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Impact of sand mining in creeks on biodiversity and water quality parameters in Ogbia, Bayelsa State

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Abstract

Sand mining in aquatic ecosystems is a common activity in the Niger Delta region of Nigeria, driven by the demand for construction materials and land reclamation. Yet, unregulated sand extraction poses significant threats to biodiversity, water quality, and ecosystem stability. This study evaluated the impact of sand mining in creek on biodiversity and water quality parameters in Ogbia, Bayelsa State. Sampling was conducted at three locations: two mining sites - Imiringi community along Kolo Creek (SL1) and Elebele Creek (SL2) - and a control site in Emeyal-2 community (SL3). Plant species diversity was assessed using transect and quadrat methods, while phytoplankton and zooplankton communities were sampled and identified following standard procedures. Physicochemical parameters such as turbidity, dissolved oxygen, conductivity, and pH were also measured. Results showed that sand mining significantly altered species composition and ecosystem structure. SL3, exhibited the highest biodiversity, with 26 plant species across 22 families in the riparian section, while SL1 and SL2 recorded lower diversity, dominated by stress-tolerant plant species. Zooplankton abundance was highest at SL3 (256 individuals), compared to SL1 (99) and SL2 (73). Phytoplankton composition also varied, with Bacillariophyta dominating the disturbed sites, reflecting increased sedimentation. Water quality deteriorated in sand-mined sites, with SL1 showing higher turbidity (17.8 NTU) and lower dissolved oxygen (3.5 mg/L), while SL2 had higher biochemical oxygen demand (6.8 mg/L), indicating organic pollution. These results emphasized the ecological consequences of sand mining, including habitat degradation, biodiversity loss, and compromised water quality. Sustainable management practices, such as regulated extraction and habitat restoration, are recommended to preserve aquatic ecosystems in Ogbia, Bayelsa State.

Keywords: Sand mining; Biodiversity loss; Creek; Water quality; Riparian ecosystems; Ogbia

1. Introduction

Sand mining from aquatic environments has become a prevalent practice in many communities in the Niger Delta region of Nigeria, this is driven by the increasing demand for construction materials to meets housing and infrastructural needs and land reclamation. Sand mining refers to the removal of natural aggregates, particularly sand, from their natural deposits (Rentier and Cammeraat, 2022). These materials are primarily sourced from inland water bodies such as rivers, lakes and creeks. As a vital provisioning ecosystem service, sand is employed for infrastructural and construction purposes, contributing to economic and social development (Ashraf *et al.*, 2011).

However, excessive and unregulated sand mining poses significant threats to ecosystem dynamics, altering hydrological regimes, aquatic habitats, and ecological interactions at various trophic levels (Pitchaiah, 2017; Mayank *et al.*, 2024; Torres *et al.*, 2017). One of the major environmental concerns associated with sand extraction is the imbalance between extraction rates and the natural replenishment of sand within aquatic ecosystems. When the rate of removal exceeds the natural regeneration capacity, severe ecological disruptions occur, leading to habitat degradation, biodiversity loss,

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and declining water quality (Nasare *et al*., 2023; Koehnken *et al*., 2020). Several studies, Pitchaiah (2017); Gavriletea (2017); Sonter et al (2018); Koehnken and Rintoul (2018) have documented the adverse effects of sand mining on aquatic ecosystem and water quality. Uwana *et al*. (2022) observed significant declines in water quality parameters in sand-extracted sites, accompanied by shifts in phytoplankton community composition and abundance. Koehnken *et al*. (2020) further reported that sand mining alters critical ecosystem attributes such as macroinvertebrate drift, fish migration patterns, species abundance, and overall community structure, leading to disruptions in food web dynamics. Similarly, Prabhakar (2019) noted that sand mining in River Ganga resulted in a significant reduction in zooplankton species diversity and abundance.

