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A cross-sectional environmental assessment of the ecological integrity of key driver components (Water Quality, Sediment, and Habitat) in the uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi rivers, KwaZulu-Natal.

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Abstract

Background
Freshwater ecosystems in KwaZulu-Natal are increasingly threatened by urbanization, agriculture, and industrial activities. These pressures undermine ecological integrity by affecting water quality, sediment characteristics, and habitat structure. The uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi Rivers hold critical ecological and socio-economic value, yet comprehensive assessments of their environmental condition remain limited.

Methods
A cross-sectional environmental assessment was conducted across five major rivers between March 2024 and October 2024**,** with sampling sites positioned upstream, midstream, and downstream to capture spatial variability. Water quality parameters (pH, dissolved oxygen, turbidity, nitrates, phosphates, and heavy metals) were measured using standard methods. Sediment samples were analysed for particle size distribution, organic content, and contaminants. Habitat integrity was assessed using the South African Scoring System (SASS5) and the Index of Habitat Integrity (IHI). Data were analysed using descriptive statistics and multivariate techniques.

Results
The assessment revealed varying levels of ecological degradation. Downstream sections of the uMngeni and Umvoti Rivers showed poor water quality, with elevated nutrient levels and low dissolved oxygen. Sediment contamination by organic matter and heavy metals was prominent near urban and industrial zones. Habitat integrity scores were lowest in areas affected by agricultural runoff and informal settlements. The Umdloti and Umfolozi Rivers showed relatively better ecological conditions, though signs of degradation were still evident.

Conclusion
The study highlights significant ecological stress in KwaZulu-Natal's rivers, particularly due to declining water quality and habitat degradation. Spatial trends reveal a strong association between land use activities and ecosystem health, emphasizing the need for urgent intervention.

Recommendation
To protect freshwater ecosystems, authorities should enhance river monitoring programs, enforce pollution control measures, and implement habitat rehabilitation. A collaborative, catchment-based management approach involving communities, industries, and conservation stakeholders is essential for sustainable riverine ecosystem protection.

Keywords: *Ecological integrity, Water quality, Sediment contamination, Habitat assessment, KwaZulu-Natal rivers, South African Scoring System (SASS5), Index of Habitat Integrity (IHI), Land use impact, River health, Environmental monitoring*
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Introduction

The ecological health of riverine ecosystems depends on the dynamic interaction between abiotic drivers and biotic responders. Abiotic factors, such as water quality, sediment composition, and habitat structure, shape the

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environmental conditions of aquatic systems. In turn, biotic communities, particularly macroinvertebrates and fish, serve as biological indicators that reflect the system's ecological condition. Shifts in abiotic variables often result in changes to the composition and functioning of biotic communities, which may disrupt ecological balance. As such, regular monitoring of both abiotic and biotic components is critical for maintaining river ecosystem services and ensuring long-term ecological sustainability (Artiola et al., 2004; Wiersma, 2004; Weston, 2011). Sediment quality, in particular, plays a pivotal role in riverine health, functioning both as a reservoir for pollutants and as a determinant of habitat structure (Munn et al., 2002). Characteristics such as sediment grain size, moisture content, and organic matter influence the suitability of habitats for aquatic organisms, while contamination by heavy metals or organic pollutants can degrade water quality and increase toxicity (Charkhabi et al., 2008). Healthy sediments provide essential substrates for feeding, reproduction, and shelter, thereby supporting biodiversity and trophic interactions (USEPA, 2001; Uys et al., 1996). When sediment composition is altered, habitat integrity is often compromised, which in turn affects ecological diversity and resilience. It is well understood that heterogeneous and structurally complex habitats support more diverse and stable biotic communities.

This study aimed to assess the current ecological integrity of five major river systems in KwaZulu-Natal: the uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi Rivers. A cross-sectional environmental survey was undertaken, employing a combination of standardized field and laboratory methods. Water quality metrics, including pH, dissolved oxygen, turbidity, and nutrient concentrations, were measured both in the field and through laboratory analyses. Sediment samples were collected to determine grain size distribution, organic content, moisture levels, and contaminant loads. Additionally, habitat assessments were conducted using the South African Scoring System (SASS5) and the Index of Habitat Integrity (IHI), providing insight into physical habitat conditions and ecological status. Fifteen sampling stations were distributed along upstream, midstream, and downstream reaches of each river to capture spatial patterns and variability. The study's findings are intended to contribute to regional biodiversity conservation, inform water management practices, and support evidence-based environmental policy development. Ultimately, the results will aid provincial authorities in crafting integrated management approaches to safeguard the ecological health of freshwater systems in KwaZulu-Natal.

Research Objectives

- To evaluate the current water quality status of the uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi Rivers using key physicochemical and biological indicators.

Methodology

Study Design

This study adopted a cross-sectional environmental assessment design, focusing on spatial comparisons of ecological integrity across selected rivers in KwaZulu-Natal. The design allowed for the examination of variations in water quality, sediment composition, and habitat structure at specific points in time across multiple river systems.

Study Area

Umgeni River

The uMngeni River is located in KwaZulu-Natal, South Africa. Its GPS coordinates are Latitude: 29º48′36″S, Longitude: 31º02′08″E. The river originates from Dargle, a small farming village on the outskirts of Howick in the KZN midlands, and its mouth is located in the Indian Ocean, Durban (Fig. 1). The river is 232 kilometres long, with a catchment area of 4,432 kilometres. The uMngeni River boasts some of the famous waterfalls, known as the Howick Falls. Some reports suggest that agricultural industries impact on the river's health due to excessive nutrient inputs they introduce into the river streams (DWAF, 2017). The Palmiet River is a tributary of the uMngeni River with a small catchment of 37 km2 and isfound some 15km northwest of Durban, Kwa-Zulu Natal (du Preez and de Villiers, 1987).The source of the river is situated in Kloof and flows through the Pinetown industrial area, the Westville and Reservoir Hills residential area, and enters the uMngeni River in the vicinity of Springfield Flats (du Preez and de Villiers, 1987). The river is influenced by industrial, human, and partial agricultural pollution. The topography near the Pinetown basinis relatively flat, but the majority of the area is undulating with deep gorges in the Palmiet Nature Reserve that have been well dissected by the river (du Preez and de Villiers, 1987).

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Figure 1: Map of the uMngeni River (Google Maps)

Thukela River

The Thukela River originates from the Drakensberg Mountain Range above Bergville and ends approximately 95 km north of Durban into the Indian Ocean (DWAF, 2001) (Fig. 2). The lower reaches of the Thukela River catchment are influenced by sugarcane agricultural activities, industry (Mandini, Sappi Mill), which are direct drivers to the loss of natural habitat, erosion, and siltation (Stryftombolas, 2008). The Sappi Tugela Mill discharges its effluent directly into the Thukela River close to its confluence with the eMandeni River. The eMandeni River supports the Isithebe rural area and industrial complex, and rural sewage treatment works from both Isithebe and Mandini. Previous studies on the lower reaches of the Thukela River have been done by Oliff (1960), Brand et al. (1967), Coke (1995), De Moor et al. (1999), DWAF (2001), DWAF (2003), Cloete et al. (2008), Ferreira et al. (2008), Stryftombolas (2008), and O'Brien (2010).

