Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.6 No. 6 (2025): June 2025 Issue
https://doi.org/10.51168/sjhrafrica.v6i6.1843
Original Article

A Cross-sectional bio-assessment of ecological integrity using SASS5 in the Umngeni, Thukela, Umvoti, Umdloti, and Umfolozi rivers, KwaZulu-Natal.

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Abstract

Background
Freshwater ecosystems provide essential biodiversity and ecological services but face increasing threats from urbanization, agriculture, and industrial discharge. In South Africa, the South African Scoring System version 5 (SASS5) is widely used to monitor river health through macroinvertebrate community responses. This study assessed the ecological integrity of five major rivers in KwaZulu-Natal, uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi, using SASS5 to evaluate biotic responses to environmental stress across spatial gradients.

Methods
A cross-sectional bioassessment was conducted between October and December 2024 at 15 sites (upstream, midstream, and downstream per river). Macroinvertebrates were sampled using SASS5 protocols across different biotopes. Taxa were identified to family level, with SASS5 scores and Average Score Per Taxon (ASPT) calculated. Physical habitat quality was assessed using the Index of Habitat Integrity (IHI). Statistical analyses, including Pearson's correlation, were used to evaluate relationships between habitat quality and biotic indices across sites.

Results
Substantial spatial variability was observed. The uMngeni and Umvoti Rivers recorded the lowest downstream scores (SASS5: 48 and 52; ASPT: 4.2 and 4.4, respectively), indicating poor ecological condition due to urban and industrial pollution. In contrast, Umdloti and Umfolozi Rivers displayed higher scores, reflecting better habitat quality and ecological integrity. The Thukela River showed moderate scores with downstream decline. A significant positive correlation between SASS5 scores and IHI ($r = 0.76$, $p < 0.01$) confirmed that better habitat conditions supported healthier macroinvertebrate communities.

Conclusion
River health in KwaZulu-Natal is highly variable, with downstream sections most impacted by anthropogenic stress. SASS5 proved effective in detecting ecological degradation across spatial gradients.

Recommendation
Integrated biomonitoring using SASS5, habitat, and water quality assessments is recommended. Degraded downstream reaches should be prioritized for restoration via land-use management, pollution control, and community-based monitoring.

Keywords: *SASS5 (South African Scoring System), Ecological Integrity, Bioassessment, River Health, KwaZulu-Natal Rivers, uMngeni River, Thukela River, Umvoti River, Umdloti River, Umfolozi River, Aquatic Macroinvertebrates, Freshwater Ecosystems, Water Quality Monitoring, Biomonitoring*
Submitted: *2025-05-27* ***Accepted:*** *2025-06-17* ***Published:*** *2025-06-24*

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Introduction

Rivers can be assessed by various indicators such as the vegetation types, the fish populations, the types of macro-invertebrates for their ecological integrity, and the state of health (Barbour *et al*., 1996; Thirion, 2007). Any change in the structures of the aquatic macro-invertebrate community will provide information on the effects or direct stress of the water body. These stressors are the water quality, pollution, hydrological and geomorphological processes, and habitat alterations (Álvarez-Cabria *et al*., 2010; Holt and Miller, 2011). Due to their wide distribution, macroinvertebrates have been known to be ideal ecological indicators. They are easily sampled, sensitive to even the slightest changes in ecosystem states, have a large-scale applicability, and can be used across regions (Álvarez-Cabria *et al*., 2010). In South Africa, several methodologies incorporate aquatic macroinvertebrates as biological indicators. The South African Scoring System, Version 5 (SASS 5) (Dickens and Graham, 2002), the Macro-Invertebrate Response Assessment Index (MIRIA) (Thirion, 2007), and the use of multivariate statistical analysis arecurrently used throughout South Africa. The ecosystem variables that are used in these assessments include water quality and habitat variables, which are referred to as ecological driver components, and are the main components of the South African Scoring System (SASS 5)

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used as a biological index of water quality (Dickens and Graham, 2002).