Beyond aquatic biodiversity, the impact of sand mining extends to riparian ecosystems, which function as crucial transitional zones between terrestrial and aquatic environments. These ecosystems play a fundamental role in maintaining biodiversity, regulating water quality, and providing essential habitats (e.g. spawning ground) for various species (Kondolf, et al. 2007; Gregory et al., 1991). The intrusion of riparian zones to facilitate sand harvesting exacerbates ecosystem vulnerability, disrupting the natural structure of plant communities and modifying hydrological conditions (Nasare et al., 2023). Riparian vegetation, plant species growing along riverbanks significantly contributes to ecosystem stability by controlling erosion, reducing water evaporation, and filtering sediments and nutrients before they enter water bodies (Tabacchi *et al.,* 2000; Valyrakis et al., 2021; Lwanga *et al*., 2022). However, Nwachukwu and Udeh (2023) reported that unregulated sand mining disrupts these delicate systems, leading to habitat destruction, biodiversity decline, and water quality deterioration.

Ogbia Local Government Area (LGA) in Bayelsa State is a region where sand mining from creeks is rampant due to proximity and availability of creeks around. Despite the ecological and economic importance of this region, there remains a dearth of study regarding the impacts of sand extraction on biodiversity and local water quality. Given the crucial role of riparian ecosystems in maintaining ecological balance and supporting local livelihoods, a comprehensive assessment of the effects of sand extraction in creeks is essential. This study aims to evaluate the impact of sand mining on biodiversity and water quality parameters in Ogbia, Bayelsa State, and to provide insights that can inform sustainable management practices and conservation efforts.

2. Material and methods

2.1. Study Area

This study was conducted at sand mining sites in Imiringi and Elebele communities, as well as a section of Kolo Creek in Emeyal-1 community, all located within Ogbia Local Government Area (LGA). Ogbia LGA is characterized by a tropical climate, marked by high rainfall levels, which are among the highest in Nigeria. Ogbia is home to the Oloibiri Oilfield, where oil was first discovered in Nigeria in 1956. The sampling locations share similar environmental characteristics, including soil type, sunlight exposure, and water flow, and are situated within the geographical coordinates, Lat 4.68^{0}N and Long 6.32^{0}E. Physiographically, Ogbia LGA lies within the saltwater and freshwater swamp geomorphic units of the Niger Delta, with a low-lying topography that ranges from below sea level in the southwestern areas to about 20 meters above sea level further inland (Oborie and Nwankwoala, 2012; Oki and Rowland, 2018).

2.2. Plant species sampling

The field studies were carried out at three sampling locations (SLs) within Ogbia LGA. Two of these locations were sand mining sites: one situated at Imiringi community designated sample location 1 (SL1) (N4^{0} 85^{1}25 Lat.; E6^{0}36^{1}87 Long.) along a section of Kolo Creek and another at Elebele Creek within Elebele community Elebele community (N4^{0}85^{1}73 Lat.; E6^{0}33^{1}85 Long.) designated Sample location 2 (SL2). The third location, selected as a control site due to minimal human disturbance and similar environmental factors (soil type, sunlight exposure, and water flow), was located in Emeyal-1 community along Kolo Creek (N 4^{0} 85^{1}73 Lat; E6^{0}33^{1}85 Long.) and designated Sample location 3 (SL3). A structured surveying schedule was designed to sample riparian vegetation within a 200 m^{2} area at each site. The transect method was employed, involving the placement of a fifty meters line along one side of the creek bank at each site. Vegetation was sampled at 5meter intervals using 1 m^{2} quadrats to capture herbaceous and shrub layers. Tree species within the designated areas were identified and enumerated. Similarly, plants at the control site were recorded for comparative analysis. All plant species encountered within each sample plot were identified by their botanical and family names, specimens (such as fruits, flowers and twiglets) of plants that could not be identified immediately were collected for proper identification at the university herbarium, Federal university Otuoke, Nigeria.