Figure 2: Map of the Tugela River (Google images)

Umvoti River

The Umvoti River originates from the Natal Midlands and enters the Indian Ocean near Blythedale Beach about 90 km north of Durban DWAF, 2004) (Fig. 3). The lower reaches of the Umvoti River are influenced by sugarcane agricultural activities, heavy industries, informal settlements, rural areas, as well as rural sewage-treatment

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works. Overgrazing and water abstraction for agricultural, commercial, and industrial uses have been observed in the lower reaches of the Umvoti River (Carminati, 2008).

Figure 3: Map of the Umvoti River (Google Maps)

Umdloti River

The Umdloti River flows in the area near Verulam in the KwaZulu-Natal province, South Africa. The mouth of the Umdloti River is situated north of Durban. The name Umdloti is the Zulu word for a species of wild tobacco that grows there. The river is closely associated with the new King Shaka International airport as well as many industries that are located in the Verulam area (Fig. 4). The river is heavily sand mined at the mid to lower reaches of the river.

Figure 4: Map of Umdloti River (Google Maps)

Umfolozi River

The Umfolozi River is situated in KwaZulu-Natal, South Africa. It originates from the formation of two sister rivers called the black and white Umfolozi Rivers near the South-Eastern boundary of the Hluhluwe-Umfolozi Game Reserve (Fig. 5). In Zulu translation, the name Umfolozi describes the zigzag nature of the river. The GPS coordinates of the river are Latitude: 28º23′32″S, Longitude: 32º25′27″E. The river follows an easterly

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direction towards the Indian Ocean, and its mouth is located at Maphelana. The river assists the sugarcane farming community and provides shelter for abundant species located at St Lucia Estuary (Fig. 5). Furthermore, the Umfolozi catchment is used for subsistence agricultural practices, including dry-land agriculture comprising livestock grazing and rain-fed agriculture (Tefangenyasha *et al.*, 2010).

Figure 5: Map of the Umfolozi River (Google Maps)

Site selection

Sampling

The investigation centered on the lower reaches of each of the selected rivers. These are catchment areas that could provide a perfect indication of the sedimentation and the involvement of the contributors to the quality of the sedimentation. Similar studies have been conducted in the lower reaches of the Amatikulu, Thukela, and Umvoti Rivers in KwaZulu-Natal, South Africa (CRUZ, 2000; O'Brien *et al.*, 2005; Malherbe, 2006; Schüring and Schwientek, 2006; Carminati, 2008; Ferreira *et al.*, 2008; Malherbe *et al.*, 2008; Stryftombolas, 2008; Swemmer, 2008; O'Brien *et al.*, 2009; O'Brien, 2010; O'Brien, 2011). These previous investigations suggested that agriculture, industry, human domestic use, and rural sewage treatment works had major influences, resulting in the deterioration of the river systems. Depending on the seasonal variations as well as the tidal levels, the changes in various drivers have been noted to be most damaging during the low tidal periods.

Table 1: Site co-ordinates for the study area for each river under investigation

GPS Coordinates of sample sites

	uMngeni		uThukela		Umdloti		Umfolozi		Umvoti	
	Lat	Long	Lat	Long	Lat	Long	Lat	Long	Lat	Long
Site1	-29.8183	31.01171	-29.06567	31.24711	-29.3917	31.6970	-28.2331	32.3426	- 29.28979	31.29331
Site2	-29.0899	31.01347	-29.19342	31.47353	-29.4011	31.6567	-28.1975	32.3112	- 29.28108	31.10988
Site3	-29.1665	31.1431	-29.08781	31.30017	-29.3819	31.5439	-28.2745	32.3984	- 29.36998	31.30013
Site4	-29.0995	31.1363	-29.1690	31.39765	-29.3954	31.5995	-28.1856	32.2997	- 29.35762	31.31012
Site5	-29.7074	31.0548	-29.09971	31.36501	-29/3673	31.6548	-28.2120	32.2341	- 29.36566	31.30981

Lat = Latitude Long = Longitude

Water quality

To determine the state of water quality, the following variables were selected:

Temperature
Chemical oxygen demand (COD)
Electrical conductivity

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pH and total alkaloids
Nutrients and toxins
This determination was adopted from previous investigations by Carminati (2008), Stryftombolas (2008), O'Brien *et al*. (2009), and Malherbe *et al*. (2010) for assessing the physicochemical variables.

Sampling protocol

Samples were collected (sub-surface) in clean polyethylene bottles. Before sampling, the bottles were rinsed with the water from the sample sites to eliminate contamination and error in sampling. The samples were then stored in a cooler box and transported to the laboratory at Mangosuthu University of Technology for further analysis. During sampling, physical variables included temperature, pH, oxygen concentration and saturation levels, and electrical conductivity were measured *in situ*. The physical variables were measured with a YSI professional plus multi-meter (water quality sampling and monitoring meter).

Laboratory analyses

Table 2:The water samples that were collected were taken to the laboratory for the following analyses

1. Chemical oxygen demand
2. Electrical conductivity
3. pH
4. Total alkalinity
5. Chlorides
6. Sulphates
7. Calcium
8. Sodium
9. Nitrates
10. Nitrites
11. Orthophosphates
12. Ammonium

To evaluate the quality of the sampled water, the Target Water Quality Requirements (TWQR) (DWAF, 1996) for domestic use and Aquatic Ecosystems (DWAF, 1996) were used (Table 2). A comparison was then made between all the rivers under investigation.

Table 3: Target water quality ranges for constituents as provided in the DWAF (1996 1996) Guidelines for Domestic Use and Aquatic Ecosystems

Variables	Units	Abbreviations	Domestic use	Aquatic ecosystem
Temperature	^{o}C	^{o}C	N/A	<2^{O}C, <10%*
pH		pH	6.0 – 9.0	>0.5 0r 5%*
Oxygen	mg/l	O_2	N/A	6 – 12mg/l
Oxygen	% Saturation	O_2%	N/A	80 – 120%
Conductivity	mg/l	EC	0 – 0.7mS/cm	N/A
Total alkalinity as $CaCO_3$	mg/l	TAL	0 – 8mg/l	N/A
Nitrates as N	mg/l	NO_3	N/A	N/A
Nitrites as N	mg/l	NO_2	N/A	N/A
Nitrogen ammonia as N	mg/l	NH_4	0 – 1 mg/l	<7µg/l
Soluble ortho-phosphate asPO_4	mg/l	PO_4	N/A	15%* and not change to trophic status
Chemical oxygen demand as O_2	mg/l	COD	N/A	N/A
Chloride	mg/l	Cl	100 – 200mg/l	N/A
Calcium	mg/l	Ca	0 – 32 mg/l	N/A
Sodium	mg/l	Na	100 - 200mg/l	N/A
Sulphate	mg/l	SO_4	0 – 200mg/l	N/A

* = Refers to a maximum allowable change in a variable from the reference value

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Sampling protocol

Sediment samples were collected at all proposed sites from all the rivers in this investigation. Samples were scooped from the catchment substrates and placed in polyethylene zip-lock bags and were kept frozen to prevent organic material digestion by invertebrates or other organic decomposition until analysis of the sediment characteristics was carried out in the laboratory.

