, the study aims to analyse physical habitat alterations, including changes in channel morphology, substrate composition, turbidity levels, and bank stability, resulting from sand mining activities. A comparative analysis will be conducted to examine biodiversity indicators across sand-mined, upstream (control), and downstream (recovery) zones, to determine the spatial extent and severity of ecological impacts. Ultimately, the study seeks to generate evidence-based recommendations that can inform mitigation strategies and support sustainable river management practices in the Umdloti River.

Methodology

This investigation was carried out between January 2024 and July 2024. Data was collected through a combination of past investigations as well as field research. Observation investigations and community interactions were done according to Zema & Lucas-Borja (2025). Structured questionnaires were distributed to government regulators, sand miners, and local community members within 5km of the sampled sites. Qualitative interviews were undertaken according to Zema & Lucas-Borja (2025). This approach allowed a more in-depth investigation into the unique experience of each interviewee.

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The study area

Figure 1: Google earth image of sand mining operation on the Umdloti River (March 2024)

Study design

This study adopted a *mixed-methods cross-sectional design*, combining quantitative ecological assessments with qualitative social inquiry to evaluate the impact of sand mining on biodiversity and local communities along the Umdloti River. The integration of biological, physical, and community-based data provided a holistic understanding of the ecological and social consequences of sand mining.

Study setting

The research was conducted along the Umdloti River in KwaZulu-Natal, South Africa, focusing on three zones: an active sand mining site, an upstream control site (minimal disturbance), and a downstream recovery zone potentially impacted by mining activity. Data collection took place between January and July 2024 and included both primary field investigations and secondary data from environmental reports and academic studies.

Participants

The *qualitative component* of the study involved 30 participants, consisting of local community members, registered sand miners, and government regulators living or working within a 5 km radius of the river sites. Eligibility criteria included being a stakeholder directly affected by, or actively involved in, sand mining activities. Participants were selected using purposive sampling to ensure broad representation. Structured questionnaires and semi-structured interviews were conducted.

Bias

To minimize bias, the questionnaires were piloted, and interviews were conducted using ethical and standardized procedures. Interviews were performed in participants' preferred language with assistance from trained facilitators. Observer bias in ecological sampling was minimized by applying standardized SASS5 protocols and using multi-person field teams. Triangulation across different stakeholder responses helped strengthen the validity of the qualitative findings.

Study size

The *ecological component* involved sampling at 9 sites (3 upstream, 3 mined, 3 downstream), selected to represent habitat gradients and varying sand mining intensities.
The *social component* involved 30 participants:

- 10 community members
- 10 sand miners
- 10 government officials/regulators

The sample sizes were determined by site accessibility and the need for ecological and social representation across spatial and stakeholder gradients. This clarification ensures that readers distinguish between ecological sampling units and human participant data.

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Data measurement / sources

Ecological data

Macroinvertebrate sampling followed the SASS5 protocol; physical habitat parameters (turbidity, substrate composition, vegetation cover, bank stability) were also recorded. Vegetation surveys used transect and quadrat methods to document species composition and cover.

Social data

- Structured questionnaires captured perceptions of environmental change, livelihood impacts, and attitudes toward sand mining.
- In-depth interviews, guided by Huntington (2000), allowed participants to provide rich narratives of their experiences.
- Observational notes were recorded using field-based protocols adapted from Rothbauer & Paulette (2008).

Statistical analysis

Quantitative ecological data were analysed using descriptive statistics (means, frequencies, SDs). ANOVA tested differences in biodiversity indices (SASS5 scores) between zones. Vegetation richness and cover were analysed using Kruskal-Wallis tests where appropriate. Qualitative data were transcribed, coded, and analysed thematically to identify patterns and concerns. Triangulation of ecological and social data ensured consistency. Missing questionnaire data (<5%) were handled using listwise deletion.

Ethical consideration

The study received ethical approval from the Faculty of Research Ethics Committee, University of South Africa, Date of approval: 15 December 2023. All participants gave written informed consent before participation. All fieldwork adhered to institutional ethical guidelines and caused minimal ecological disturbance.