Species diversity and composition across the sites were evaluated using similarity and diversity measures such as Jaccard index, Sorensen-Dice index, species richness, Simpson's dominance, Margalef index and the Shannon-Wiener diversity index. The indices were chosen to provide an understanding of the impact of sand mining on riparian ecosystems by assessing both the number of species present and their relative abundance. Descriptive statistics including a graph were used to quantified data.

2.3. Plankton Collection and Identification

Plankton samples were collected from the three locations: SL1, SL2, and SL3. At each location, sampling was conducted using a 50-µm mesh plankton net attached to a pole for depth control. The net was gently lowered into the water and held steady to minimize disturbance before being swept horizontally for 1 meter over 1 minute to ensure uniform collection. After retrieval, the net's contents were rinsed with filtered creek water into labelled sample bottles. To account for spatial variability, samples were collected from three points within each location, spaced 2 meters apart. All equipment was thoroughly cleaned between samples at the different SLs to prevent cross-contamination. Each sample was preserved with 5% unbuffered formaldehyde and transported to Biochemistry laboratory, Federal University Otuoke. Whereas, physicochemical parameters including pH, turbidity, water temperature, electrical conductivity (EC), salinity and total dissolve solid (TDS) were determined in-situ with Sper scientific 860033 Bench-top water quality meters. Other parameters alkalinity, hardness, CO2, DO and BOD were determined at Biochemistry Lab. Federal University Otuoke, Nigeria following the procedures of AOAC, (2016).

In the laboratory, samples were concentrated by centrifugation before phytoplankton identification and enumeration. Identification was performed using a Zeiss inverted microscope (×400 and ×1000 magnification), with taxonomic classification (genus and species) based on Newell and Newell (1977), Belcher and Swale (1979), Hallegraeff et al., (1995), Tomas (1997), Prescott (1962, 1964), APHA (2005). Enumeration was carried out using a Sedgwick-Rafter counting chamber for accurate quantification of plankton abundance.

Zooplankton samples were also collected from the same three locations using a 64-µm mesh plankton net, following a similar procedure but sampling from just above the bottom to the surface, following the procedures of Prabhakar et al. (2019) and Goswami, 2004. Sampling was replicated three times per location. In the laboratory, zooplankton samples were concentrated by centrifugation before being transferred into Petri dishes placed over graph paper for examination under a movable stereomicroscope. Identification followed the protocols of Yamaguchi and Bell (2007) and Giere (2009) and was conducted up to the species level using taxonomic guides including Suther and Rissik (2009), Newell and Newell (1977), Ricci and Melone (2000) and Opute (1991).

3. Results and Discussion

Table 1 presents the diversity of plant species across the sampled locations, showing varying levels of species richness, a key measure of biodiversity. Sample Location 1 (SL1) recorded 14 species across 6 plant families, Sample Location 2 (SL2) had 12 species spanning 8 families, while Sample Location 3 (SL3) exhibited the highest diversity with 26 species distributed across 22 families. The variation in species richness indicates ecological gradient influenced by environmental stressors, particularly sand mining activities. SL3 exhibited a more diverse composition dominated by tree species, whereas SL1 and SL2 were primarily populated by grasses, predominantly from the Poaceae family. The dominance of grasses in SL1 and SL2 suggests a higher level of environmental disturbance, likely due to sand mining activities, which alters habitat conditions and reduces species diversity (de Mazancourt et al., 2013; Loreau and de Mazancourt, 2013; Pimm et al., 2014). Certain species, such as *Ipomoea asarifolia*, *Andropogon gayanus*, *Sacciolepis africana*, *Pennisetum purpureum*, *Elaeis guineensis*, and *Musanga cecropoides*, were observed in both mining-impacted sites, emphasising their resilience to ecological stress. In contrast, the higher species diversity in SL3 suggests a relatively undisturbed habitat with a balanced ecological structure. These findings corroborate Nasare et al. (2023), who reported that sand mining disrupts habitats, leading to biodiversity loss. The significant reduction in tree species at SL1 and SL2 further supports this assertion, as trees are generally more vulnerable to habitat degradation caused by human activities, including sand mining.