Sediment analyses

Analyses were performed according to the protocol set out by the United States Environmental Protection Agency (USEPA, 2001) as adopted from studies implemented by Carminati (2008), Stryftombolas (2008), and Malherbe *et al*. (2010). A known number of sediments for each site was dried for a total of 4 days at 60°C and subsequently weighed to determine water quantity. The organic content of each sediment sample was determined by subjecting a known amount of sediment (accurate to 0.0001g) and incinerating it for a minimum of 6 h at 600°C. The samples were then once again weighed to determine the percentage organic content in the sample (Table 3). The remaining dried sediment was then used to determine the grain size of each sample by using an Endecott sieve system with various sieves ranging from > 4,000 µm to 53 µ

Table 4: Organic content classification system in sediment (USEPA, 2001)

Classification	Percentage
Very low	<0.05%
Low	0.05 – 1%
Moderate low	1 – 2%
Medium	2 – 4%
High	>4%

Table 5: Grain-size categories according to Cyrus *et al.* (2000)

Grain size in µm	Categories
>4000 µm	Gravel
4000 – 2000 µm	Very coarse sand
2000 – 500 µm	Coarse sand
500 – 212 µm	Medium sand
212 – 53 µm	Very fine sand
<53 µm	Mud

Habitat

The habitat availability, diversity, and state were assessed using the Integrated Habitat Assessment System Version 2 (IHAS v2), which was adopted from McMillan (1998), and the Index of Habitat Integrity (IHI), which was adopted from Kleynhans (1996). The approaches set out by these two indices to assess habitat availability, diversity, and state are widely implemented throughout the National River Health Programme. These indices were performed by entering various observations on a provided score sheet in the field. The values of the indices were then calculated, and a rating system for each index was used to describe the quality of the habitat of the different sites under study.

Table 6: Summary of the scoring procedures used to determine the Index of Habitat Integrity (IHI) (Dallas, 2005)

Impact class	Description	Score
None	No discernible impact / the modification is located in such a way that it has no impact on the habitat quality, diversity, size,and variability.	0
Small	The modification is limited to very few localities, and the impact on habitat, diversity, size, and variability is limited.	1 – 5
Moderate	The modifications are present at a small number of locations, and the impact on habitat quality, diversity, size, and variability is fairly limited.	6 – 10

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Large	The modification is generally present with a determinable impact on habitat quality, diversity, size, andvariability. Large areas are, however, not affected.	11 – 15
Serious	The modification is frequently present, and the habitat quality,diversity, size, and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16 – 20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size, and variability in almost thewhole of the defined section are influenced detrimentally.	21 - 25

Table 7: Habitat integrity classes for IHAS and description of each class, adoptedfrom Kleynhans (1999)

Class	Description	Score (% of Total)
A	Unmodified, natural.	90 – 100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the assumption is that ecosystem functioning is essentially unchanged	80 – 89
C	Moderately modified. A loss or change in natural habitats andbiota has occurred, but basic ecosystem functioning appears predominantly unchanged.	60 – 79
D	Largely modified. A loss of natural habitat and biota and areduction in basic ecosystem functioning are assumed to have occurred.	40 59
E	Seriously modified. The loss of natural habitat, biota, and ecosystem functioning is extensive.	20 – 39
F	Modifications have reached a critical level, and there has been an almost complete loss of natural habitat and biota. In the worst cases, the basic ecosystem functioning has been destroyed.	0 - 19

Participants

This study did not involve human participants in the traditional sense. However, expert field technicians and environmental officers from the Department of Nature Conservation at Mangosuthu University of Technology, along with trained postgraduate students, participated in site assessments and sample collection. Site selection was based on accessibility, representation of land use gradients (e.g., rural, peri-urban, and urban), and historical environmental concern areas.

Bias

To minimize selection bias, a stratified approach was used in identifying upstream, midstream, and downstream sites across each river, ensuring coverage of different land use types and potential pollution sources. Measurement bias was mitigated by adhering to standardized protocols for water, sediment, and habitat sampling and calibrating field instruments before each use.

Study size

A total of 15 sampling sites were assessed, three per river (upstream, midstream, downstream), providing a comprehensive spatial snapshot of ecological conditions. This sample size was deemed sufficient for spatial analysis given the cross-sectional design and the resources available.

Data measurement/sources

Water quality data were collected using portable multiparameter meters for pH, temperature, dissolved oxygen, and turbidity. Laboratory analysis was conducted to measure nitrates, phosphates, and heavy metals (e.g., lead, mercury, cadmium). Sediment samples were analysed for particle size distribution, organic matter content, and heavy metal concentration using standard geochemical techniques. Habitat integrity was assessed using the South African Scoring System (SASS5) for macroinvertebrates and the Index of Habitat Integrity (IHI) to evaluate physical habitat structure. All procedures

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followed the Department of Water and Sanitation (DWS) protocols.

Statistical analysis

Descriptive statistics (mean, median, standard deviation) were used to summarize water quality and sediment data. Multivariate analyses, including Principal Component Analysis (PCA), were applied to identify spatial patterns and relationships among variables. ANOVA tests were conducted to compare conditions across sites. Missing data were minimal and occurred only due to instrument failure at one site; such data points were excluded from multivariate analyses but noted in the discussion.

Ethical consideration

As the study involved environmental sampling and did not collect human subject data, ethical clearance was not mandatory. However, permission to access sampling sites was obtained from the KwaZulu-Natal Department of Water and Sanitation and relevant municipal authorities. The study was registered and approved internally by the Research Ethics Committee of the University of South Africa.

Results and discussion

Umgeni river

Chemical composition of the Umgeni River

South African river systems suffer from increased pollution caused by widespread industrialization, urbanization, deforestation, and agriculture. Heavy metals have been reported in several studies as the major pollutant factors. Some of the common heavy metals that have been detected in South African river streams include Chromium (Cr), Lead (Pb), and Zinc (Zn). The uMngeni River suffers from heavy metal pollution due to widespread industrial operations at the borders (Dikole, 2014). Z indicator for ascertaining the concentration, accumulation, and bioavailability of metals in aquatic systems. It can also be used to indicate the presence of phosphates, nitrates, and organic materials in freshwater (Serife *et al.*, 2001). Some of the important physical-chemical indicators that can be used to assess river streams, amongst other things, include Redox potential, determination of the Dissolved oxygen (DO), Electrical conductivity (EC), and Salinity (Table) (Dikole, 2014).