Results

Descriptive data

Participant characteristics

A total of 30 participants (n = 30) took part in the qualitative component of this study. The sample comprised:

- 10 local community members (33%)
- 10 registered sand miners (33%)
- 10 government officials and environmental regulators (33%)

Demographic profile of participants

- Gender: 60% male (n = 18), 40% female (n = 12)
- Age range: 24 to 65 years; mean age 41.5 years (SD = 11.2)
- Residence proximity: 80% of community participants lived within 3 km of the river; 20% between 3–5 km
- Duration of involvement in sand mining activities (miners/regulators): mean 6.8 years (range: 1–15 years)

Socio-economic characteristics (community members)

- 70% reported some reliance on the river for subsistence activities (fishing, gathering plants)
- 50% reported a loss of access to cultural or spiritual sites along the river due to active mining

Exposure and potential confounders

- 100% of sand miners and government officials were directly involved in regulatory or operational aspects of sand mining.
- Among community members, 80% reported regular direct contact with the river (domestic or livelihood use), exposing them to environmental changes caused by mining.
- No known prior ecological restoration projects or baseline monitoring were conducted before this study, limiting the ability to fully control for pre-existing ecosystem variability (potential confounder).

Ecological sampling sites

- 9 ecological sites were sampled across the three zones: upstream (n = 3), mined area (n = 3), and downstream (n = 3).
- Baseline physical parameters (turbidity, vegetation cover, bank stability) varied significantly between the mined zone and control sites, confirming observable disturbance gradients.

The percentage of females to males that participated was 55:45. The ages ranged between 21 and 65 years. The ecological assessment revealed a clear gradient of biodiversity degradation associated with sand mining activities. Macroinvertebrate sampling using the SASS5 protocol showed high biodiversity in the upstream control zone, where SASS5 scores ranged from 110 to 120, accompanied by high Average Score Per Taxon (ASPT) values. This indicated a healthy ecological condition with the presence of sensitive taxa such as *Baetidae*, *Heptageniidae*, and *Tricorythidae*. In contrast, the

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sand mining zone exhibited significantly reduced biodiversity, with SASS5 scores between 45 and 60 and a dominance of pollution-tolerant organisms such as *Chironomidae* and *Oligochaeta*. Sensitive taxa were almost completely absent in this zone. Downstream of the mining activity, partial recovery was observed, with SASS5 scores improving to between 70 and 85. However, the reappearance of sensitive species was limited, suggesting that the effects of sand mining extend beyond the immediate extraction zone. Riparian vegetation patterns mirrored the macroinvertebrate results. The upstream sites showed dense native plant cover, averaging around 80%, and were dominated by species such as *Cyperus spp.*, *Typha capensis*, and *Phragmites australis*. In contrast, the sand mining zone had severely reduced vegetation cover (average 35%), with large patches of exposed soil and the presence of invasive species like *Arundo donax*. The loss of stabilizing vegetation was particularly evident along disturbed riverbanks, contributing to erosion and sediment displacement. The downstream zone displayed some regrowth of indigenous plants but remained patchy and vulnerable to further degradation.

Physical habitat assessments further confirmed the impact of sand mining. The mined zones were characterized by altered channel morphology, with widened and shallower sections. Turbidity levels were significantly elevated, often exceeding 100 NTU, while riverbanks showed clear signs of destabilization, including collapsed edges and exposed root systems. These physical changes suggest a loss of ecological functionality, with implications for both aquatic life and downstream sediment transport. The social dimension of the study added valuable context to the ecological findings. Community interviews revealed that 80% of local residents observed environmental degradation over time, including increased water discoloration, reduced fish abundance, and erosion of communal land. Additionally, 70% reported that sand mining had negatively impacted their daily lives and livelihoods, particularly for those reliant on fishing and agriculture. While sand miners acknowledged the visible environmental changes, they emphasized their economic dependence on the activity. Interestingly, 60% expressed willingness to comply with future regulations and participate in rehabilitation initiatives if proper support and alternatives were provided. Government regulators cited enforcement challenges as a key barrier to sustainable sand mining practices. Many pointed to resource limitations, overlapping responsibilities among agencies, and weak community engagement as systemic issues that hinder effective monitoring and policy implementation.