This South African Scoring System is now the benchmarked guidelines where all rivers can be assessed on their ecological integrity and community structures. The technique also provides valuable information regarding the current state of ecological integrity of the aquatic invertebrate communities (Dickens and Graham, 2002; Thirion, 2007). The credibility of the South African Scoring System is not questionable as it has been revised and improved upon since it was developed in 1994 and is now in its 5th revision, hence the acronym SASS 5 (Dickens and Graham, 2002). Different families show different tolerance to pollution and range from highly tolerant families (e.g., Muscidae and Psychodidae) to less tolerant families (e.g., Oligoneuridae). The Macro-Invertebrate Response Assessment Index (MIRAI) method used the information generated by SASS to evaluate the water-quality and quantity impacts, and at the same time assess the habitat suitability for aquatic macro-invertebrates (Thirion, 2007). This method delivers to the end user the habitat-based cause-and-effect, which then can be used to interpret the deviation of the aquatic macro-invertebrate assemblage attributes from a pre-established reference condition (Thirion, 2007). The most often used approach nationally is the SASS 5 method (Thirion, 2007). Van den Brink *et al.* (2003) indicated that several multivariate statistical techniques have also been used to evaluate the structure of aquatic invertebrate assemblages and their response to different altered ecosystem driver components. To determine community structure, Multivariate statistical analysis techniquesare the most often used. This method also derives the patterns in various ecosystems (Van den Brink *et al.,* 2003; O'Brien *et al.,* 2009). Statistical analysis for this study was undertaken by a qualified statistician.

Objectives

- To assess the ecological integrity of the uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi Rivers using the South African Scoring System version 5 (SASS5) and Average Score Per Taxon (ASPT) as biological indicators.
- To identify spatial variations in macroinvertebrate community structures across upstream, midstream, and downstream sites within each river system.
- To evaluate the impact of anthropogenic activities on the biological health of the rivers, particularly in areas affected by urbanization, agriculture, and industrial development.

Methodology

Study design

This study adopted a cross-sectional, field-based bioassessment design to evaluate the ecological integrity of five rivers in KwaZulu-Natal using the South African Scoring System version 5 (SASS5). The study aimed to capture spatial and seasonal variations in macroinvertebrate communities and relate these patterns to habitat quality and anthropogenic impacts.

Study setting

The research was conducted in the uMngeni, Thukela, Umvoti, Umdloti, and Umfolozi Rivers, which span a range of ecological zones across KwaZulu-Natal. These rivers represent varying land-use contexts, from heavily urbanised catchments to relatively undisturbed rural systems. Sampling was conducted between October and December 2024, during both the late spring/early summer season, in order to assess spatial patterns and seasonal influences on macroinvertebrate communities. Within each river, three sites were selected, upstream, midstream, and downstream, based on accessibility, known land-use gradients, and habitat heterogeneity.

Participants

The study did not involve human participants. Field sampling was conducted by a trained team of aquatic ecologists, postgraduate environmental science students, and technical assistants. All team members had prior experience with SASS5 protocols and aquatic invertebrate identification. Participation was voluntary and adhered to institutional field safety and environmental research ethics standards.

Bias

To minimise sampling and observer bias, standardised SASS5 protocols were strictly followed at all sites. Field teams were rotated between sampling trips to minimise observer variability. Macroinvertebrate identifications were verified independently by two technicians in the laboratory to ensure consistency. Sampling of habitat types (biotopes) was conducted consistently using fixed time and area constraints across all rivers and sites.

Study size

A total of 30 sampling events were conducted across 15 sites (3 sites per river) in two seasons (summer and winter). At each site, macroinvertebrates were collected from three primary biotopes:
Stones (in and out of current, including bedrock), sampled for 2 minutes
Marginal vegetation, covering a 2-metre length
Gravel, sand, and mud (GSM), sampled for 30–60 seconds
This produced 90 biotope samples per season, resulting in 180 total biotope samples across the study. Sampling effort followed recommendations by Dickens & Graham (2002), which suggest three replicate samples across key biotopes to represent habitat diversity at each site.

Data measurement/sources

Data were collected using the SASS5 protocol (Dickens & Graham, 2002). Kick-sampling was performed with a standard SASS net (mesh size 1 mm, dimensions 30 cm x 30 cm). Collected specimens were preserved in 10% buffered formaldehyde, stained with phloxine dye, and transported to the laboratory for identification under a dissecting microscope, guided by Kleynhans (1999).
Key metrics included:
SASS5 Score: total taxon-based score

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ASPT (Average Score Per Taxon): SASS5 score divided by the number of taxa. In addition, habitat conditions were assessed using the Index of Habitat Integrity (IHI) at each site.

Statistical analysis

Descriptive statistics (mean, range, and standard deviation) were used to summarise SASS5 and ASPT scores across rivers and seasons. Two-way ANOVA was used to test for differences in macroinvertebrate indices between rivers and seasons. Pearson's correlation analysis evaluated relationships between SASS5 scores and IHI. Non-metric multidimensional scaling (NMDS) was used to explore community composition patterns across sites. Minor missing data (due to high flow events or inaccessibility of some biotopes) were addressed through mean substitution, provided that missing values were <5% of the dataset.