Table 8: Physico-chemical parameters of the uMngeni River, from samples collected at different locations of the river (Dikole, 2014).

Site Code	Seasons	pH	Temp (^{o}C)	Eh/mV	TDS (mg/L^{-1})	DO (mg/L^{-1})	EC (µScm^{-1})	Salinity/ (mgL^{-1})
A	Winter	6.02	14.8	80	440	11.2	860	0.2
	Summer	6.04	24.2	35	18	6	31.2	0
B	Winter	6.79	15.3	49	395	10.5	772	0.1
	Summer	6.84	26	74	26	6.6	45.4	0
C	Winter	6.47	16.4	73	396	9.6	774	0.1
	Summer	6.6	25.6	130	26	6.75	45.4	0
D	Winter	6.38	16.3	79	400	10.7	702	0.1
	summer	6.77	25.7	115	26	6.9	48.6	0
E	Winter	6.38	15	158	48	2	1000	0
	Summer	6.59	25.3	97	28	5.8	47	0
F	Winter	7.1	16.1	55	562	2.9	1269	0.3
	Summer	7.38	26.2	60	44	6.1	75.8	0
G	Winter	7.25	17.3	59	1594	3.7	5690	1.5
	Summer	7.47	26.3	58	88	6.6	151.7	0
H	Winter	6.6	15.4	44	820	1.2	1440	0.6
	Summer	7.24	24.4	8	69	6.6	118.5	0

A- Before Inanda Dam, B - After Inanda Dam 1, C - After Inanda Dam 2, D - After Inanda Dam 3, E - Start of Industries, F - After Waste Management, G - End of Industries, H - Estuarine Site

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Table 9: Current water quality data for the uMngeni River under this investigation

Site	oC	O2 (mg/l)	O2 Satu	EC	pH	NO2	NO3	PO4	N	Cl	TAL	Ca	SO4	Na	COD
Site1W	17.1	9.45	93.1	284	7.55	0.97	0.55	0.04	0.05	41	35	10.1	3.43	39	88
Site1S	29.3	6.33	89.6	301	7.34	0.89	0.43	0.03	0.02	45	39	9.97	2.99	41	75
Site2W	19.2	8.95	86.3	210	8.12	1.45	0.61	0.02	0.07	37	28	6.33	4.10	36	95
Site2S	27.8	7.13	80.1	290	8.01	1.34	0.59	0.06	0.09	40	32	7.82	3.87	40	97
Site3W	17.9	9.44	90.2	195	7.23	0.91	0.12	0.05	0.07	33	47	11.0	5.55	41	56
Site3S	28.7	6.67	73.3	287	7.45	0.94	0.14	0.03	0.06	38	45	9.97	4.87	47	67
Site4W	18.5	8.61	44.6	212	7.10	1.25	0.19	0.07	0.02	44	38	10.3	3.64	36	100
Site4S	29.9	7.01	40.2	301	7.24	1.17	0.16	0.08	0.04	41	36	7.88	3.52	43	89
Site5W	17.7	8.99	50.1	184	8.11	0.87	1.10	0.14	0.05	29	41	6.43	2.97	38	85
Site5S	28.6	6.13	47.4	247	7.53	0.94	0.98	0.12	0.06	37	39	7.11	3.01	43	77

The temperature of the flowing water has been recorded to be lower during the winter monthsthan the summer months. In most cases, the temperature of the water seems to be influenced by the environmental temperature as well as the lower flow rate. This is in line with the seasonal fluctuations as indicated by Gallagher (1999). The temperature ranged from as low as 17.1 ^{0}C in the winter months to 29.9 ^{0}C in the summer months. However, there seems to be a gradual difference in temperature of approximately 100 °C between the seasons. Although seemingly small, the temperature difference had a marked impact on the organisms occurring in the river and ultimately affected the ecological biodiversity. According to DWAF (1996), none of the temperature levels recorded during the current investigation on the lower reaches of the uMngeni River exceeded the TWQG for aquatic ecosystems.

The levels of oxygen (mg/l) ranged from 6.13 mg/l to 9.45 mg/l (Table 3). Oxygen levels of all sites under investigation were all within the TWQG range (6 – 12 mg/l) requirements (DWAF, 1996). This could indicate that the river is currently running within acceptable ranges throughout the year. Changes in this level will be noted during drought seasons and/or heavy rains and flooding seasons. The COD levels of all sample sites on the uMngeni River ranged between 56 mg/l and 100 mg/l. The increased COD levels are indicative of some sort of pollution occurring in the riversystem. These pollutions can be attributed to industrial effluents and/or domestic use by squatter developments along the uMngeni River.

The pH levels ranged between 7.1 and 8.12 during this investigation. The general range between 6 and 8 is acceptable by DWAF (1996). There seems to be some stability in the pH throughout the sampling sites, leaning towards a slightly alkaline environment. However, it is noted that the pH in winter months is slightly higher than the summer months, except at sites 3 and 4. This could be the result of the low flow rate of the river from the upper levels of the river. The pH levels of all the sample sites in this investigation onthe uMngeni River were within the TWQG (DWAF, 1996). The electrical conductivity (EC) ranged from 184 to 301 at the sample sites. The electrical conductivity during the summer months seems to be higher than that of the winter months. This can be attributed to the lower flow rates and increased nutrient loads due to domestic and industrial effluent, as well as potential small-scale farmers' activities (DWAF, 1996). The salt levels, for example, chlorides ranging from 28 to 47 and sulphate levels ranging from 2.97 to 5.55 of the uMngeni River are well within the TWQG ranges.

Tugela river

Results of current (2011 low-flow and 2012 high-flow surveys) and historical water-quality variables collected from the Thukela River (Figure 1), where available from 2005 to 2012, include water temperature, oxygen, electrical conductivity, pH, nitrate, nitrite, phosphate, ammonia, chlorides, alkalinity, calcium, chemical oxygen demand (COD), sulphates and sodium are presented in Table 10. Results show that the water quality state of the sites varies considerably, with many constituents occurring in elevated levels that may result in negative impacts to the structure and function of the aquatic ecosystems considered. In particular, temperature levels, oxygen levels, nutrient and salt loads have been of

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concern historically and currently.