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Table 1: List of Plant species identified along the Umdloti River

Scientific name	Common name
Cymbopogon validus	Giant turpentine grass
Sporobolus africanus	Ratstail dropseed
Hyparrhenia tamba	Blue thatching grass
Pycreus nitidus	Leya-butle
Phoenix reclinata	Wild palm
Trema orientalis	Pigeon wood
Dichrostaychys cineria	Sickle bush
Trichilia gregeana	Natal mahogany
Erythrina lysistemon	Common coral tree
Erythrina caffra	Coast erythrina
Albizia adianthifolia	Flat crown
Brachlaena discolor	Silver oak
Ficus natalensis	Common fig
Syzygium cordatum	Water berry
Mimusops caffra	Coastal red milkwood
Strelitzia nicolai	Wild strelitzia
Arundo donax	Spanish reed
Melia azedarach	Syringa
Arundo donax	Spanish reed
Cardiospermum grandiflora	Balloon vine
Casuarina sp	Casuarina

Table 2: List of insects noted

Scientific name	Common name
Anisoptera sp	Dragon flies
Zygoptera sp	May flies
Plecoptera sp	Stone flies
Anopheles sp	mosquito

Table 3: Knowledge of regulations on sand mining of participants

Summative question	YES	NO
Knowledge of Regulations	66	34
Knowledge of the application process	32	68
Possession of a valid permit	33	67

The graph titled "Summative Questions" reveals important insights into participants' understanding of and compliance with regulatory requirements. A majority of respondents (approximately 66%) indicated that they know relevant regulations, suggesting general awareness of legal or procedural frameworks. However, this awareness does not appear to translate into practical understanding or compliance. In contrast, a significant proportion of participants (around 68%) reported not knowing the application process for obtaining relevant permits, indicating a substantial gap in procedural knowledge. This lack of clarity is further reflected in the high percentage (about 67%) of participants who reported not possessing a valid permit. These findings highlight a disconnect between regulatory awareness and the ability to act on that knowledge, pointing to a need for targeted education, clearer guidance, and accessible support structures to improve both understanding and adherence to regulatory procedures.

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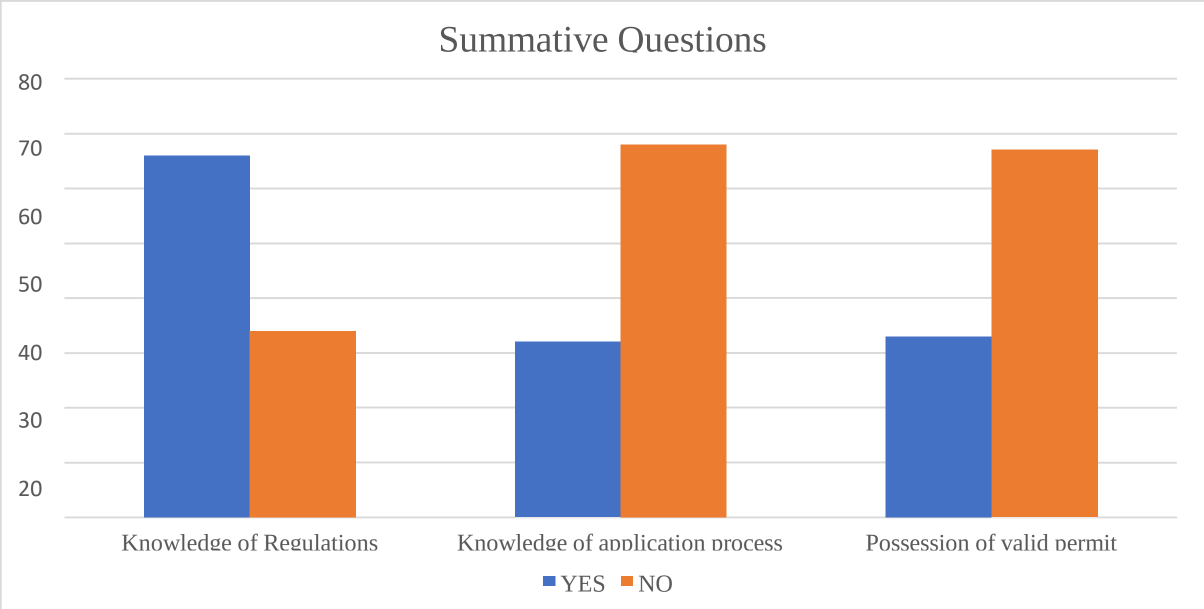