Table 1 Diversity of Plant Species and Families Across Sampling Locations

Family	Species	*SL I	SL II	SL III
Annonaceae	*Cleistoplolis patens* (Benth)			✓
	Hexalobus crispiflorus (A. Rich)			✓
Apocyanaceae	*Alstonia boonei* (De.wild)	✓		✓
Araceae	*Pistia stratiotes* (L.)		✓	✓

	Podococcus barteri Mann & H. w.			✓
Burseraceae	*Canarium schweinfurthii* (Engl.)			✓
Clusiaceae	*Symphonia globulifera* (L.f.)			✓
Combretaceae	*Combretum* Sp.			✓
Commelinaceae	*Commelina benghalensis* (L.)	✓		
	Ancropogon tectorum Schum & T.		✓	
Convolvulaceae	*Calycobolus africanus* G. Don			✓
	Ipomoea asarifolia (Desr.)	✓	✓	
	Ipomoea eriocarpa (R. Br.)	✓		
Euphorbiaceae	*Anthostema aubreyanum*			✓
	Alchornea cordifolia Sch.. &T.		✓	
Gentianaceae	*Anthocleista vogelii* (Planch)			✓
Humiriaceae	*Sacoglottis gabonensis* (Baill)			✓
Moraceae	*Ficus cyathistipula* (Warb)		✓	✓
	Treculia Africana (Decne)			✓
Myristicaceae	*Coelocaryohn preussii* (Warb)			✓
Ochnaceae	*Lophira alata* (Banks ex C.F. G.)			✓
Pandaceae	*Panda oleosa* (Pierre)			✓
Phyllanthaceae	*Uapaca heudelotti* Baill			✓
Poaceae	*Axonopus compressus* Sw.		✓	
	Andropogon gayanus Kunth	✓	✓	
	Sacciolepis africana (hubb & S.)	✓	✓	
	Paspalum scrobiculatum (L.)	✓		
	Leersia hexandra (Sw)	✓		
	Acroceras zizannioides L.	✓		
	Panicum maximum (Jacq)	✓		
	Pennistum purpureum (Schumach)	✓	✓	
	Elaeis guineensis (Jacq)	✓	✓	✓
Polypodiaceae	*Microsorium* sp.			✓
	Platycerium sp.			✓
Ponterderiaceae	*Eichhornia grassipes*	✓	✓	
Rubiaceae	*Mitragyna ledermannii* (K. Krause)			✓
Rutaceae	*Zanthoxylum gilletii* (De wild)			✓
Sepotaceae	*Synsepalum stipulatum* (Radlk)			✓
Urticaceae	*Musanga cecropoides* (R. Br.)	✓	✓	✓
Vitaceae	*Leea guneensis* G. Don			✓
24		14	12	26

*Sample Locations

The diversity status and similarity comparison of the plant groups across the three sample locations are presented in Table 2. Shannon-Wiener diversity index (H') values indicate that SL3 (H' = 3.434) has the highest biodiversity, implying a more ecologically stable environment. SL1 (H' = 2.639) exhibits moderate diversity, while SL2 (H' = 1.946) records the lowest, suggesting significant ecological degradation, most likely linked to mining activities. Jaccard (J) and Sørensen-Dice (Cs) indices reveal that SL3 and SL1 share the highest similarity (J = 0.605, Cs = 0.753), indicating that while SL1 is impacted, it retains some ecological traits of less disturbed environments. Conversely, the very low similarity between SL2 and SL3 (J = 0.296, Cs= 0.456) suggests that SL2 is the most ecologically altered, likely due to heavy sand mining in that location. These findings align with the previous studies of Aliu et al. (2022) Mohammed et al. (2022) and Ashraf et al. (2011), which reported that mining activities lead to biodiversity loss and species turnover.

