Evaluation of the South African Scoring System (SASS 5) Biotic Index For Assessing The Ecological Condition of the Mara River, Kenya

Denis K. Oigara* and Frank O. Masese

Department of Fisheries and Aquatic sciences, School of Natural Resource Management, University of Eldoret, P.O. Box1125-3010, Eldoret, Kenya

Emails: *dennohdingi@yahoo.com; fmasese@uoeld.ac.ke

Abstract

The use of rapid assessment protocols for bioassessment of streams and rivers is gaining prominence all over the world. In Africa, biotic indices are limited and only the South African Scoring System Version 5 (SASS5) has been validated for use in southern Africa. However, the popularity of SASS5 has seen its adoption for use in many countries in southern and eastern Africa, with modifications now available for Tanzania and Ethiopia. In Kenya, efforts are being made to adopt and modify SASS5 to suit local conditions. This study aimed at determining the suitability of the SASS5 protocol in the Mara River, Kenya. Macroinvertebrate samples were collected from different biotopes during the wet season to generate qualitative presence-absence and quantitative data. There were no significant differences between field-and and laboratory based site scores based on paired t-tests (p>0.05). There were significant differences in the number of taxa and ASPT Scores among sites for both field- and laboratory- based data, total SASS5 Score field data, total SASS5 Score for laboratory data (p<0.05). There were spatial differences in site scores with headwaters sites recording higher values indicating that they were in a better ecological state compared with sites in agricultural areas and grazing areas. Some taxa such as Oligochaetae and Chironomidae were widespread and abundant, which is an indication of deteriorating water quality. The use of the SASS5 protocol in the Mara River is promising and this study shows that with modification to generate quantitative data, the findings are still comparable with the field-based qualitative approach. The advantage with the labaratory-based approach, even though it has not been widely tested, generates quantitative data that can be used in statistical analyses to identify drivers of changes in macroinvertebrate community composition.

Key words*:* Bioassessment, ecological condition, water quality, biotic indices, macroinvertebrates

INTRODUCTION

Benthic macroinvertebrates have been used around the world in various biomonitoring programs as indicators of environmental degradation or restoration (Barbour *et al.*, 1999). The south African Scoring System (SASS) is a successful example of a rapid biomonitoring protocol used in South Africa (Thirion and Metcelf,1995), and other countries in southern Africa (Dickens and Graham, 2002; Dallas, 2004; Lowe *et al.*, 2012).

The SASS Version 5 (SASS5) evaluates stream health by incorporating habitat and aquatic invertebrates' health (Chutter, 1998, Dallas, 2004). In East Africa, similar macroinvertebrate scoring indices have been developed. In Ethiopia they have developed the Ethiopian Biological Score index (ETHbios) used to determine and assess the ecological water quality (Aschalew *et al.*, 2015). This index is a rapid and inexpensive biomonitoring method similar to the Biological Monitoring Working Party (BMWP; Armitage et al., 1983) index, but excludes taxa that do not occur in Ethiopia and includes some endemic species. Similar biotic indices include the Zambian Invertebrate Scoping System (ZISS) used in Zambia (Lowe *et al.*, 2012). The Tanzania River Scoring System (TARISS) was also developed following modifications on the SASS5.

Following these developments, a need for such an index in Kenya has been recognized (Masese *et al.*, 2013). Currently, Kenya does not have a rapid bioassessment protocol for use in evaluating the ecological status of streams and rivers. However, a number of studies have used macro invertebrate-based multimetric indices such as the index of biotic integrity to assess the condition of a number of river systems (Raburu *et al*., 2009, Masese *et al*., 2009a; Aura *et al*., 2017), and many more studies have used the composition and distribution tolerant and intolerant taxa to infer human influences on water and habitat quality (Ndaruga *et al*., 2004; Masese et al., 2009b; Minaya *et al*., 2013; Mbaka *et al*., 2014; M'Erimba *et al*., 2014; Raburu *et al*., 2017). The problem with these studies is that they are based on individual streams and river systems, and cannot be widely used. The aim of this study was to test the applicability of the SASS5 protocol in Kenya, by using the Mara River as an example. More recently, SASS5 has been used in Kenya for eflows assessment in the Mara River (McClain *et al*., 2014) and as part of the overall assessment of ecological condition of streams and rivers (Minaya *et al*., 2013; Mbaka *et al*., 2014; M'Erimba *et al*., 2014). However, the use of SASS5 in these studies has not followed the guidelines as per Dickens and Graham (2002), and only the sensitivity scores have been used. Additionally, the SASS5 method was developed as a rapid qualitative assessment for determining river health and not as a cause-effect assessment (Dickens and Graham, 2002). In this study, this limitation is addressed by enumerating the samples collected from the various biotopes in the laboratory so that statistical analyses could be performed on quantitative macroinvertebrate abundance data. Having abundance data is important because it would allow for statistical analysis of samples to enable in the identification of drivers of changes in macroinvertebrate community composition and SASS scores.