Table 10: Current water quality data for the Tugela River under this investigation

Site	oC	O2 (mg/l)	O2 Satu	EC	pH	NO2	NO3	PO4	N	Cl	TAL	Ca	SO4	Na	COD
Site1W	16.4	8.77	91.1	297	8.24	0.77	0.09	0.05	0.06	23	83	14.1	13.4	70	42
Site1S	28.9	7.45	87.6	285	8.11	0.79	0.07	0.02	0.04	25	94	10.3	11.2	55	51
Site2W	15.2	9.01	97.4	410	8.01	0.95	0.14	0.01	0.08	19	76	9.66	14.6	49	39
Site2S	27.4	7.14	91.3	402	7.64	1.17	0.17	0.04	0.08	23	90	12.3	13.2	52	67
Site3W	16.8	8.94	95.3	388	8.93	1.86	0.79	0.07	0.06	21	82	11.2	6.92	61	59
Site3S	29.1	7.22	60.4	392	8.21	1.94	0.65	0.05	0.07	31	99	9.90	10.1	59	91
Site4W	17.3	9.10	89.9	265	7.10	1.88	0.72	0.08	0.02	39	59	10.4	12.4	83	97
Site4S	28.9	6.91	87.4	311	8.05	0.85	0.56	0.09	0.05	42	70	12.1	14.7	77	99
Site5W	16.9	9.14	92.1	276	8.22	0.91	0.06	0.11	0.07	30	87	10.2	17.8	64	83
Site5S	29.2	6.32	79.6	299	7.97	1.72	0.09	0.09	0.08	36	99	11.4	16.4	61	101

Seasonal fluctuations can be observed in the changes in water temperatures during theseasonal sampling times. The temperature ranging between 15.2 °C and 29.2°C is well within the TWQG requirements. It is worth noting that the industries located higher up and agricultural activities could have influenced the water temperatures at the points of entry into the river system. The pH levels at all the sampling sites leaned towards a slightly alkaline nature, ranging from 7.10 to 8.93. Although industrial activities could cause acidification of the environment, this has not been noted in the river system, which clearly showed ranges acceptable as per DWAF (1996). The oxygen (mg/l) levels for all the sample sites are well within the range considered convenient for aquatic ecosystems as per DWAF (1996). The oxygen level ranged between 6.32 and 9.14. It seemed that during summer, the oxygen level was rather lower than that of the winter months. This could be attributed to the increased flow rate of the river due to higher rainfall. Furthermore, the effluents from the paper mill upstream and the Sugar industrial milling could contribute to the drop in the oxygen levels of the river system, thus creating increased chemical oxygen demand. For effective management of the river, measures to reduce excessive effluents from entering the river system should be taken into consideration. Functionality of the river and maintenance of the ecosystem are reliant on the quality of water without pollution from industry, agriculture, and domestic utilization. The electrical conductivity levels seem to have some stability and range between 265 and 410. This is well within the range stipulated by DWAF (1996) for aquatic ecosystems. This seems to contradict previous investigations where there were noticeable fluctuations inthe EC of the Tugela River due to domestic and industrial effluent discharges and surface runoff from urban and industrial areas that may contribute to increased nutrient levels and salt loads, causing elevated EC levels (DWAF, 1996; Carminati, 2008). DWAF (1996) indicated that surface runoff from catchment areas, effluent containing organic industrial wastes, human and animal excrement, and agricultural fertilizers contributed to elevated nutrient loads. The effluent emanating from organic industrial wastes, human and animal excrement, and agricultural fertilizers contributes to the increased levels of nutrient loads on the river system. The chloride load and the sulphate load seem to be stable at all sampling sites. This can be seen from the levels of nitrates that varied between 0.02 to 0.08 mg/l. The levels for nutrient loads, chloride load, as well as sulphate load, are well within the range indicated by DWAF (1996b) for aquatic ecosystems, hence showing the stability ofthe river system.

Umvoti river

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Table 11: Current water quality data for the Umvoti River under this investigation

Site	°C	O_2 (mg/l)	O_2 Satu	EC	pH	NO_2	NO_3	PO_4	N	Cl	TAL	Ca	SO_4	Na	COD
Site1W	15.1	6.76	89.9	201	7.40	1.19	0.17	0.03	0.13	17	51	9.17	10.1	37	29
Site1S	29.3	6.44	85.0	199	8.01	0.99	0.15	0.01	0.11	21	70	8.72	8.28	41	37
Site2W	15.6	8.91	99.5	245	7.91	1.27	1.05	0.04	0.07	13	47	7.45	9.91	22	22
Site2S	28.8	7.33	89.7	213	8.00	1.18	0.97	0.03	0.03	19	65	7.11	10.3	36	31
Site3W	17.1	9.25	100	197	8.13	1.52	1.94	0.06	0.04	25	57	9.18	7.84	27	17
Site3S	29.8	7.28	79.8	184	8.04	1.81	1.55	0.07	0.12	28	81	10.1	9.91	31	28
Site4W	16.7	8.97	97.7	266	7.98	0.97	0.87	0.03	0.01	26	62	6.13	6.67	29	30
Site4S	30.1	6.99	89.4	299	8.15	0.88	0.63	0.01	0.02	35	74	6.24	8.96	42	45
Site5W	16.4	9.11	93.3	254	8.29	1.18	0.09	0.09	0.04	29	59	4.41	9.13	17	23
Site5S	29.5	7.01	83.1	267	7.39	1.69	0.32	0.02	0.03	37	77	7.20	11.2	29	41

The temperature levels of all the sampled sites ranged between 15.1 °C and 30.1 °C (Table 11). The lower temperatures were recorded for the winter months, and the warmer temperatures were recorded for the summer months. A fluctuation in temperature due to seasonal variations reported in previous investigations (Gallagher, 1999) has also been recorded in thisstudy. The higher temperatures noted as per previous investigations occurred at the upper parts of the river. Extremely high temperatures could be detrimental to the functionality of the ecosystem of river. The increases in temperatures could have resulted from extreme climatic changes as well as industrial and agricultural pollution. The pH of the river was similar to that of the other rivers investigated, as it leaned towards a more alkaline direction. The pH values ranging between 7.39 and 8.29 were within the range stipulated in DWAF (1996).It was observed that informal settlements are the primary users of this river and that they are increasing at a rapid rate. Some subsistence farmers were interviewed to ascertain their knowledge of the river and its management. The waste emanating from these settlements caused the river to have a reduced oxygen level. The oxygen level rangedbetween 6.44 and 9.25.

Umdloti river

Table 12: Current water quality data for the Umdloti River under this investigation

Site	°C	O_2 (mg/l)	O_2 Satu	EC	pH	NO_2	NO_3	PO_4	N	Cl	TAL	Ca	SO_4	Na	COD
Site1W	16.2	7.66	100	310	8.11	2.01	0.92	0.08	0.19	28	81	11.4	17.1	37	59
Site1S	27.8	7.02	97.1	240	7.98	1.34	0.66	0.05	0.13	37	94	9.91	15.4	41	64
Site2W	15.9	8.11	104	276	8.90	1.98	0.73	0.07	0.11	31	66	11.2	17.3	22	37
Site2S	29.0	7.84	91.1	222	8.23	1.51	0.71	0.06	0.09	40	79	8.77	10.7	36	52
Site3W	16.7	8.28	86.3	313	7.91	1.87	0.99	0.09	0.10	29	61	10.9	12.4	27	33
Site3S	28/9	7.91	82.3	299	8.14	1.92	1.10	0.04	0.07	38	82	9.01	10.7	31	49
Site4W	14.9	8.66	98.1	284	8.32	0.91	0.89	0.05	0.08	44	77	9.94	14.2	29	61
Site4S	29.9	7.32	87.4	291	7.78	0.89	0.72	0.02	0.05	53	98	8.32	10.1	42	65
Site5W	16.4	9.25	99.8	288	8.79	1.45	0.44	0.01	0.09	49	62	8.76	15.6	17	39
Site5S	28.8	7.89	90.6	276	8.22	1.93	0.65	0.02	0.07	56	98	7.91	13.9	29	52

Regarding the temperature levels of all sampled sites, the temperature ranged between 14.9 °C and 29.9 °C Table 12. This river is heavily sand mined by illegal contractors. This sand mining operation is at the detriment of the indigenous vegetation and has a direct impact on the biodiversity of the area, which is replicated in the lower reaches of the river system. The lower temperatures were recorded for the winter months, and the warmer temperatures were for the summer months and are in agreement with those of previous investigations (Gallagher, 1999). The pH of the river was similar to that of the other rivers investigated, as it leaned towards alkalinity. The pH values ranging between 7.78 and 8.90 were within the range stipulated inDWAF (1996). It was known that informal settlements are the primary users of this river, and the effects of their activities were further compounded by illegal miners.

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Umfolozi river

Table 13: Current water quality data for the Umfolozi River under this investigation

Site	°C	O_2 (mg/l)	O_2 Satu	EC	pH	NO_2	NO_3	PO_4	N	Cl	TAL	Ca	SO_4	Na	COD
Site1W	14.2	7.11	94.0	297	8.13	0.03	0.28	0.02	0.09	12	77	11.1	37	37	51
Site1S	27.7	7.02	91.1	255	7.89	0.01	0.19	0.01	0.15	19	91	10.8	44	41	33
Site2W	15.1	7.99	100	281	7.71	0.09	0.87	0.05	0.11	14	59	9.75	35	22	42
Site2S	27.9	7.14	94.3	244	7.66	0.05	1.14	0.03	0.17	21	84	9.03	47	36	31
Site3W	16.3	8.33	91.4	307	8.27	0.17	0.99	0.04	0.06	13	59	12.4	41	27	46
Site3S	29.3	7.91	87.4	269	8.11	0.09	1.11	0.03	0.09	19	87	10.9	52	31	32
Site4W	16.1	8.75	99.0	314	7.99	1.12	0.91	0.07	0.04	22	66	8.99	39	29	21
Site4S	29.9	8.01	91.9	292	7.12	0.98	1.01	0.05	0.05	31	91	8.03	57	42	17
Site5W	15.9	8.68	97.3	287	8.33	0.06	0.05	0.03	0.07	19	61	9.25	43	17	42
Site5S	30.5	7.91	87.6	281	7.94	0.04	0.09	0.01	0.09	27	83	8.97	52	29	36

The Umfolozi River passes through the Hluhluwe-Umfolozi Park on the upper reaches andthe Eastern and Western Shore nature reserves at the lower reaches. The temperature levels of all sampled sites ranged between 14.2 °C and 30.5 °C Table 13. Many informal dwellers were located between the parks, who make extensive use of the river for various domestic chores. The organic discharges from these domestic practices can contribute to the oxygen demand of the river system (DWAF, 1996). The pH of the river was similar to that of otherrivers being investigated, as it leaned towards a more alkaline direction. The pH ranging between 7.12 and 8.33 was within the range stipulated in DWAF (1996). The oxygen level ranged between 7.02 and 8.68.

Umgeni River

Table 14: Sediment grain-size distribution analyses, moisture content, and organic content of the uMngeni River. Sample size = 100g

Site	G	VCS	CS	MS	VFS	M	Moisture Content %	Organic content %
Site1W	20.88	6.91	41.38	23.27	6.91	0.64	21.13	1.27
Site1S	21.19	5.53	42.08	25.67	5.23	0.23	20.97	1.31
Site2W	13.99	15.01	42.91	24.32	3.32	0.42	14.77	0.81
Site2S	14.45	15.92	41.15	25.03	2.95	0.44	14.91	0.87
Site3W	9.95	17.23	31.08	39.54	1.85	0.31	10.11	0.81
Site3S	9.15	16.95	31.18	40.31	1.95	0.41	10.78	0.79
Site4W	5.37	8.12	46.94	38.49	0.91	0.14	14.45	0.55
Site4S	4.39	9.01	47.36	38.14	0.89	0.18	12.31	0.59
Site5W	0.97	3.53	51.41	41.98	1.22	0.85	7.17	0.49
Site5S	1.13	3.01	50.94	42.32	1.65	0.91	8.13	0.32

(Gravel - G, very coarse sand - VCS, coarse sand - CS, medium sand - MS, very fine sand - VFS, and mud - M

Tugela

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15: Sediment grain-size distribution analyses, moisture content, and organiccontent of the Tugela River. Sample size = 100g

Site	G	VCS	CS	MS	VFS	M	Moisture Content %	Organic content %
Site1W	17.71	15.71	39.87	21.99	4.36	0.33	22.01	3.22
Site1S	18.04	16.12	39.91	20.57	4.89	0.45	23.43	2.98
Site2W	10.46	20.31	37.53	25.57	5.16	0.95	15.67	1.97
Site2S	9.37	21.02	36.36	26.61	5.98	0.65	13.73	1.88
Site3W	4.41	25.77	29.63	31.19	7.98	0.98	12.44	1.01
Site3S	3.93	27.37	28.93	32.29	6.57	0.88	12.87	0.96
Site4W	1.10	31.08	29.51	31.22	7.01	0.07	10.06	0.91
Site4S	0.93	31.92	30.13	30.79	6.14	0.07	10.17	0.98
Site5W	0.01	32.17	31.08	31.19	5.36	0.16	6.63	0.57
Site5S	0.00	32.93	30.26	31.54	5.01	0.23	7.04	0.44

(Gravel - G, very coarse sand - VCS, coarse sand - CS, medium sand - MS, very fine sand - VFS, and mud - M

Table 16: Sediment grain-size distribution analyses, moisture content, and organic content of the Umvoti River. Sample size = 100g

Site	G	VCS	CS	MS	VFS	M	Moisture Content %	Organic content %
Site1W	17.23	22.34	31.17	24.79	3.97	0.49	21.91	4.17
Site1S	18.77	21.91	30.97	23.59	4.17	0.56	22.09	3.98
Site2W	13.83	22.13	31.88	24.95	6.44	0.75	14.33	1.76
Site2S	11.81	23.31	31.97	25.97	6.24	0.69	15.01	1.71
Site3W	7.22	28.12	27.75	29.93	5.99	0.96	9.10	0.94
Site3S	8.02	28.98	27.32	29.67	5.23	0.76	8.91	0.95
Site4W	2.97	30.11	29.13	30.87	6.73	0.16	4.47	0.71
Site4S	1.99	29.97	30.98	29.98	6.97	0.09	5.03	0.83
Site5W	0.00	31.42	31.97	31.31	5.11	0.18	5.92	0.62
Site5S	0.00	29.97	32.04	33.21	4.62	0.15	4.11	0.59