Table 2 Diversity and similarity comparisons between plant species in the three Sample Locations

Measure	***SL 1**	**SL2**	**SL3**
Shannon-Wiener Index (H')	2.639	1.946	3.434
Similarity Measure	SL1 vs SL2	SL2 vs SL3	SL3 vs SL1
Jaccard Index (J)	0.412	0.296	0.605
Sørensen-Dice Index (Cs)	0.583	0.456	0.753

*Sample Location

The distribution of six phytoplankton taxonomic groups across the three sample locations (Figure 1) shows key ecological variations. Bacillariophyta (Diatoms) dominated all locations, particularly in SL2 (22 counts), suggesting increased nutrient levels, which may be attributed to sediment deposition from sand mining activities. Charophyta were most abundant in SL3 (6 counts) and absent in SL2, while Chrysophyta, though present in all locations, were most represented in SL3 (12 counts). The reduced presence of Charophyta and Chrysophyta in SL1 and SL2 indicates environmental stress, likely from increased turbidity and reduced water quality (Uwana et al., 2022). Dinoflagellates (8 counts) and Euglenophyta (11 counts) were more abundant in SL1, suggesting a potential link to higher turbidity and organic pollution, which are characteristic of mining-affected water bodies (Surthers and Rissik, 2009). These findings reinforce the notion that sand mining significantly alters aquatic primary producer communities, which in turn affects higher trophic levels in the food web.

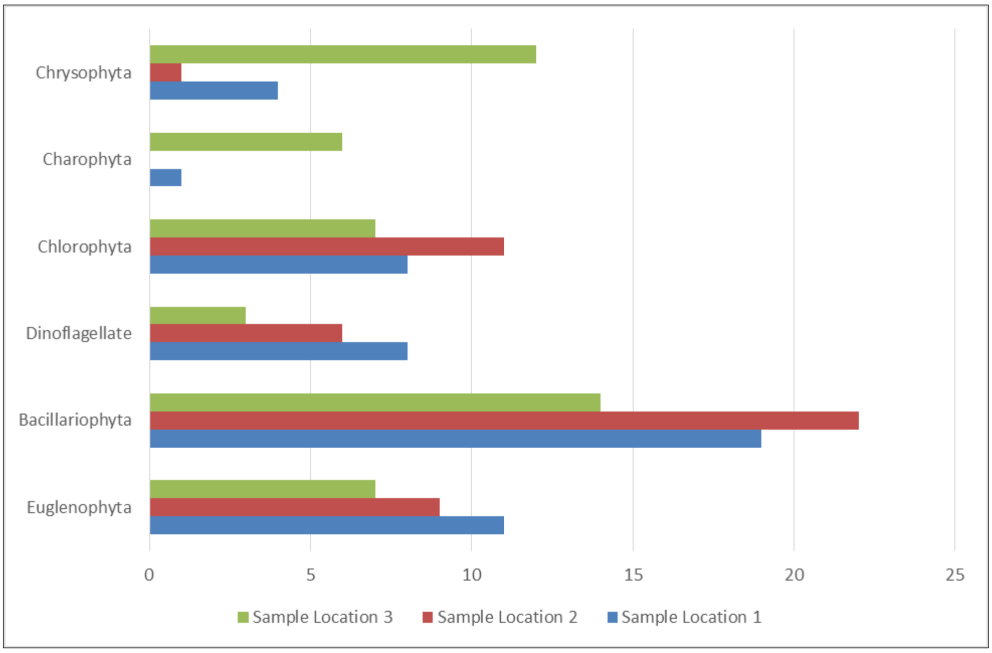

Figure 1 Phytoplankton Taxomonic Group Identified in the Sample Locations

The abundance and diversity status of zooplankton across the sample locations are presented in Table 3. SL3 recorded the highest zooplankton counts across all taxonomic groups, indicating a more stable and less disturbed habitat. Protozoa, critical in microbial food webs, were most abundant in SL3 (105 individuals), compared to SL1 (22) and SL2 (15), further suggesting that SL3 supports a more stable microbial ecosystem.