Figure 2: Graph of summative questions

The graph illustrates monthly sand extraction quantities by three miners from January 2024 to July 2024. Miner 2 consistently extracted the highest volumes, with a peak of 160 tons in May, significantly influencing the total extraction levels. Miner 1 maintained a steady output ranging between 40 and 60 tons throughout the period, while Miner 3 had the lowest and most stable extraction rates, hovering around 30 to 50 tons. The total monthly extraction peaked in May at 240 tons, driven by Miner 2's sharp increase, and showed lower levels in January (150 tons) and April (160 tons). Overall, the data suggest that Miner 2 is the primary contributor to total sand extraction variability, while Miners 1 and 3 maintain relatively stable outputs.

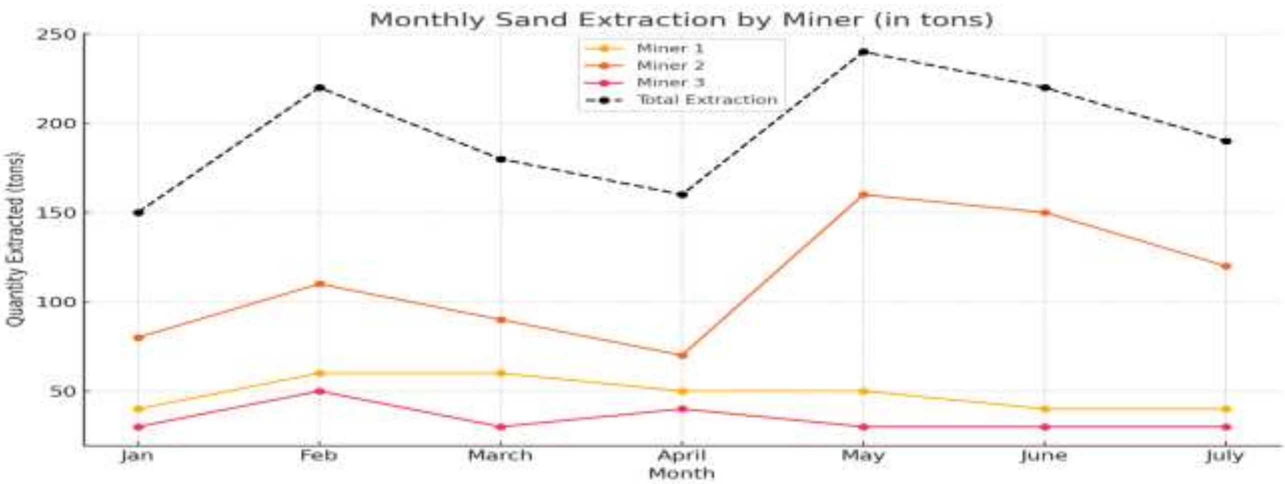

Figure 3: Monthly sand extraction (in tons) by miner 1, miner 2, and miner 3 from January to July

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The stacked bar chart illustrates the gender-based distribution of adaptive and maladaptive coping strategies among postgraduate students facing supervision challenges. Female students reported a higher overall use of both coping categories compared to their male counterparts. Specifically, adaptive strategies such as peer support and informal academic networks were more frequently cited by females, with 6 and 5 participants, respectively, compared to 4 and 3 males. Similarly, females reported slightly higher engagement in maladaptive coping mechanisms, including emotional withdrawal (4 females vs. 2 males) and delaying research tasks (3 females vs. 2 males). This pattern suggests that while both genders are affected by supervisory difficulties, female students may experience greater emotional strain and seek both formal and informal mechanisms to cope. The findings highlight the importance of targeted interventions that consider gender-specific coping needs within postgraduate support systems.