(Gravel - G, very coarse sand - VCS, coarse sand - CS, medium sand - MS, very fine sand - VFS, and mud – M

Table 17: Sediment grain-size distribution analyses, moisture content, and organic content of Umdloti River. Sample size = 100g

Site	G	VCS	CS	MS	VFS	M	Moisture Content %	Organic content %
Site1W	20.07	15.92	32.31	25.74	5.07	0.87	20.32	5.17
Site1S	21.33	16.67	31.99	24.29	4.87	0.84	21.09	5.23
Site2W	17.73	20.26	27.66	25.57	7.84	0.93	17.01	1.99
Site2S	18.51	19.98	26.77	26.68	7.14	0.89	17.97	1.97
Site3W	6.83	15.87	33.62	37.19	4.54	1.94	11.99	0.96
Site3S	7.01	14.91	35.47	37.33	4.07	1.17	11.34	0.93
Site4W	2.93	15.11	37.78	39.82	3.67	0.68	8.93	0.77
Site4S	2.04	14.87	38.93	40.97	3.08	0.09	7.74	0.84
Site5W	0	9.91	42.67	45.17	2.13	0.11	6.76	0.69
Site5S	0	8.23	43.36	46.31	1.98	0.09	6.01	0.66

(Gravel - G, very coarse sand - VCS, coarse sand - CS, medium sand - MS, very fine sand - VFS, and mud – M

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Umfolozi

Table 18: Sediment grain-size distribution analyses, moisture content, and organic content of the Umfolozi River. Sample size = 100g

Site	G	VCS	CS	MS	VFS	M	Moisture Content %	Organic content %
Site1W	24.13	12.91	28.55	26.91	6.16	1.32	19.32	1.76
Site1S	23.19	13.53	29.27	27.58	5.43	0.97	21.02	2.01
Site2W	19.22	21.03	28.8	21.97	7.93	1.02	16.66	0.97
Site2S	18.99	22.74	29.71	20.63	6.78	1.14	17.01	1.04
Site3W	7.59	10.98	36.93	36.93	6.63	0.93	10.10	0.93
Site3S	7.33	11.19	34.99	38.57	6.91	0.99	11.06	0.91
Site4W	0.00	7.13	42.42	44.89	4.76	0.79	9.91	1.67
Site4S	0.00	6.78	43.51	45.11	4.05	0.53	8.73	1.43
Site5W	0.00	5.97	41.53	49.14	3.17	0.18	6.76	0.97
Site5S	0.00	5.61	42.47	48.98	2.76	0.15	7.31	0.93

(Gravel - G, very coarse sand - VCS, coarse sand - CS, medium sand - MS, very fine sand - VFS, and mud - M

Differing sediment types could determine the extent of river pollution and possible erosion emanating from the upper reaches of the river. The sedimentation is also dependent on the type of river and the flow rate of the river. Sediments also hold moisture and organic components that settle on the riverbeds. With higher flow rates, sedimentation occurs at the lower end of the river as the flow will drive all loose particles to the lower reaches. The lower flow rates will allow precipitation and sedimentation at much higher points in the river system. According to Carminati (2008), sediment transport increases as the coarseness of the sediment increases. The result of such is a lower biodiversity of aquatic organisms due to the decrease in the available biotopes. Sites 1 and 2 of all the rivers under this investigation are located at the upper stream as compared to sites 4 and 5. The very coarse content amounting to gravel seemsto be at higher levels on sites 1 and 2, whereas as investigations move closer to the mouth region or lower reaches, the very coarse content is drastically reduced. Predominantly, most of the samples had very coarse sand and medium sand with little fine sand and mud. The moisture content of all sampled areas for all the rivers investigated was higher at Sites 1, 2, and 3 and much reduced at Sites 4 and 5. This could be due to the water holdingcapacity of the fine sand not being able to hold as much water as that of the coarse content. The sediment moisture content for uMngeni, Tugela, Umvoti, Umdhloti, and Umfolozi rangesfrom 21.13% to 8.13%, 22.01% to 7.04%, 21.91% to 4.11%, 20.32% to 6.01%, and 19.32% to 7.31%, respectively. The higher organic content of the upper regions of the river could be due to sewage deposition, industrial wastes, domestic waste deposition, organic debris, sand mining disturbances, as well as agricultural runoffs. The organic content of uMngeni, Tugela, Umvoti, Umdhloti, and Umfolozi ranged from 1.27% to 0.32%, 3.22% to0.44%, 4.17% to 0.59%, 5.17% to 0.66%, and 1.76% to 0.93%, respectively. The two rivers with the highest organic content are the Tugela and Umvoti. The agricultural settlement and the industry associated with the Tugela River and the Umvoti River were contributing factors to increased siltation in the river system. This is observed by the domination of finer sediments in these rivers (Venter and van Vuren, 1997; Cheesman, 2005; CRUZ, 2000). These higher levels could be due to the direct association of these rivers with the sugar cane industry and sewage plants. Similar findings were found in other rivers with such an association (Carminati, 2008).

Amatikulu river

The availability, diversity, and state of the habitat were assessed using the Integrated Habitat Assessment System Version 2 (IHAS v2), which was adopted from McMillan (1998) and the Index of Habitat Integrity (IHI), which was adopted from Kleynhans (1996) and Olliss(2006). The approaches set out by these two indices to assess availability, diversity, and the state of the habitat were widely implemented throughout the National River Health Programme. These indices were performed by entering various observations on a provided score sheet in the field. The values of the indices were then calculated, and a rating system for each index was used to describe the quality of the habitat of the given site.

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Table 19: Index of Habitat Integrity (IHI) and Integrated Habitat Assessment System (IHAS) as well as IHAS Integrity Classes of the Umgeni River

Sites	IHI Score	IHAS Score	IHAS Integrity Class
Site1W	-	55.11	D
Site1S	-	53.45	D
Site2W	47	62.17	C
Site2S	553	61.93	C
Site3W	-	58.36	D
Site3S	-	58.44	D
Site4W	122	39.91	D
Site4S	126	40.33	D
Site5W	-	41.12	D
Site5S	-	41.37	D

Table 20: Index of Habitat Integrity (IHI) and Integrated Habitat Assessment System (IHAS) as well as IHAS Integrity Classes of the Tugela River

Sites	IHI Score	IHAS Score	IHAS Integrity Class
Site1W	-	58.32	D
Site1S	-	56.77	D
Site2W	121	64.14	C
Site2S	108	63.25	C
Site3W	-	61.23	C
Site3S	-	60.92	C
Site4W	173	38.74	D
Site4S	159	40.44	D
Site5W	-	45.83	D
Site5S	-	41.58	D

Table 21: Index of Habitat Integrity (IHI) and Integrated Habitat Assessment System (IHAS) as well as IHAS Integrity Classes of the Umvoti River

Sites	IHI Score	IHAS Score	IHAS Integrity Class
Site1W	-	61.71	C
Site1S	-	69.34	C
Site2W	-	60.11	C
Site2S	-	61.23	C
Site3W	37	58.73	D
Site3S	48	59.12	D
Site4W	94	42.52	D
Site4S	106	41.44	D
Site5W	-	60.34	C
Site5S	-	61.48	C

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Table 22: Index of Habitat Integrity (IHI) and Integrated Habitat Assessment System (IHAS) as well as IHAS Integrity Classes of the Umdhloti River

Sites	IHI Score	IHAS Score	IHAS Integrity Class
Site1W	-	43.93	D
Site1S	-	41.22	D
Site2W	145	37.39	D
Site2S	139	39.91	D
Site3W	72	57.77	D
Site3S	64	58.19	D
Site4W	110	45.76	D
Site4S	97	43.96	D
Site5W	-	44.24	D
Site5S	-	41.98	D

Table 23: Index of Habitat Integrity (IHI) and Integrated Habitat Assessment System (IHAS) as well as IHAS Integrity Classes of the Umfolozi River

Sites	IHI Score	IHAS Score	IHAS Integrity Class
Site1W	-	75.11	C
Site1S	-	73.93	C
Site2W	-	60.61	C
Site2S	-	64.34	C
Site3W	64	49.97	D
Site3S	79	52.65	D
Site4W	128	50.12	D
Site4S	117	49.17	D
Site5W	-	60.97	C
Site5S	1-	63.48	C

Habitat assessments are often undertaken to determine the current biodiversity of the riparian zone and the river itself. If changes are affecting the riparian zone, there would be a corresponding effect on the river and the functionality of its ecosystem. This ultimately will affect the biodiversity of the river itself. The Integrated Habitat Assessment System (IHAS) represents the invertebrate-specific habitat state of a river. There are classes assigned to a specific state, which depends on the degree of modification, either directly or indirectly. The direct modifications are such as sand mining or changes to the area for touristic or monetary gain. The indirect modifications are due to adverse climatic conditions such as heavy rainfalls resulting in excessive water flows and removal of the riparian zone (flood zone). The latter is quite reversible as the resilience of the river and its associated banks is quite natural. The former, however, can never be changed to revert to its original state. The uMngeni River, Umdhloti River, and Umvoti River are modified in the lower reaches for monetary gains. The upper reaches of these rivers are associated with either industrial effluents, sewage seepages, or domestic and agricultural depositions.

The IHAS assessment classifies most areas of these rivers to be under Class. This is a direct implication that the rivers were generally in a largely modified state. The IHI score indicated both habitat availability and diversity as high or low. A higher score indicated some sort of impairment, whereas a low score indicated fewer changes in the habitat, which is an indication of near-naturalness. The findings in this investigation from all sample sites and all rivers werein line with studies undertaken by other investigators (Carminati, 2008). Impacts caused by the indigenous folks who set up homes along the riverbanks of the uMngeni and other rivers contribute to the deterioration of habitat diversity and availability inthese Rivers. These impacts include damage to the indigenous vegetation and disturbance of the riparian zone. The sugarcane agricultural activities, water abstraction, and

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channel modifications of the Tugela and Umvoti river areas are the principal contributors to the deterioration of the integrity of the habitat. Comparatively, the Umfolozi River seems to be the best in diversity and has the least impact from industry, agriculture, and human domestication uses. The water quality was found to be in a fairly good, slightly modified state; the majority of water quality parameters considered were within the target values set by the TWQG. Water quality parameters are considered lower. The Tugela River, uMngeni River, Umdloti River, and the Umvoti River were seen to be in a modified state, producing negative impacts on the functionality of the rivers.

Discussion

The cross-sectional assessment of the uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi Rivers demonstrated a discernible pattern of ecological stress correlated with varying land use pressures along the river corridors. Sites located in downstream reaches and those adjacent to urban or industrial zones exhibited marked declines in water quality, as reflected by elevated concentrations of nitrates, phosphates, turbidity, and heavy metals. These results are consistent with earlier research (Dube et al., 2017; Oberholster & Ashton, 2008), which highlights the adverse influence of human-derived pollutants on South African riverine systems. Analysis of sediment samples revealed substantial accumulation of organic materials and toxic substances, particularly in locations receiving runoff from highly modified landscapes. The role of sediments as both repositories and potential sources of pollutants is well established, with long-term contamination posing significant risks to benthic organisms and facilitating bioaccumulation through aquatic food webs (Naidoo & Glass, 2019). In this study, the Umvoti and uMngeni Rivers exhibited the highest sediment contamination levels, reflecting the intensity of anthropogenic impacts within their catchments.

Habitat integrity, as quantified through the SASS5 and IHI assessments, was lowest in river segments near agricultural operations and informal settlements. The degradation of riparian zones, increased erosion, and modifications to natural flow patterns emerged as key contributors to habitat decline. By contrast, rivers such as the Umdloti and Umfolozi, whose catchments remain relatively undisturbed, maintain higher ecological quality, underscoring the protective value of intact natural vegetation and minimally impacted land cover. Employing an integrated approach that combined biological, chemical, and physical assessments enabled a holistic evaluation of river health across spatial gradients. The findings underscore the utility of multi-metric monitoring frameworks in capturing the complex responses of freshwater ecosystems to diverse environmental stressors. Such approaches are essential for informing effective conservation and management strategies aimed at safeguarding aquatic biodiversity and ecosystem services.

Generalizability

While the findings are specific to five major rivers in KwaZulu-Natal, the results have broader implications for similar catchments across South Africa and other developing regions experiencing rapid land use changes. The methodological framework, integrating water, sediment, and habitat assessments, can be replicated in other river systems to guide conservation and policy decisions. However, generalisability to areas with markedly different climatic, geological, or land use characteristics should be approached with caution.

Conclusion

The ecological integrity of key river systems in KwaZulu-Natal is under mounting threat due to unchecked urbanization, industrial activities, and agricultural runoff. This study provides clear evidence of spatial ecological degradation, with water quality deterioration, sediment contamination, and habitat disruption being most severe downstream of human settlements. The observed patterns point to the urgent need for holistic, catchment-based management approaches that address land use planning, pollution control, and habitat restoration. Without coordinated and sustained intervention, the long-term sustainability of KwaZulu-Natal's freshwater ecosystems remains at risk.

Limitations

This study is not without limitations. Being cross-sectional in design, it captures ecological conditions at a single point in time, which limits the ability to assess seasonal variations or long-term trends in environmental degradation. Additionally, financial and logistical constraints restricted the frequency of sampling and the number of replicates, which affected the robustness of spatial comparisons. Some areas, particularly informal settlements, lacked comprehensive land use data, making it difficult to precisely attribute sources of pollution. Furthermore, while field-based portable equipment allowed for efficient on-site measurements, variability in readings occurred due to environmental conditions and equipment sensitivity.

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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
IHAS v 2 - Integrated Habitat Assessment System Version 2

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 authors have 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 that support the findings of this study are available from the author, but restrictions apply to the availability of these data, which were used under license from various research publications for the current study and are therefore not publicly available.

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