Rotifera, known for their resilience to environmental stress (Hayward, 2023; Sao et al., 2024), showed a slight decline from SL1 (34) to SL2 (24), but were highest in SL3 (73). Cladocera, sensitive to habitat disturbances (Choedchim et al., 2017), were lowest in SL1 (15) and highest in SL3 (38), further indicating that SL3 is the least impacted by sand mining. Copepoda, which thrive in stable environments, were significantly lower in SL2 (16) compared to SL3 (40). These trends align with the previous findings of Prabhakar et al., (2019); Obot and Jacob (2024), who reported that sand mining negatively impacts zooplankton by increasing turbidity and altering habitat conditions.

Table 3 Abundance Status and Diversity Among Zooplankton Across Sample Locations

Taxonomic Group/Sp.	***SL 1**	**SL2**	**SL3**
PROTOZOA			
Arcella arenaria	2	0	12
Arcella costata	0	1	7
Arcella radiosa	2	2	5
Arcella mitrata	3	0	9
Arcella villgari	1	0	7
Cyphoderia ampulla	0	0	3
Euglypha turberculata	2	1	8
Tintinnidium entzii	1	2	9
Epistylis sp	2	2	5
Centropyxis aculeata	3	2	7
Euglypha ciliata	3	3	11
Centropyxis constricta	0	1	6
Hemiophxis Pleurosigma	1	1	5
Nephroselmis olivacea	0	0	4
Actinophaerium aichorin	1	0	7
Total	22	15	105
ROTIFERA			
Rotaria nepturia	3	0	4
Rotaria citrina	2	0	6
Rotaria rotatoria	2	1	11
Philodina roseola	3	1	10
Lepadella patella	2	2	4
Anuraeopsisa fissa	5	5	6
Leptodora kindtii	3	5	5
Euchlanis lyra	0	3	5
Chronogaster testudo	3	4	6
Pompholyx complanata	4	1	5
Colurella obtuse	4	0	3
Ploesoma tonncatum	0	0	2
Filinia passa	3	2	6
Total	34	24	73
COPEPODA			

Mesocyclops leuckarti	3	1	5
Tropocyclops bferispinus	6	4	6
Tropocyclops prasinus	4	0	2
Enclyclop macruroides	3	2	5
Macrocyclops albidus	2	0	3
Thermocyclops talhokuensis	2	2	5
Neutrodiaptomus incongruens	4	2	4
Neutrodiaptomus pachypoditus	2	3	3
Calamoecia ampulla	3	2	4
Boeckella fluvialis	0	0	3
	29	16	40
CLADOCERA			
Alonella excisa	5	3	7
Alonella karua	4	4	5
Alonella rostrata	0	4	6
Ceriodaphnia cornuta	2	2	4
Ceriodaphnia setosa	3	2	5
Daphnia lumhotzi	0	0	3
Diaphanosoma aspinosum	1	3	8
Total	15	18	38

*Sample Location

Table 4 presents ecological metrics for zooplankton abundance and diversity. SL3 exhibits the highest total abundance (256) and mean abundance (6.24), further supporting its role as the least disturbed environment. SL2 records the lowest abundance (73, mean 2.28), suggesting significant ecological stress, likely due to sand mining.

Margalef Index and Shannon-Wiener Index indicate that SL3 supports the most diverse zooplankton community, while SL2 is the least diverse. The Simpson's Dominance Index is highest in SL2 (0.181), indicating that fewer species dominate, likely due to environmental stress. These patterns align with earlier research indicating that sand mining leads to habitat degradation, favouring a few stress-tolerant species while reducing overall biodiversity (Imam and Balarabe, 2012; Siddique et al., 2024).