Ethical consideration

Although the study did not involve human or animal participants under medical or clinical guidelines, ethical best practices in environmental research were followed. The project received approval from the Research and Ethics Committee of the University of South Africa on 24 October 2024with sampling conducted under required environmental permits and with efforts taken to minimise ecological disturbance at all field sites.

Results

South African scoring system (SASS 5)

Each river was sampled in both seasons, making a total of ten assessments. From the assessments, the number of taxa as well as the diversity were noted. The ASPT value was generated by dividing the SASS score by the number of taxa for each sampled site. Table 2 indicates the SASS scores, Number of taxa, and the ASPT for each of the rivers under this investigation.

Table 1: Habitat integrity classes for IHAS and description of each class, adoptedfrom (Thirion, 2007)

Ecological Category	Description of category	Acceptable/ Unacceptable
A	Unmodified, natural state, macro-invertebrate communities compare with reference assemblages	Acceptable
B	Largely natural with few modifications. A small change in natural habitats and macro-invertebrate communities may have taken place, but the ecosystem. Functions are essentially unchanged	Acceptable
C	Moderately modified. A loss of natural habitats and a moderate change in macro-invertebrate community structure. Ecosystem functioning is still predominantly unchanged.	Acceptable
D	Largely modified. A loss of natural habitat and a large change in macro-Invertebrate community structures. Ecosystem functions are impaired.	Unacceptable
E	Seriously modified. Extensive loss in natural habitats and changes to macro-invertebrate community structures. Ecosystem function disruptions are extensive.	Unacceptable
F	Critical or extensively modified. Modifications have reached a critical level, resulting in almost complete loss of natural habitat and macro-invertebrate community structures. In the worst cases, basic ecosystem functions have been completely removed, and changes are irreversible.	Unacceptable

Figure 1 presents SASS5 bioassessment results for the Umgeni River across ten sites, showing that SASS scores are generally high (ranging between 130 and 150+), indicating good ecological integrity and macroinvertebrate diversity. ASPT values remain consistent across all sites (around 5–6), suggesting a stable community composition with similarly sensitive taxa. However, a noticeable dip in both SASS scores and the number of taxa at Site3W and Site3S may point to localized environmental disturbances or water quality issues in the midstream region. In contrast, the downstream sites (Site4W, Site4S, and Site5S) show higher taxa richness, possibly reflecting ecological recovery or more diverse habitats. Overall, the river appears to be in moderate to good ecological condition, with isolated areas of concern requiring further investigation.

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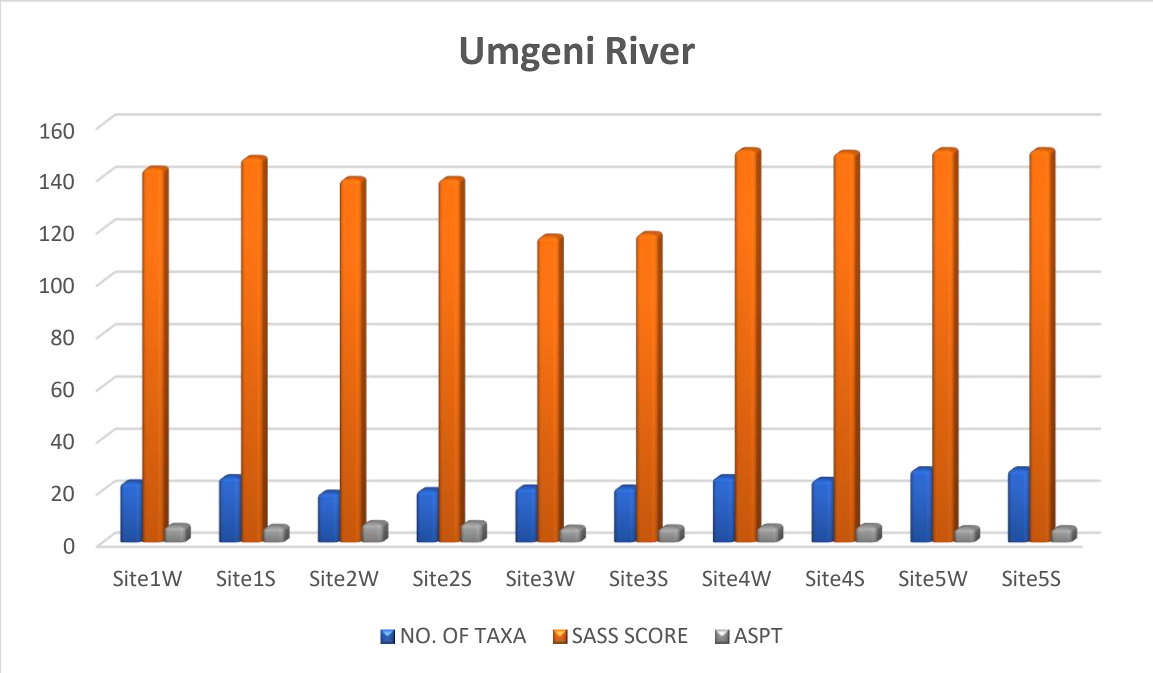