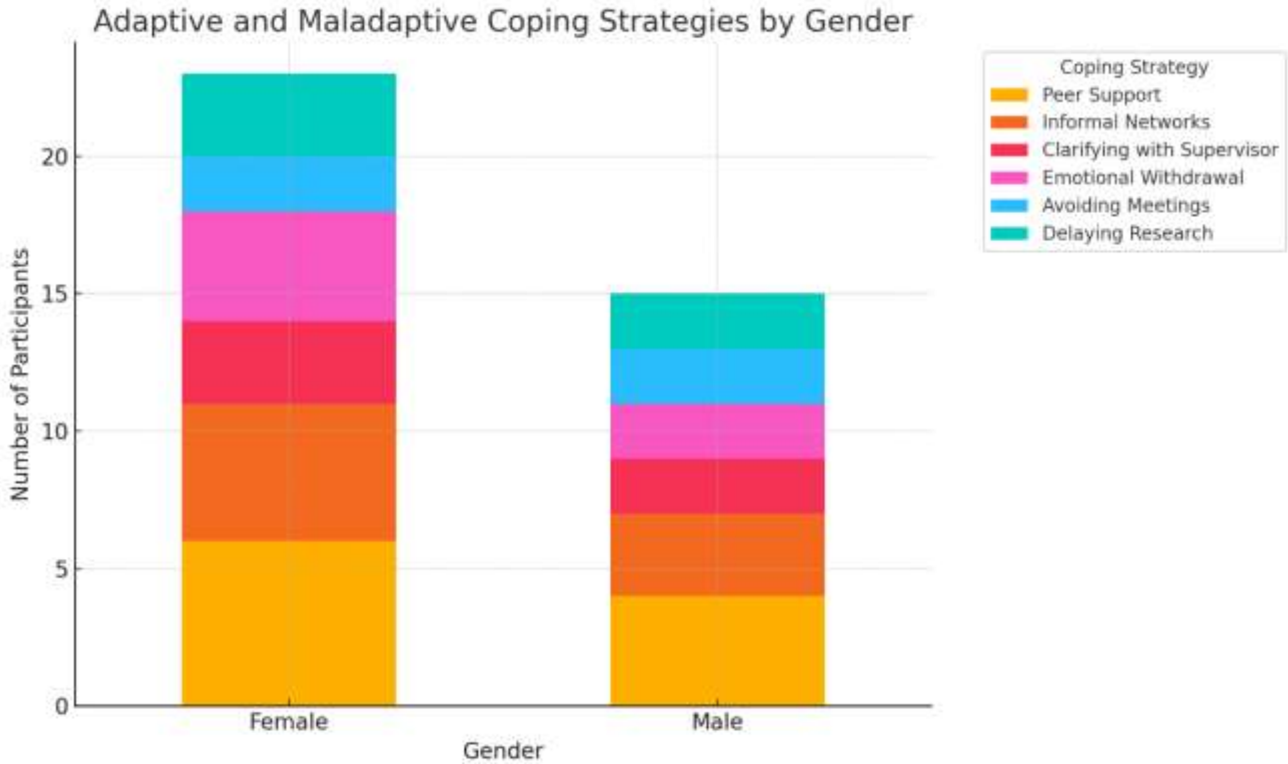

Figure 4: Stacked bar chart showing gender-based distribution of adaptive and maladaptive coping strategies among postgraduate students.

Figure 5 reveals that *perceived ecological degradation* was the most dominant theme, mentioned by 93% of participants. This indicates a widespread perception among community members and environmental staff that sand mining has severely altered the river ecosystem. Closely following this, *disruption of livelihoods and cultural use* (80%) also emerged as a key concern, highlighting that the environmental impacts extend beyond biodiversity loss to affect traditional practices and socio-economic well-being. *Loss of fish and aquatic species* was cited by 73% of respondents, reinforcing the view that species diversity and abundance have declined. Furthermore, 67% of participants expressed concerns about *governance and enforcement challenges*, while 60% pointed to *increased water pollution and turbidity*. Collectively, these themes suggest that stakeholders view the consequences of sand mining as both ecological and social, with insufficient institutional controls to mitigate damage.

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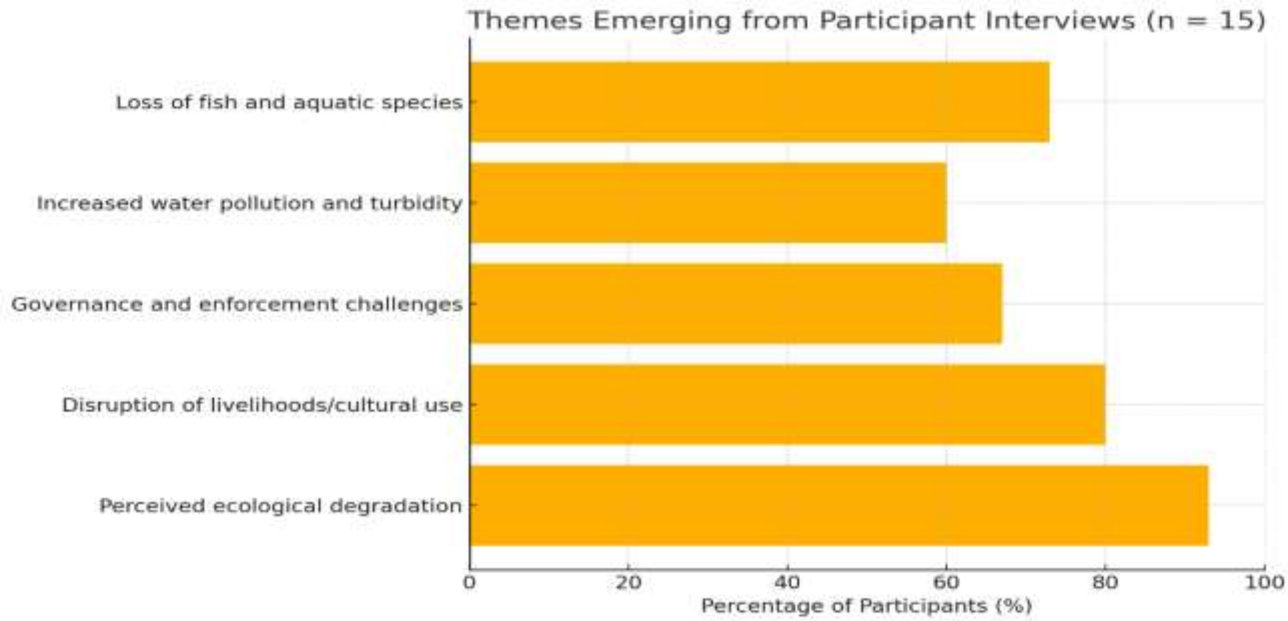

Figure 5: The graph showing major themes from the interviews

Figure 6 shows that 40% of participants perceived *major species loss* in the Umdloti River as a direct result of sand mining activities, while an additional 33% reported observing *minor species loss*. This suggests that nearly three-quarters (73%) of respondents recognised a negative change in biodiversity. In contrast, only 13% reported *no observed change*, and 14% were *unsure or had no opinion*. These perceptions align with the findings from Graph 1, reinforcing the view that sand mining is contributing significantly to ecological degradation in the river system. The fact that very few participants reported no change demonstrates the visible and tangible nature of the environmental impacts.

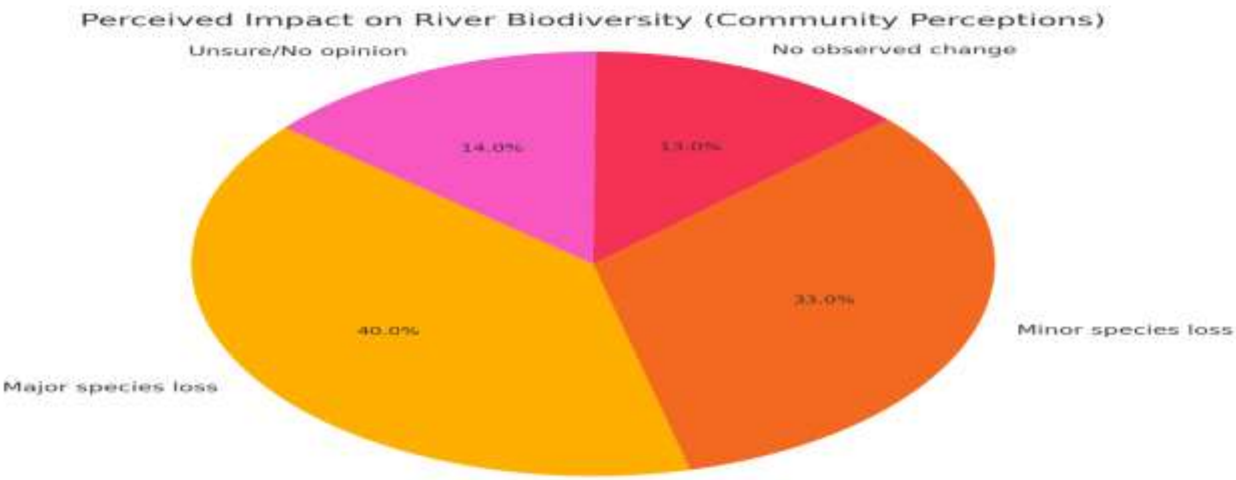

Figure 6: The graph summarizing the perceived impact on river biodiversity

Figure 7 highlights the most frequently used words and phrases in participant narratives. Terms such as *"pollution," "muddy*

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water," "loss of fish," "erosion," "unsafe," "disappearing," and *"ecosystem damage"* were repeatedly mentioned, indicating that participants associate sand mining with declining water quality and biodiversity loss. Culturally significant words like *"tradition"* and *"sacred river"* also featured prominently, suggesting that the impact extends to cultural practices and community identity. The prominence of terms related to habitat disturbance and risk reflects the community's concern for both ecological integrity and human well-being.

Figure 7: The word cloud highlighting common words from participant narratives

Discussion

The study findings clearly illustrate the socio-economic motivations and ecological consequences associated with sand mining activities along the Umdloti River, with strong resonance in both the, and quantitative data. The stacked bar chart revealed that both male and female participants, particularly females, engaged in a range of adaptive and maladaptive coping strategies, reflecting the complex emotional toll of informal and unregulated mining practices. This aligns with the broader social narrative uncovered in interviews, where many younger individuals cited economic hardship and lack of employment as their primary reasons for involvement in sand mining. The word cloud further reinforces the emotional dimension of these experiences, with dominant terms such as *stress*, *withdrawal*, and *pressure* underscoring the psychological burden faced by participants.

The line graph showing monthly sand extraction patterns revealed extraction levels ranging from 150 to 240 tons, which supports participants' claims that output was driven by the fluctuating demands of local buyers. These volumes, while economically sustaining, correspond with the findings of Musah (2009), who emphasized that unchecked mining activities result in irreversible vegetation loss, soil destabilization, and reduced biodiversity. Ecologically, the results echo Musah's (2009) concerns regarding the failure to preserve topsoil and the rapid colonization of alien vegetation in disturbed areas, as supported by the observational data. The drastic drop in SASS5 scores and near absence of sensitive macroinvertebrates in mining zones confirm the degradation of aquatic habitats, consistent with broader literature on in-stream mining impacts (e.g., erosion, turbidity, substrate loss). Additionally, the partial but limited ecological recovery downstream reinforces findings by other scholars who argue that such impacts extend spatially and temporally beyond the mining site (e.g., Davies, 2011; de Villiers, 2016). Despite these environmental and regulatory shortcomings, the study also uncovered a willingness among miners and community members to support conservation efforts, highlighting a potential entry point for inclusive policy development. However, persistent issues such as the lack of permit issuance, with only three granted out of 20 applications, and the absence of clear communication from the Department of Mineral and Resources (DMR) reinforce systemic dysfunction. This supports Musah's call for mapped mining zones and the prohibition of re-mining previously disturbed areas.

Generalizability

The findings of this study are context-specific to the Umdloti

River. However, the methodological approach, combining ecological indicators with community-based data, provides a framework that can be applied in other river systems. The direct applicability of these results is constrained in catchments with different geomorphological features, governance structures, or socio-economic conditions. Nevertheless, the lessons from this study contribute valuable insights to regional river management strategies in KwaZulu-Natal and similar environments experiencing unregulated resource extraction.

Conclusion

This study provides strong evidence that sand mining along the Umdloti River is contributing to ecological degradation, particularly through reduced macroinvertebrate biodiversity, disturbed vegetation, and altered physical habitats. The activity not only affects riverine ecosystems but also has social and economic consequences for nearby communities. Although some downstream ecological recovery is apparent, the damage within the active mining zones is substantial and ongoing. If left unmanaged, the cumulative effects of sand mining may lead to long-term biodiversity loss and further compromise the ecological integrity of the river system.

Limitations

The study is limited by its cross-sectional design, capturing data during a single season and relying on selected spatial zones. This design does not reflect seasonal or long-term trends in biodiversity and sediment dynamics. The sample size for community interviews, while adequate for qualitative insight, does not represent the full diversity of opinions across all affected populations. Additionally, the study focuses on one river system, which constrains the ability to account for ecological and social variations present in other river systems.

Recommendations

To mitigate the impacts of sand mining, a combination of regulatory, ecological, and social strategies is needed. Firstly, environmental authorities should enforce strict guidelines for sand extraction, including designated buffer zones, seasonal restrictions, and mandatory rehabilitation of mined areas. Regular ecological monitoring using tools such as SASS5 and vegetation surveys should be institutionalized to track changes and evaluate recovery. Secondly, riparian restoration initiatives must be launched to stabilize banks and reintroduce native plant species in degraded zones. Thirdly, sand miners should be offered training and incentives to adopt environmentally sustainable practices, while alternative income-generating opportunities should be explored to reduce economic dependence on mining. Finally, greater investment in inter-agency collaboration and community education is critical to ensuring long-term compliance, transparency, and local stewardship of river resources. The integration of ecological and qualitative evidence in this study generated clear recommendations to inform sustainable river management in the Umdloti River. Findings from the SASS5 ecological assessments demonstrated significant declines in macroinvertebrate diversity and habitat quality at active mining sites, while qualitative data highlighted strong community concern over biodiversity loss, water pollution, and the erosion of cultural ecosystem services. Together, these results suggest the urgent need for stricter enforcement of sand mining regulations, including the designation of ecological buffer zones and limits on extraction volumes. Furthermore, stakeholders expressed support for community-based monitoring programs, which would empower local residents to report illegal or excessive mining activities. Restoration of degraded habitats, through bank stabilisation, replanting of riparian vegetation, and sediment management, is also recommended to support ecosystem recovery. The study also identified gaps in coordination between regulatory agencies, pointing to the need for an integrated management framework that brings together municipal, provincial, and community stakeholders. These evidence-based recommendations provide a strong foundation for developing mitigation strategies and more sustainable sand mining practices, aligned with the conservation of riverine biodiversity and the long-term well-being of communities that depend on the Umdloti River.

List of Abbreviations

SASS5 - South African Scoring System
ASPT - Average Score Per Taxon
IHI - Index of Habitat Integrity
GSM - Gravel, Sand, and Mud
NMDS - Non-metric multidimensional scaling
MIRIA - Macro-Invertebrate Response Assessment Index
CSIR – Council for Scientific and Industrial Research
UNEP – United Nations Environmental Programme
NEMA – National Environmental Management Act
DMR - Department of Mineral Resources

Biography

Dr. Sibonelo Thanda Mbanjwa is a dedicated lecturer in the Department of Nature Conservation at Mangosuthu University of Technology (MUT), South Africa. He holds a Ph.D. in Environmental Science and specializes in biodiversity conservation, sustainable development, and environmental education. Dr. Mbanjwa is deeply committed to community engagement, student mentorship, and the integration of indigenous knowledge systems into conservation practices. His work bridges academia and practical application, empowering students and communities through innovative teaching, research, and outreach initiatives.

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Competing Interests

The author has no relevant financial or non-financial interests to disclose.

Author Contributions

I, the author, contributed to the study conception and design. Material preparation, data collection, and research were performed by Mbanjwa S.T. The first draft was written by Mbanjwa S.T.

Data Availability

The data supporting the findings of this study are available upon reasonable request from the corresponding author. Due to ethical considerations and confidentiality agreements, individual participant data cannot be publicly shared. However, anonymized and aggregated data may be provided for academic or research purposes upon institutional approval.

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