Table 4 Zooplankton Ecological Metrics, Abundance and Diversity in the Sample Locations

Metric	**SL1**	**SL2**	**SL3**
Sum	99	73	256
Mean	2.75	2.28	6.24
Standard Deviation (SD)	1.456	1.482	2.382
Margalef Index (d)	17.53	16.10	18.27
Species Richness (R)	36.0	31.0	45.0
Simpson's Dominance Index (D)	0.132	0.181	0.031
Shannon-Wiener Index (H')	3.49	3.31	3.72

Table 5 compares the physicochemical properties of water across the sample locations, highlighting significant impacts of sand mining on water quality. SL2 recorded the highest temperature (31.5°C), exceeding the recommended limit (30°C), which can influence zooplankton metabolism and community composition (Richardson, 2008; Chiba et al., 2015; Siddique et al., 2023). This finding further confirms Nasare et al. (2023), who reported extreme temperatures of water surface in sand mining area due to the removal of tree species.

Turbidity levels in all locations exceeded the recommended 10 NTU, with SL1 recording the highest (17.8 NTU), likely due to suspended particles from sand mining. Dissolved oxygen (DO) was highest in SL3 (8.7 mg/L), reflecting better water quality, whereas SL1 (3.5 mg/L) and SL2 (4.5 mg/L) were below recommended limits, suggesting poor oxygenation and potential stress on aquatic life. Higher conductivity in SL1 (199.80 µs/cm) and SL2 (183.69 µs/cm) suggests increased dissolved solids, possibly from sedimentation. These findings support previous studies linking sand mining to degraded water quality (Imam and Balarabe, 2012; Siddique et al., 2023).

Table 5 Comparison of Physicochemical Properties of Water in the Sample Locations

Parameters	**SL I**	**S LII**	**S L III**	**DRP/ FMEnv (1993) Recommendation**
Temperature (^{0}C)	28.8	31.5	28.3	30
Conductivity (EC, µs/cm)	199.80	183.69	90.81	1000
pH	7.04	6	8.37	6.5 – 8.5
Turbidity (NTU)	17.8	15.6	13.8	10
DO (mg/l)	3.5	4.5	8.7	5
Alkalinity (mg/l)	69.4	87.8	96.3	200
CO2 (mg/l)	5.1	7.06	7.5	-
BOD (mg/l)	5.2	6.8	3.5	10
Hardness (mg/l)	21.04	22.04	18.28	<100
TSD (mg/l)	74.1	66.17	52.66	< 500
Salinity (ppm)	0.03	0.03	0.01	-

4. Conclusion

In conclusion, sand mining in creeks within Ogbia LGA, Bayelsa State, has a significant impact on both biodiversity and water quality parameters. The reduction in plant species diversity at mining sites (SL1 and SL2) compared to the control site (SL3) suggests habitat degradation caused by sand extraction activities. The predominance of grass species in mining-affected areas, as opposed to the tree-dominated ecosystem in the control site, further emphasizes the ecological disruption resulting from sand mining. Similarly, variations in phytoplankton and zooplankton composition across the sample locations were observed. The low diversity and abundance of key zooplankton groups, such as Cladocera and Copepoda, at the sand mining sites indicate adverse impacts on aquatic ecosystems, due to increased turbidity and sedimentation. The presence of pollution-tolerant taxa, such as Euglenophyta and Dinoflagellates, in SL1 and SL2 further suggests that sand mining alters water quality, leading to reduced oxygen availability and habitat degradation for aquatic organisms. Results from this study indicate that unregulated sand mining disrupts riparian ecosystems, decreases species diversity, and compromises water quality. And if left unchecked, continued sand mining in the creeks at Ogbia LGA may increase biodiversity loss and alter ecological balance, eventually affecting both environmental sustainability and local livelihoods that depend on the water bodies.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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