Figure 1: SASS5 score for the Umgeni River

Figure 2 (Tugela River) illustrates spatial variation in ecological integrity across ten sites using SASS5 metrics. The highest SASS scores and number of taxa are observed at Site1W and Site1S, indicating excellent water quality and macroinvertebrate diversity upstream. A marked decline in both metrics occurs from Site2W to Site4S, with the lowest scores at Site4W, suggesting potential pollution or habitat degradation in the midstream region. However, an improvement is noted at Site5W and Site5S, where scores rise again, pointing to possible ecological recovery downstream. ASPT values remain relatively stable across all sites, indicating consistent taxa sensitivity and suggesting that despite fluctuations in richness and total scores, the overall community structure remains ecologically balanced.

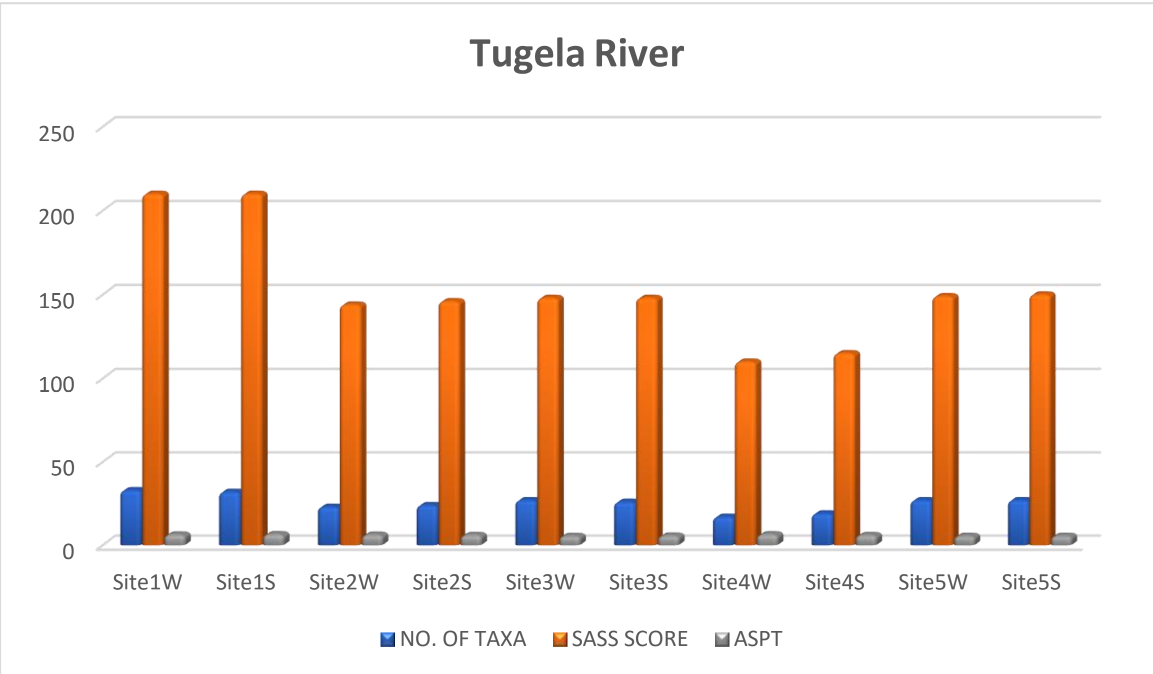

Figure 2: SASS5 score for the Tugela River

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The graph for the Umvoti River shows a general decline in ecological integrity from upstream to downstream, based on SASS5 bioassessment indicators. Sites 1W and 1S exhibit the highest SASS scores (above 170) and a relatively high number of taxa, suggesting excellent water quality and habitat conditions in the headwaters. From Site2W through to Site5S, there is a gradual decrease in both the SASS scores and the number of taxa, with the lowest values recorded at Site5W and Site5S. This downward trend may indicate cumulative impacts of anthropogenic