MATERIALS AND METHODS

Study area

This study was carried out during the wet season, in the Mara Rriver during October and November, 2015, at nine different sites (Figure 1). The Mara River basin is located at Latitudes $1^0$30’50S and 33^0 55’56’N. The basin covers an area of 13,504 km2, of which 65% is located in Kenya and 35% in Tanzania.Sampling sites included Silibwet, Chemolol, Kapkimolwa, Emarti, Purungat, Sand river, Mara mines and Talek from upstream heading downstream.

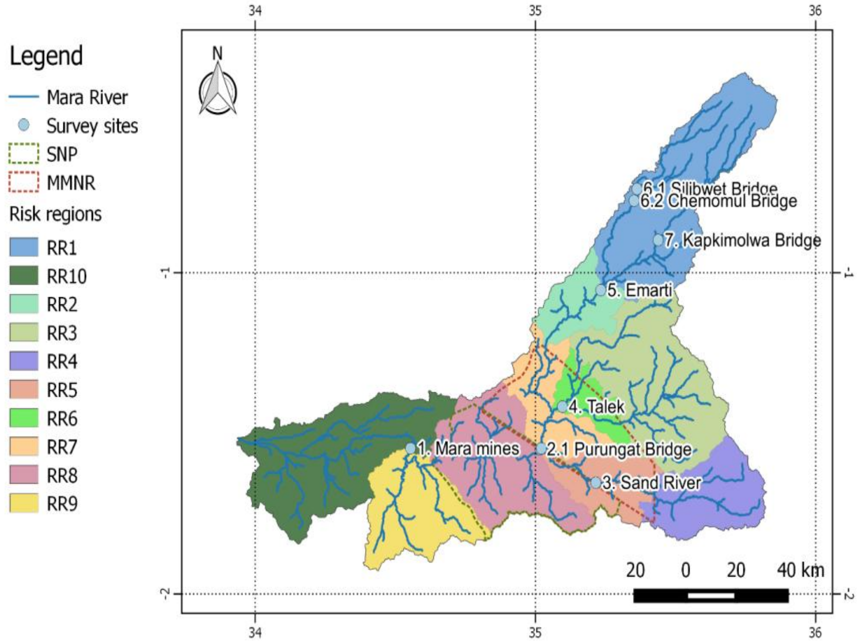

Figure 1: The survey sites in the Mara river, (source, Kelly Fouchy, UNESCO-IHE).

Methods

The SASS5 protocol was applied in this study according to Dickens and Graham (2002). This sampling protocol uses the SASS net, a modified Kick net with a mesh size of 1000 µm. A number of biotopes were sampled within a prescribed time limit and/or areal coverage (Dickens and Graham, 2002). The stones-inside-current (SIC) and bedrock was searched (‘kicked’) for a period of 2 – 5 minutes. Similarly, stones-out-of-current (SOOC) and bedrock were searched for 1 minute. The SIC and SOOC samples were combined into a ‘Stones’ (STONES) sample. Suitable stretches covering 2 m marginal vegetation (IC & OOC) was swept as well as aquatic vegetation covering $1m^2$. This represented the ‘Vegetation’ (VEG) sample. Gravel, sand and mud (GSM sample) was stirred and swept for 1 minute and filtered to check for presence of any macro-invertebrates. Hand picking and visual observation was also employed for 1 minute and biotopes where macro-invertebrates were found recorded. Loose stones were picked and screened for presence of benthos. For each biotope, abundance estimates of macroinvertebrate taxa were made and recorded.

As a modification to the SASS procedure, all samples from the three habitats, Stones, GSM and Vegetation, were preserved in formalin in separate containers and taken to the laboratory for further processing and enumeration of abundances of the various taxa. This data was particularly useful for statistical analyses to determine the preferences of the various taxa in terms of flow velocity, depth and substrate type.

Sample processing

Macroinvertebrates specimens were identified in the field to the family level and samples retained for further sorting and identifications in the laboratory. Identified taxa in the field were captured in the SASS Score sheet and the total number of taxa per site determined and abundances estimated (Dickens and Graham, 2002). The South African Sensitivity Score and its associated average score per taxon (ASPT) were used to characterize macroinvertebrates at each site (Dickens and Graham 2002. Macroinvertebrate samples collected were further processed in the laboratory. They were sorted, enumerated and identified to the family level, using a number of taxonomic keys (Gerber and Gabriel, 2002; Day and de Moor 2002a,b; Day *et al*. 2002; de Moor et al., 2003a,b; Merritt *et al*., 2008).

Data analysis

SASS5 Score Indices

The SASS scores were calculated and recorded at family level, a procedure used in assessing the present ecological state (PES). This was calculated for both laboratory and field samples as follows (Chutter, 1998):

$$ASPT = \sum_{i=1}^{i=s} \frac{(n_i \times a_i)}{N}$$

Where:
S = the total number of taxa in the sample
n_i = is the coded abundance in the i^{th} scoring taxon
a_i = is the sensitivity score for the i^{th} taxon (SASS scoring table), and
N = the total number of taxa contributing to the SASS score
The references for each site were based on comparable data from historical studies that have been done in the river. An interpretation of the SASS score (Table 1), for various indices in relation to SASS score also assisted in analyzing the present ecological condition of the river.

Table 1: Interpretation of SASS5 Scores

SASS 5 Score	ASPT Score	Class
> 100	> 6	Water quality natural; habitat diversity high
< 100	> 6	Water quality natural; habitat diversity reduced
< 100	< 6	Border line good/ bad water quality. Interpretation based on extent that SASS < 100, ASPT < 6
50 - 100	< 6	Some deterioration in water quality
< 50	Variable	Major deterioration in water quality

Source: Chutter, 1998

RESULTS

Relative abundance of macroinvertebrates in different biotopes

Both field and laboratory samples showed variation in the relative abundance of the various taxa (Figure 2). Baetidae, Gomphidae and Oligochaeta (including Tubificidae), dominated the GSM biotope in both field and laboratory processed samples in the Mara River. The Stones biotope was dominated by the rheophilic taxa among Hydropsychidae, Simuliidae, Tricorythidae and Baetidae. Lastly, The Vegetation biotope was dominated by Baetidae, corixidae, Naucoridae and Gomphidae. Baetidae displayed the widest biotope preferences by occurring at all biotopes in high abundances. This is attributed to the many genera and species in Baetidae which have different water quality and habitat requirements.

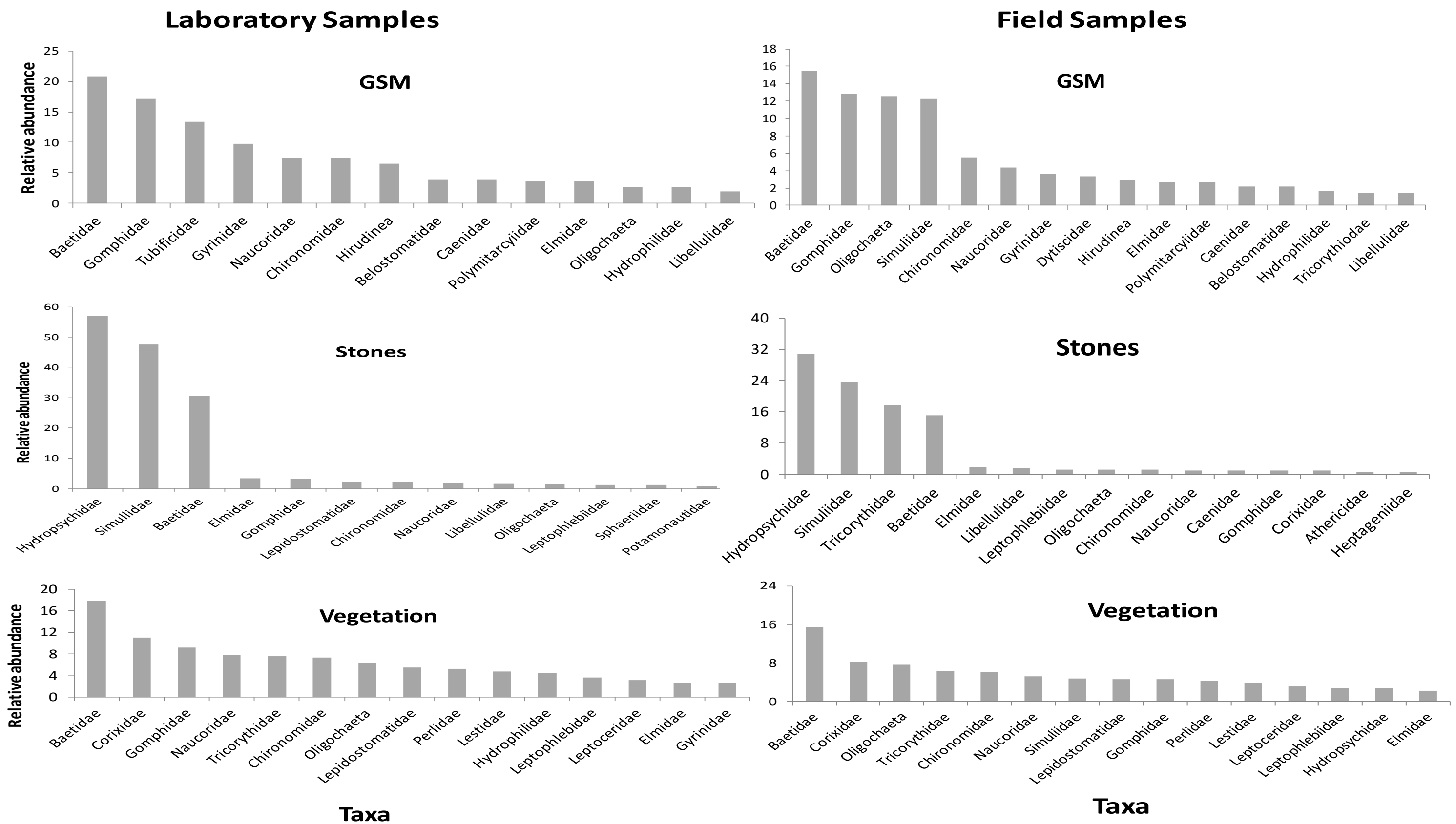

Figure 2: Relative abundance of different families of macroinvertebrates per biotope (GSM, Stones and Vegetation) for both the laboratory- and field-based samples

Comparison of laboratory and field samples

A comparison was made between SASS5 indices generated using field and laboratory processed samples. Samples were identified and scoring done initially in the field as per the SASS5 protocol (Dickens and Graham, 2002), while another scoring was performed after laboratory processing of the samples. Figures 3 and F4 shows the ASPT, Total SASS Score and the Number of taxa metrics based on field and laboratory samples, respectively. The most upstream sites, Silibwet and Chemomul, were used as reference ecological state because of their relatively unimpaired water quality conditions; the upstream catchment is forested with conservation agriculture practiced in most areas.

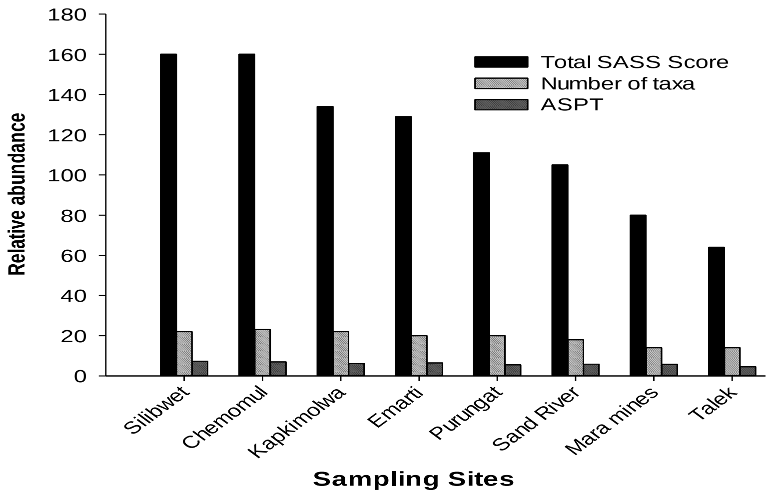

Figure 3: Macroinvertebrate SASS5 metric scores at the different sites along the Mara River based on field samples.

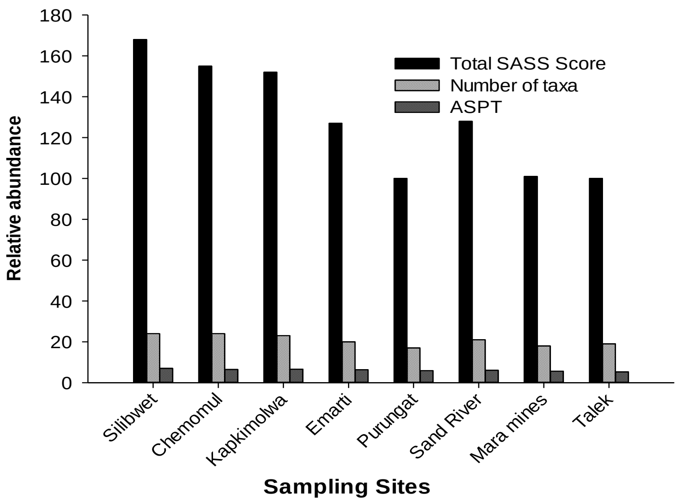

Figure 4: Macroinvertebrate SASS5 metric scores at the different sites along the Mara River based on laboratory samples.

Average scores per taxon (ASPT), Total SASS score and Number of taxa displayed a downstream trend for both field and laboratory samples, but the chnages were more profound for the Total SASS score metric (Figures 3 and 4). Overall sites in the upper reaches scores better, indicating that they were in a relative good ecological condition as compared to sites in agriocultural areas, and in the Mara River where human influences included erosion from agricultural and urban areas and grazing.

Table 2 shows statistical analysis of both laboratory and field samples in which a one-sample paired t-test was performed between field and laboratory samples on Total SASS score and ASPT. There was a significant (p=0.035) difference in Total SASS and ASPT (p<0.034) between field and laboratory samples (Table 1). However, there was no significant difference in the Number of taxa metric between field and laboratory samples (p = 0.316). A one sample t-test for all the three indices were significantly different for both field and laboratory samples.

Table 2: Results of paired t-test comparing metrics based on laboratory and field macroinvertebrate samples

Test	Sample	t-value	p-value
One sample t-test	Total SASS Score -Field	9.577	<0.001
	Total SASS Score –Lab	13.423	<0.001
	Number of Taxa -Field	15.355	<0.001
	Number of Taxa-Lab	44.750	<0.001
	ASPT –Field	44.750	<0.001
	ASPT-Lab	44.750	<0.001
Paired sample t-test	Total SASS Score between Field and Lab	-2.623	0.035
	Number of Taxa between Field and Lab	-1.080	0.316
	ASPT between Field and Lab	-2.623	<0.034

DISCUSSION

By relative abundance of macroinvertebrate families, Baetidae, Gomphidae and Hydropspychidae were the most abundant in all biotopes. These results also agree with studies in the Lake Victoria region which found these families to be the most dominant (Minaya *et al.,* 2013; Kilonzo *et al.,* 2014; Masese *et al.,* 2014 a, b). The stones biotope was dominated by Hydropsychidae, Simulidae and Batidae in the field and laboratory samples. These results are also in line with studies carried out by (Moore *et al.,* 2007) in which these families have been found to occur in stones in riffles. Some families were found to occur in all biotopes from Stones, GSM and Vegetation. For example Chironomidae were almost found across all the sampled biotopes and these results agree with findings of (Minaya *et al.,* 2013; Kilonzo *et al.,* 2014; Masese *et al.,* 2014a, b) where these families are usually cosmopolitan and their abundance increase in polluted areas where water quality is poor.

For laboratory samples, Silibwet Bridge showed a higher ASPT at 7.0 with a total of 24 taxa identified. Silibwet Bridge site was the most upstream and near the Mau Forest and acted as the reference site for the other sites. Water and habitat quality was in good condition as shown by high ASPT values (Chutter, 1998). Talek, Mara Mines and Purungat sites had the lowest number of taxa, and ASPT values at 5.3, 5.6 and 5.8

respectively. These three sites also recorded the lowest number of taxa, below 20. The lowe Number of taxa and low ASPT values at the Talek can be attributed to large number of hippopotami (hippos) upstream which defecate in the river and input a lot of organic matter (excreta) whose decomposition compromises water quality. Hippos have been noted to compromise water quaity and reduce the diversity of benthic biota, including invertebrates (Dawson *et al.,* 2016). The hippos also occur upstream of the Purungat site and large section of the Mara River within the Maasai Mara Game Reserve, and this can explain the low metric values at the site. At Mara Mines, sampling was not easy because the river was in flood and accessing the permanent habitats that could have harboured more taxa was not possible. Sampling was conducted in the marginal areas which had been inundated for a short period, and hence macroinvertebrates had not colonized the new habitats. High river flow may dislodge some taxa that colonize a given biotope, hence affecting the abundance and SASS indices in a river system.

Similar trends were noted for field-based metric values. These results are in line with previous studies where the SASS5 method has been applied, as higher ASPT scores indicate a diverse community with many taxa that are sensitive to pollution or disturbance (Dickens and Graham, 2002). Overall metrics for both laboratory and field samples indicated a longitudinally deterioration in water quality in the Mara River. This can be attributed to the overall increase in human activities and livestock numbers in agricultural areas and areas around the MMNR.

Interestingly, the findings from field and laboratory samples agreed in terms of their evaluation of the ecological condition of the various sites. The SASS5 is the mostly used field-based protocol (Dichens and Grahham, 2002), and the developers argue against the use of preserved samples. Although the field-based approach generates some abundance data, these are usually estimates with broad ranges, eg. 0-10, 10-100, 100-1000, > 1000, which cannot be used for statistical analyses. In cases where statistical analyses have been performed, it has always forced researchers to use a quantitative gear, e.g., Surber sampler, in addition to the SASS method. This is double work that can be avoided by using field and laboratory samples for the SASS scores and metrics, and the same time use the same laboratory processed and generated data for statistics, as used in this study. This will lessen the field work and lead to more understanding of the drivers of macroinvertebrate community structure, and elucidation of abiotic and biotic relationships in streams and rivers.

In its present form, the SASS5 protocol gives reliable findings as applied in the Mara River. However, there is a need for broad testing and validation for the protocol before use in other river systems in Kenya. The validation can be done by comparing with other indices, such as the index of biotic integrity (IBI) that has been developed for a number of river systems (Masese *et al.,* 2009a, Raburu et al., 2009; Aura *et al.,* 2017).

CONCLUSIONS

Both laboratory- and field-based SASS5 metrics responded to changes in ecological conditions across sites in the Mara River. This implies that the laboratory generated scores are reliable, and the quantitative data can be used for statistical analyses. Considering that the study was conducted during the wet season, dry season findings should be more accurate because sites have been found to be more distinct and reflective of influences more clearly as compared with the wet season (Masese *et al.*, 2014b). In future studies, collection of water quality parameters would help explain sources of impediment and establish thresholds for the various taxa.

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