activities such as pollution, habitat modification, or reduced flow further downstream. Despite this decline, ASPT values remain stable across all sites, implying that while species richness and abundance may be decreasing, the sensitivity of the remaining taxa is consistent. Overall, the river reflects a pattern of ecological stress downstream, warranting targeted conservation and rehabilitation interventions in the lower reaches.

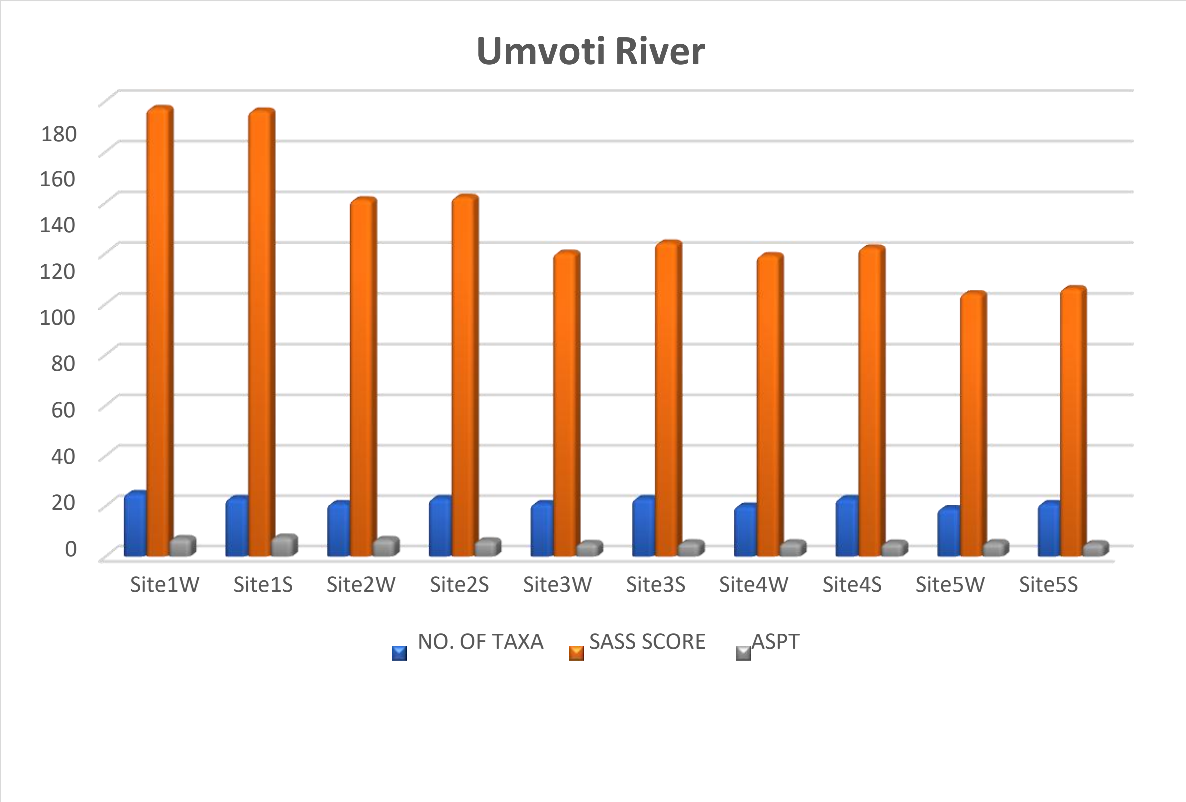

Figure 3: SASS5 Score for the Umvoti River

The graph for the Umdloti River reveals a clear upstream-to-downstream improvement in ecological integrity based on SASS5 bioassessment metrics. The lowest SASS scores and number of taxa are recorded at Site1W and Site1S, indicating potential environmental stress or poor water quality in the headwaters. From Site2W onward, there is a progressive increase in both the number of taxa and SASS scores, reaching the highest values at Site5W and Site5S, which suggests significant ecological recovery and improved habitat conditions downstream. This trend may be attributed to reduced upstream pollution inputs, natural purification processes, or increased habitat complexity further downstream. ASPT values remain relatively stable across all sites, indicating that the sensitivity of taxa remains consistent, even as richness and total abundance improve. Overall, the Umdloti River shows a positive longitudinal gradient in river health, highlighting the downstream sections as ecologically healthier and more biodiverse.

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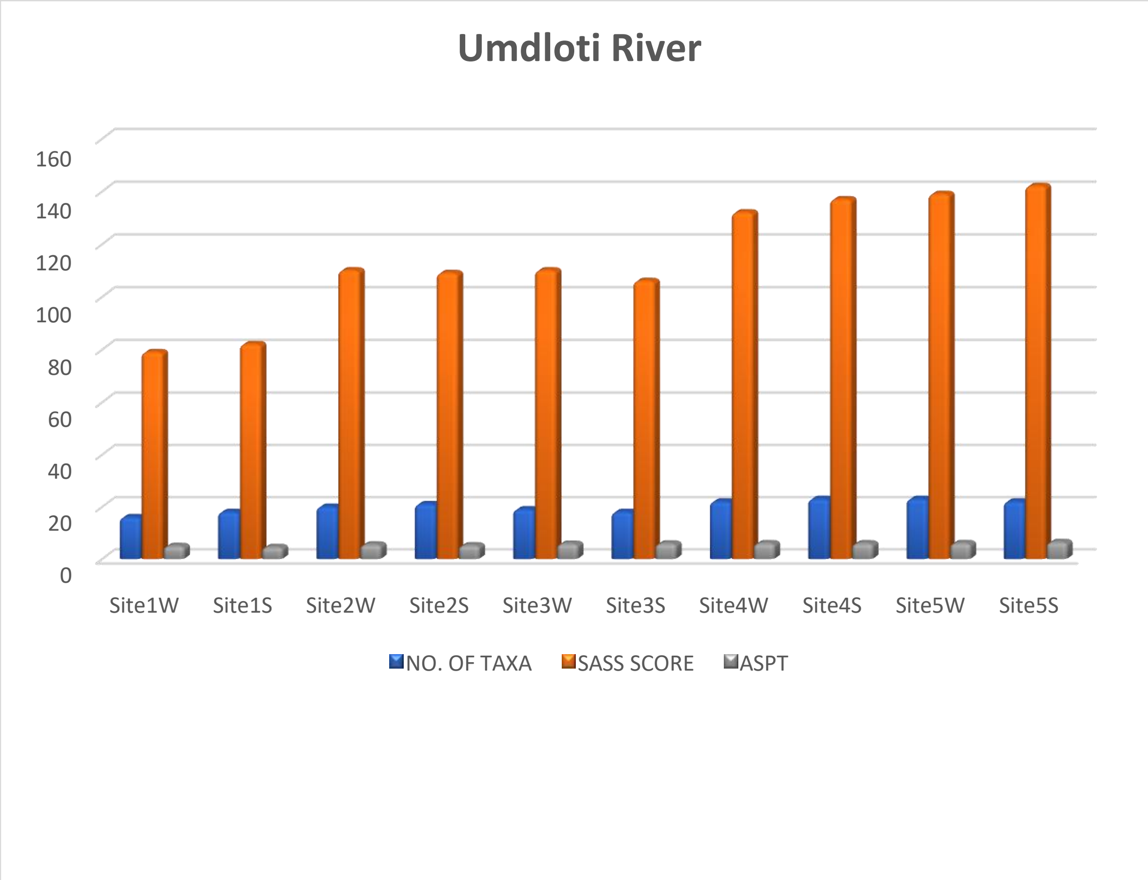

Figure 4: SASS5 score for the Umdloti River

The Umfolozi River graph demonstrates notable spatial variation in ecological condition across the ten sampled sites. SASS scores are moderate at upstream sites (Site1W and Site1S), hovering around 140, and remain relatively stable through Site2W and Site2S. A significant peak occurs at midstream sites (Site3W and Site3S), where both the SASS scores and the number of taxa increase sharply, indicating enhanced biodiversity and water quality, possibly due to improved habitat or reduced human disturbance in this section. However, a decline is observed at Site4W and Site4S, suggesting localized degradation, which could be attributed to pollution or land-use changes. The downstream sites (Site5W and Site5S) again show an improvement in both metrics, pointing to potential ecological recovery or improved conditions further downstream. ASPT values remain consistent throughout, suggesting the presence of equally sensitive taxa across the sites. Overall, the Umfolozi River appears to maintain generally good ecological health, with the midstream section standing out as the most biologically rich and least disturbed area.

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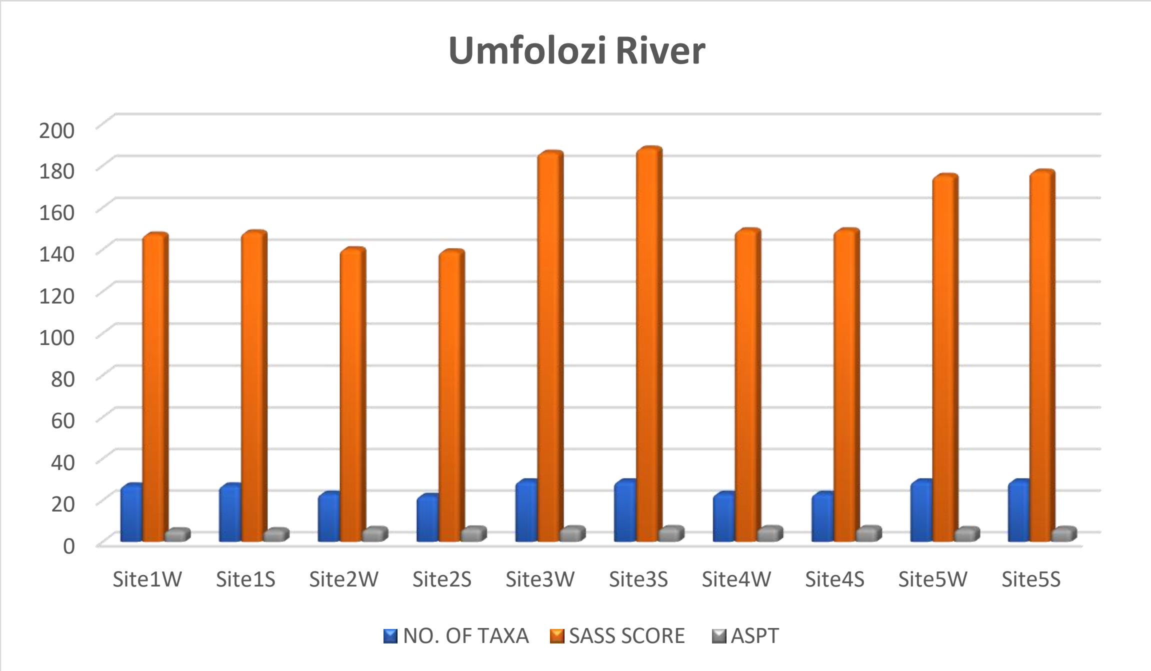

Figure 5: SASS5 score for the Umfolozi River

Discussion

The SASS 5 assessment for all five rivers under this investigation seems to have some sort of consistency in the number of taxa, which ranged between 16 and 33. The Tugela River had the greatest number of taxa in Site 1W and differed slightly from Site 1S. The lowest number of taxa was noted at the Umdhloti River, ranging between 16 and 23, with the lowest ASPT value of 4.56 and 4.94. Across all rivers, the ASPT values for the winter assessments seem to be much better than the summer values. Previous investigation on the Umvoti River showed that SASS scores were better during high flow periods as compared to low flow periods (Carminati *et al*., 2008). This could be due to the low flow periods having little effect on the organisms associated with rock and stones that form homes for these organisms. However, the organisms are easily washed down the river due to the high pressure of the flow during the high flow periods. The summer months are dominated by random rainfall. Hence, the summer months had a much lower SASS score as compared to the winter months. Furthermore, sedimentation as well as abstractions contributed to the water flows of the rivers.

The rivers that are more affected by sedimentation and abstractions due to the industrial influence are the Umvoti River, Umgeni River, and Tugela River. These sedimentation and abstraction resulted in flow modification had a rippled effect on the lower reaches of the river. The Umvoti River is associated with effluents from the paper mill (SAPPI) and the sewage plants near the Stanger region. These effluents affected the biodiversity of the river itself due to the increased chemical and waste pollution that these plants would contribute, and ultimately affect the SASS score of the river (Carminati *et al*., 2008). The Umdhloti River is mainly affected by the extensive sand mining operation currently taking place just after the Verulam area. The sand mining is impacting the biodiversity of the riparian vegetation and that of the river itself. The most taxa collected for the uMngeni River were 28, which were at the site nearest the lower reaches of the river. For Tugela River, Umvoti River, Umdhloti River, and Umfolozi River, the number of taxa collected was 33, 25, 23, and 29, respectively. The least taxa collected for the uMngeni River, Tugela River, Umvoti River, Umdhloti River, and Umfolozi River were 19, 17, 19, 16, and 22, respectively.

The SASS5-based bioassessment revealed significant spatial and seasonal variability in macroinvertebrate community structure across the five rivers studied. Consistent with previous research (O'Brien et al., 2009), lower SASS and ASPT scores were generally recorded at downstream sites, particularly in the uMngeni and Umvoti Rivers. These findings align with patterns of increased anthropogenic pressure in lower catchment areas, including urban runoff, wastewater discharge, agricultural effluents, and habitat modification. Conversely, the Umdloti and Umfolozi Rivers maintained relatively higher SASS scores, suggesting lesser degrees of disturbance and better-preserved habitat conditions. Seasonal variation was also evident, with macroinvertebrate richness and SASS scores generally higher in summer than in winter. Warmer temperatures and higher flow variability in summer may enhance macroinvertebrate activity and habitat complexity

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(Carminati *et al*., 2008). The strong positive correlation between SASS scores and the Index of Habitat Integrity (IHI) further confirms the dependence of macroinvertebrate communities on habitat quality, reinforcing the utility of integrating biotic and abiotic indicators for river health assessment. The results corroborate findings from similar South African studies (Carminati *et al*., 2008), which have demonstrated the sensitivity of SASS5 to habitat degradation and pollution. Importantly, the identification of biotopes with particularly low ASPT values provides a targeted approach for prioritizing rehabilitation efforts. Overall, this study validates the efficacy of SASS5 as a cost-effective and ecologically meaningful tool for routine biomonitoring in KwaZulu-Natal's river systems.

Conclusion

This study assessed the ecological integrity of five key rivers in KwaZulu-Natal using macroinvertebrate-based indices (SASS5 and ASPT), revealing spatial and seasonal variation in river health. The uMngeni and Umvoti Rivers exhibited the greatest ecological stress, especially at downstream sites, while the Umdloti and Umfolozi Rivers showed healthier macroinvertebrate communities. Seasonal changes also influenced macroinvertebrate assemblages, with richer communities typically observed in summer. These findings affirm the role of macroinvertebrate-based biomonitoring in detecting ecological change and guiding riverine management and policy interventions.

Limitations

The study was limited by its cross-sectional design, capturing only two seasonal periods (summer and winter) in 2024. As a result, it did not capture inter-annual variation or extreme seasonal events such as floods or droughts. Although SASS5 protocols were strictly followed, macroinvertebrate identification was performed only to the family level, which limited the taxonomic resolution of the findings. Furthermore, the study focused solely on abiotic-to-biotic relationships through habitat integrity and macroinvertebrate assessments and did not include direct measurements of water chemistry, which would have provided additional explanatory context for ecological patterns observed.

Recommendations

To enhance the effectiveness of freshwater ecosystem monitoring in KwaZulu-Natal, an integrated biomonitoring framework should be institutionalized. This includes conducting regular SASS5 (South African Scoring System) assessments, supplemented by habitat evaluations and water quality testing across major river systems. Such an approach ensures a comprehensive understanding of ecological health. Catchment management practices must also be strengthened through the enforcement of land-use regulations, pollution control measures, and the establishment of riparian buffer zones to prevent downstream degradation. Furthermore, implementing seasonal sampling protocols, particularly during both wet and dry seasons, will capture the temporal variability in macroinvertebrate communities, providing a more accurate picture of river health. Community involvement is essential; developing citizen science programmes will empower local residents to engage in SASS-based monitoring, fostering environmental stewardship. Finally, sustained capacity building is crucial. Environmental officers, students, and municipal personnel should be trained in the application of SASS5 and the interpretation of biomonitoring data to ensure that results are effectively used to inform policy and conservation actions.

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

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.

Acknowledgements

I acknowledge the moral support and encouragement from the Deans and HOD of the Department of Nature Conservation, Faculty of Natural Science, Mangosuthu University of Technology.

Funding

This work was not supported by any grant. The author did not receive research support from any company. The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

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Original Article

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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Publisher details

Student's Journal of Health Research (SJHR)
(ISSN 2709-9997) Online
(ISSN 3006-1059) Print
Category: Non-Governmental & Non-profit Organization
Email: studentsjournal2020@gmail.com
WhatsApp: +256 775 434 261
Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa