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EVALUATION OF THE USEFULNESS OF THE SOUTH AFRICAN SCORING SYSTEMS IN A SAVANNA RIVER

[EVALUACIÓN DE LA UTILIDAD DEL SISTEMA DE CALIFICACIÓN SUDAFRICANO EN UN RÍO DE SABANA]

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SUMMARY

The usefulness of the South African Scoring Systems (SASS) in a savanna river was studied for an array of lowveld streams. The streams were also characterised using standard chemical methods from August 2004 to May 2005 to complement biological monitoring methods. Nutrients such as total nitrogen, nitrate nitrogen and total phosphates did not show differences ($p>0.05$) between the wet and dry seasons. The SASS and ASPT scores were different ($p<0.05$) between dry and wet season at test sites but not between the dry and wet season at control sites. Site, media and site x media interaction had a significant effect on SASS scores and only site showed significant difference in ASPT scores. Multiple comparison tests using paired t-tests with Bonferoni adjustment showed site effect ($p<0.05$) on total nitrogen, ammoniacal nitrogen, ASPT scores and SASS scores. Media effect showed difference ($p<0.05$) on total nitrogen, nitrate nitrogen and SASS scores. The effect of season was significant ($p<0.05$) on total nitrogen and total phosphate. In this study, nutrient data show that water quality is dynamic and the nutrients change with season because of real changes in nutrient concentrations. The results indicate that SASS indices provide a better measure of water quality since they integrate seasonal influences on changes in water bodies than chemical data that reflect conditions at the time the water samples were taken. The study of seasonal effects on nutrients and water quality has the potential to develop our conceptual understanding of the impact of discharges on the fluvial ecology for an environment that is naturally challenging for organisms, given the temporal variation in river flow, temperature and suspended solids.

Key Words: Season, nutrients, lowveld river systems, SASS scores, ASPT scores

RESUMEN

La utilidad del sistema sudafricano de evaluación (SASS) en un río de sabana fue estudio en un conjunto de arroyos. Los arroyos fueron también caracterizados empleando métodos químicos estándares de Agosto de 2004 a Mayo de 2005 para complementar los métodos de monitoreo biológico. Nutrientes tales como: Nitrógeno total, nitrógeno en forma de nitrato y fosfatos totales no mostraron diferencias ($p>0.05$) entre la estación seca y lluviosa. Los valores del SASS y ASPT fueron diferente entre la época seca y lluviosa en cada sitio de muestro ($p<0.05$) pero no en el sitio control. El sitio, medio y su interacción tuvieron un efecto en la calificación del SASS y sólo el sitio tuvo un efecto en la calificación ASPT. Comparaciones múltiples, empleando pruebas de t pareadas y con ajuste de Bonferoni mostraron un efecto ($p<0.05$) en el nitrógeno total, nitrógeno amoniacal, ASPT y SASS. El efecto de estación fue significativo únicamente para nitrógeno total y fosfatos totales. Este trabajo mostró que la calidad del agua es dinámica y que los nutrientes cambian con la estación debido a cambios reales en su concentración. Los resultados indican que el SASS provee una mejor evaluación de la calidad del agua debido a que integra influencias estacionales con los cambios en la calidad de los cuerpos de agua mientras que los datos químicos reflejan las condiciones al momento de tomar la muestra. El estudio de los efectos estacionales sobre los nutrientes y calidad del agua tienen el potencial de desarrollar nuestro entendimiento conceptual del impacto de las descargas en la ecología fluvial en una ambiente que es naturalmente retador para los organismos, dadas las variaciones temporales en el flujo del río, temperatura y sólidos suspendidos.

Palabras clave: Estacionalidad, nutrientes, sistemas de ríos, SASS, ASPT.

INTRODUCTION

The seasonal changes of river water nutrients has drawn attention in Africa to the problems of water quality (Marshall, 1997, Nhapi and Tirivarombo, 2003). Nhapi and Tirivarombo (2003) observed that despite the importance of the status of water bodies in tropical savanna systems being well established, pollution remains a contentious issue, with considerable debate on nutrient load limitations. Two types of water pollutants exist; point source and nonpoint source. Point sources of pollution represent those activities where wastewater is routed directly into receiving water by, for example, discharge pipes where they can be easily measured and controlled. A nonpoint source pollution, sometimes known as "diffuse" source pollution, arises from human activities for which the pollutants have no obvious point of entry into receiving waters. Nonpoint source pollutants are transported overland and through soil by rainwater and the pollutants find their way into groundwater, wetlands, rivers and oceans.

Many causes of pollution including sewage and fertilizers contain nutrients such as nitrates and phosphates. Excess levels, nutrients over stimulate the growth of aquatic plants and algae. Excessive growth of these types of organisms consequently clogs waterways, make pumping of water facilities difficult, and use up dissolved oxygen as they decompose, and block light to deeper waters. The growing need to preserve and restore the physical, chemical and biological integrity of rivers and other water bodies is implicit in several ongoing studies (Van der Merwe *et al.*, 1993, Don-Pedro *et al*, 2004, Novotny *et al*, 2005). This has become necessary in order to maintain the diversity of species and water quality. Stricter legislation has already been enforced worldwide on mining, industry and agriculture to protect natural water bodies.

In southern Africa, concern has been expressed about the possible impacts of nutrients on waterways, potable water and conservation of biodiversity. In Zimbabwe, the seasonal changes of nutrients are not well understood or overlooked. This point is illustrated by the omission impact of seasonal changes on nutrients in most major studies (Van der Merwe *et al.*, 1993, Buermann *et al.*, 1995, Marx and Avenant-Oldewage, 1998). Agricultural pollution is a feature of global concern (Don-Pedro *et al.*, 2004, Novotny *et al.*, 2005). Aquatic ecosystems are sinks of pollutants generated in catchments (Dallas, 2004, Ricklefs, 2001, Novotny *et al.*, 2005, Tilman *et al.*, 2002). Anthropogenic activities tend to modify the condition and character of ecosystems at an accelerated rate making restoration work difficult. The South African Scoring System (SASS) method measures stream health by incorporating habitat and aquatic invertebrate health (Chutter, 1998, Dallas, 2004). The method produces three different and complimentary scores, SASS Score, Number of Taxa and ASPT (Average Score per Taxon). ASPT Scores are the least variable of the scores (Dallas, 2004) and these provide the most reliable measure of a natural class of river health (Dallas, 2004).

The development of irrigation in intensive agricultural areas can have important implications for water quality because of changes in physical and chemical properties and aquatic organisms. Application of water for crop production in semi-arid areas has been attributed to increased evapotranspiration, with a potential for accumulation of soluble salts within the soil. Where rivers draining irrigated land receive waters highly charged in soluble salts, marked changes in water quality may result. Nitrogenous fertilizers are generally associated with the NO_3 ion, either directly or as a result of mineralization and nitrification, and this ion is readily leached through the catchment system to watercourses.

Sewage and other effluents rich in decomposable organic material, cause primary organic pollution. As stated by Marshall (1997), organic wastes mineralize in the receiving water bodies and the resulting nutritive elements stimulate plant production, leading to eutrophication. In this situation, the biomass increases considerably and goes beyond the assimilation limit by herbivores. The excessive production of organic matter leads to the build up of "sludge" and the mineralization process consumes all dissolved oxygen from the water column, which causes fish kills. The relatively high temperatures in tropical countries accelerate this process.

Gower (1980) suggests that drainage water passing under grassland contains less NO_3^- N than from under arable soil. Drainage water from a grassland/lucerne section analysed separately showed average concentrations of 22 and 4 mg/l NO3-N, respectively (Gower, 1980). Therefore, the composition of the water entering a watercourse from the drains will depend on the proportions of arable and grassland soils or buffer zones with natural vegetation.

Interactions between sediments and the solution phase may occur in the river channel through adsorption and ion exchange mechanisms. Ca^{2+}, Mg^+, K^+, and PO_4^{3-} may be sorbed to a considerable degree by stream sediments. Anion exchange mechanisms involving adsorption of anions (PO_4^{3-}, SO_4^{2-}, and NO_3^{-}) onto positively charged sites. However, adsorption capacity of the sediments for anions is of little importance at pH above 7. It is important to understand whether nutrients among stream sites become more similar after exposure to a common stressor in the wet and dry seasons. Using data from intensive agricultural zone and reference sites located in peasant agriculture the nutrients in the water column and stream bottom sediments were investigated over time to compare among seasons sites having different levels (background and high) of nutrient pollution. This, in turn, will help us predict how the ecosystem responds when 'stressed' by human activities, such as by pollution from the land. Biological monitoring that uses living organisms as sensors for environmental quality may be coupled to seasonal changes of nutrients by determining the behaviour of SASS and ASPT as the water quality improves or decreases.

Gratwicke (1998/1999) investigated the effect of season using the South African Scoring System (SASS) biotic index on the Yellow Jacket and Mazowe Rivers in Zimbabwe. According to Gratwicke (1998/1999) several impacts that include habitat destruction, acid mine drainage and organic pollution degraded the water quality. The effect of season on nutrient dynamics in a lowveld aquatic ecosystem may be an important determinant of benthic macroinvertebrate distribution and is critical to the assessment of water quality. Seasonality of nutrients could lead to several adaptations by invertebrates such as emergence, feeding and growth. Water quality at impacted sites may be a dynamic variable related to the activities of polluters and to season. This paper seeks to investigate the effects of season on nutrients and South African Scoring Systems of a tropical savanna river. The study of seasonal effects on nutrients and other water quality has the potential to develop our conceptual understanding of the impact of season on fluvial ecology for an environment i.e. naturally challenging for organisms given temporal variations in river flow, temperature, suspended solids and other habitat modifying factors

MATERIAL AND METHODS

Study area

The study area is located 20^{o}00'S and 32^{o}00'E, 500 m a.s.l. in the southern highveld of Zimbabwe and include the area drained by the Chiredzi, Mtirikwi, Tokwe and Runde Rivers (Figure 1) about 350 km south east of Harare. The tributaries of the Runde River that include the Chiredzi, Mtirikwi and Tokwe pass through low input peasant agricultural areas and these streams are minimally polluted in this river study. The Runde River tributaries flow from their source to the Runde River passing through incised granite plain zone and Lowveld zone. Annual runoff from the Runde/Save hydrological zone is estimated at 5900 X 10^6 m^3 per year making the Runde/Save hydrological zone the second most important in terms of runoff yield. The Runde River mean daily flows vary greatly between 0 m^3/s in winter and drought situations and 75x10^3 m^3/s in summer. Not only does the annual runoff vary with mean annual rainfall, but it also varies from year to year in a particular year making river conditions and aquatic organisms sensitive to agricultural runoff perturbations. The Runde River captures agricultural runoff from the intensive agricultural areas and is thought to be polluted by fertilizers and sewage that modify the habitat conditions for aquatic organisms.

The study area is underlain by granite and gneiss, but in the east volcanics and rocks of Karoo age form the geological template. The Runde River is characterized by sandy and gravelly substrate. The riverbanks of the Runde River are lightly wooded with riparian vegetation of variable height that is critical to the life cycles of most aquatic insects found in the river waters. This study area was selected because it covers a wide range of typical Zimbabwean land uses, including the intensive sugarcane production at Triangle Sugar Estates and Hippo Valley Estates, and sugarcane processing mills at Hippo Valley and Triangle where mineral and organic fertilizers are applied in varying quantities.

Seasonal trends are clear in both the precipitation and the flow regime (Magadza *et al.*, 1993). Severe droughts have the effect of concentrating nutrients, shrinking and fragmenting aquatic habitats while excessive cyclonic rainfall has the effect of increasing current and diluting nutrients to trace levels. Drying up of the river waters is a frequent and important hazard. Surface water varies dramatically over time, with dry periods characterized by extreme habitat shrinkage and fragmentation. The flow regime is characteristic of semiarid watercourses; extremes of discharge occur with low winter baseflows of 1 or 2 cumecs/s and occasional high summer flood flows exceeding 100cumecs. Climatic variability has been identified for the lowveld (Dube, 2002). Dube (2002) and Dube and Jury (2000) have reported on the impacts of drought, drought forming processes and atmospheric circulation systems that affect the south eastern african region precipitation events.

The study area lies below 600 m contour and is hot and semi-arid. The climate of the lowveld is hot and wet from mid-November to April, cool and dry from May to August, and hot and dry from September to mid November. The temperatures range from 8.1^{o}C in July to 50^{o}C in January, with a mean of 24^{o}C to 36^{o}C. A significant feature of the rainfall is its unreliability, both in terms of quantity and duration. The variation from year to year is so great that the annual rainfall can range from 20% to 200% of normal. The rainfall varies considerably from a low of 92.7 mm in 1991/92 to a high of 834.0 mm in 1977/78 (Magadza *et al.*, 1993).

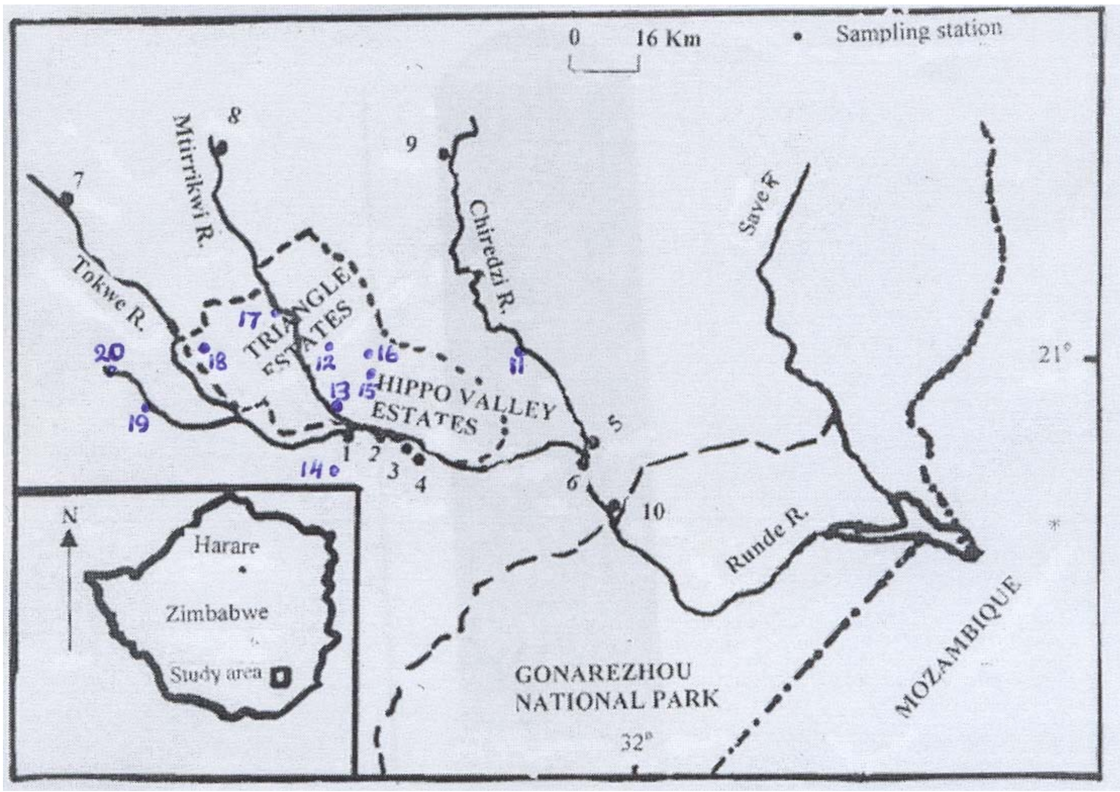

Figure.1. Simplified map of the southeast lowveld river system showing the different sampling stations and the sewage inputs along the studied watercourses.

Tropical depression and cyclone activity can produce unprecedented rainfall and floods as recorded in March 2000 across the eastern African subcontinent (Dube, 2002; Dube and Jury, 2000; Heritage *et al.*, 2001). The variability in habitat conditions make the monitoring of the effects of season important on river water nutrients and aquatic organisms.

The Runde watershed is situated within an area of intensive commercial farming area characterized by the Hippo Valley and Triangle Sugar Estates. Site 4 (Figure 1) is situated on a discharge point. Site 2 receives domestic and agricultural effluent discharged into the lower section of the Mtirikwi River. Site 5 receives agricultural runoff from the small scale intensive farms -in the proximity of lower-Chiredzi River. Other sampling sites along the Runde River receive inflow from surrounding areas. Due to difficult terrain conditions of finding an alternative site, (site 8 is situated on a dam impounded on Mtirikwi River. All sampling stations are ecologically similar with respect to bottom substrate i.e. sand, gravel, rock, or mud, depth, stream width and banks.

Sample collection

Stratified random sampling in which the rivers were subdivided according to land use zones was undertaken. Sampling positions were randomly selected within stratified zones thus ensuring that chances of missing any general biotic associations are extremely small. Sample stations were to be readily accessible. A total of eight stations on the upstream (control stations) and 12 stations on the downstream (test stations) of intensive agriculture were sampled. The sampling stations represent a wide range of water quality conditions in the study area (Figure 1). Station 4 is a discharge point of pre-treated sewage. Station 17 is characterized by both pre-treated sewage and runoff from the fertilized fields. Effluent from agricultural processing factories was investigated at stations 12 and 16. Field runoff was investigated at site 14. Sample stations 7, 8 and 9 were selected on the reference streams and are situated in peasant agricultural areas. Samples taken from the control stations on Chiredzi, Mtirikwi and Tokwe establish expected biological conditions in the absence of the persistent point nutrient discharges.

Benthic samples were taken in the dry season August 2004 and wet season of April 2005 at Hippo Valley and Triangle sugar estates, using a $0.1m^2$ Van-Veen grab. The limitations and the problems involved in using a grab of this type have been noted by Lie and Pamatmat (1965) and Edmondson and Winberg (1971). Upon retrieval all accumulated material from the samplers were collected and preserved. Live sorting and preliminary counting of readily identified taxa were carried out in trays in the field, before preserving the sorted invertebrates in 70 % isoproppryl alcohol for laboratory identifications and checks using keys of Parish (1975), Pennak (1978), Needham (1962), Thirion *et al.*, (1995), Appleton (1996), Braack, (2000) and Picker *et al.*, (2003). All benthic specimens were examined with an Olympus binocular microscope, using an objective lens with a zoom magnification from 0.7 to 4.0 and eye-pieces of 15x. When necessary an adapter lens fitted to the objective doubled the magnification.

The sampling stations were organized into two groups: the first includes the group of stations that were located upstream of the effluent sources and are meant to be control stations indicating the unpolluted state of the rivers. The second group of stations includes stations located downstream of the effluent sources and are presumably meant to indicate the effect of agriculture on the Runde River. The stations located upstream of the effluent sources are meant to be control stations indicating the unpolluted state of the rivers. The stations located downstream of the effluent sources are presumably meant to indicate the effect of agriculture on the Runde River. The number of sampling locations were limited due to the expense of laboratory analyses and available funding.

The SASS protocol envisages recognition of benthic invertebrates at the family level with the aid of identification manuals. The SASS index was calculated by assigning a score to each of the families present based on their sensitivity to organic pollution (Day and de Moor, 2002, Thirion, *et al.*, 1995, and Chutter, 1998). The SASS score was the sum of the scores of each invertebrate taxon present while the Average Score Per Taxon (ASPT) is the SASS score divided by the number of families. The SASS indices were analysed for differences between months. In this case, months served as the treatment and sites were the replicate blocks.

The temperature of the water and the concentration of dissolved oxygen were measured using an YSI dissolved oxygen meter. Water was collected in thoroughly rinsed 1 litre bottle containers and immediately stored in a freezer for later analysis. Site data collected include substrate composition (such as sand, gravel, stones, etc.) and description of surrounding area (amount of tree cover and land use, etc). In the laboratory, the samples were filtered through Whatman GF/C fibre glass filters with 0.45um filter size mention the size. The concentrations of total phosphorous were then determined by the reactive molybdate method, ammonia by the indophenol method, and nitrate and total nitrogen by the sulphanilamide method, using a cadmium reduction column and a Hitachi 100-40 spectrophotometer (Golterman *et al.*, 1978). The concentrations of inorganic cations (lead, magnesium, cadmium, copper, zinc and calcium) were determined by atomic absorption spectrophotometry. Potassium was determined by flame photometry. The physical analyses of water carried out in the field will be reported elsewhere.

Data analyses were also done using Excell. Inter-site differences in concentrations of nutrients were analysed using ANOVA. A T-test was also used to test the means of the nutrient concentrations between the upstream and downstream stations. The assumption in the T-test is that any difference in response is due to the treatment or lack of treatment and not to other factors. Repeated-measures ANOVA was carried out using the General Linear Model command in SPSS version 10 to test the effects of season, time since pollution and its interaction on media and site occurs over time. Season was specified as a within-subjects factor, site and media as between subjects factor and TotN, NO_3-N, NH_4-N and $TotPO_4$ as measures. Differences between means were tested using the Bonferoni adjustment with a level of significance of $P<0.05$.

RESULTS

The concentrations of total phosphate in ppm were not significantly different ($p>0.05$) between the wet and dry seasons. Table 1 shows no significant differences in total nitrogen and nitrate nitrogen between test and control sites in the dry and wet season. Nitrate nitrogen was significantly different ($p<0.05$) in media only. Ammoniacal nitrogen showed significant differences ($p<0.05$) between the test and control sites in the wet season only. Dry season ammoniacal concentrations were higher than wet season at test sites and control sites. Levels of ammonium nitrogen were almost the same at the test stations and control stations in both dry and wet seasons. SASS scores showed significant difference between test and control sites in the wet season only. The South African Scoring Systems (SASS) scores were significantly different between dry and wet season at test sites but not between the dry and wet season at control sites. ASPT scores were significantly different between the dry and wet season at test sites but not between dry and wet season at control sites. ASPT scores recorded during the dry season were higher than the wet season scores at test sites and the same pattern was recorded at the control sites (Table 1). The effects of season, interaction of season with site and interaction of season of season with media showed a significant effect ($p<0.05$) with total nitrogen. The interaction of season with site showed a significant effect ($p<0.05$) with nitrate nitrogen concentration in ppm. The interaction of season with media was significant ($p<0.005$) with nitrate nitrogen and ammoniacal nitrogen concentrations in ppm. The interaction of season, site and media showed a significant effect ($p<0.05$) with nitrate nitrogen, ammoniacal nitrogen and total phosphate concentrations in ppm. The effects of site, media and their interaction were significant ($p<0.005$) with total nitrogen. Media showed a significant effect ($p<0.05$) with nitrate nitrogen, ammoniacal nitrogen and total phosphates concentrations in ppm.

A total of 12 orders, 25 families and 33 genera of the benthic organisms were identified during the study (Table 2). There was a significant effect ($p<0.005$) of interaction of season, site and media on ASPT scores. The effects of site, media and their interaction on ASPT scores were significant ($p<0.005$) with site only. The effects of site, media and their interaction on SASS scores were significant ($p<0.005$) with site, media and interaction of site with media. Multiple comparisons after the analysis of variance had indicated differences using paired t-tests with Bonferoni adjustment showed significant site effect on total nitrogen, ammoniacal nitrogen, ASPT scores and SASS scores. Media effect was noted on total nitrogen, nitrate nitrogen and SASS scores. The effect of season was noted on total nitrogen and total phosphate.

Table 1. Mean nutrient concentrations and SASS indices measured in the media in control and test sites in the study.

Variables	Wet season					Dry season				
	Control sites	SEM	Test sites	SEM	Sig	Control sites	SEM	Test sites	SEM	Sig
Total N										
Water	7.3	±8.5	5.6	±5.6	Ns	6.3	±2.43	8.7	±0.73	Ns
sediment	43.8	±3.6	49.5	±4.3	Ns	19.9	±1.7	10.7	±2.1	Ns
NO_3N										
Water	4	±0.68	4	±0.68	Ns	1.7	±2.44	5.7	±0.79	Ns
sediment	2	±0.5	1	±0.8		4.6	±0.1.5	5.2	±3.6	Ns
NH_4N										
Water	5.7	±0.23	5	±1.35	Ns	4	±0.28	3	±2.17	Ns
sediment	5.7	±1.7	5	±1.5	Ns	12.4	±1.8	5.6	±2.4	Ns
Total PO_4										
Water	29.8	±5.9	44.7	±4.7	Ns	2.8	±0.6	29.9	±5.5	p<0.05
sediment	5.7	±1.6	5.1	±2.1	Ns	53.6	±7.8	11.6	±2.8	ns
ASPT	0.39	±0.4	1.57	±1.6	p<0.05	0.29	±0.39	1.51	±1.57	p<0.05
SASS	0.68	±0.68	6.72	±6.72	p<0.05	1.67	±1.97	6.5	±6.5	ns

Where SEM=Standard error of the mean, NS

Table 2. Summary of benthic macroinvertebrates identified in all sample stations.

Order	Family	Genera
Acari	Hydrachnidae	Hydrachna
Anisoptera	Gomphidae	Ictinogomphus
Coleoptera	Dysticidae	Cybister
	Gyrinidae	Aulogyrus
	Hydrophilidae	Hydrophillus
	Psephenidae	Cybister
Collembola	Sminthuridae	Sminthurus
Crustacea	Arrenuridae	Arrenura
Diptera	Chironomidae	Chironomus
Ephemeroptera	Heptageniidae	Afronurus
	Baetidae	Baetis
Hemiptera	Belostamitadae	Belostoma
	Gerridae	Gerris
	Vellidae	Velia
Megaloptera	Corydalidae	Taeniochauloides
Mollusca	Corbiculidae	Corbicula
	Limnaediae	Limnaea
	Planorbidae	Planorbis
		Helisoma
		Gyraulus
		Promenetus
	Physidae	Physa
	Sphaeriidae	Sphaerium
		Pisidium
		Eupera
		Quadrula
	Unionidae	Coelatura
Odonata	Aeshnidae	Aeshna
		Anax
	Chlorocyphidae	Platycypha
	Libellulidae	Libellula
	Coengriidae	Agrion
Trichoptera	Hydropsychidae	Hydropsyche

DISCUSSION

The water quality is dynamic and the nutrients changed with season because of real changes to in nutrient concentrations. Total nitrogen tends to show seasonal effect (Tables 1). There is significant site effect with total nitrogen and significant site and media interaction with total nitrogen. In addition, site effects with total nitrogen and ammonium nitrogen were also recorded. Significant season x media interaction ($p<0.05$) was recorded with total nitrogen. The higher concentrations of total nitrogen, nitrate nitrogen, ammoniacal nitrogen and total phosphates in ppm during the dry seasons at the test sites suggest concentration of nutrients due to diminishing levels of water in streams due to evaporation. Nitrogen in sewage wastewater is in the form of ammonia, not nitrate (Puckett, 1995).

Individual nutrient removal processes in streams include filtration, adsorption, ion exchange, assimilation and denitrification. The bacterial mineralization of organic matter is an important biotic influence on soil water quality. Organic nitrogen contained in organic matter, such as structural proteins, may be converted to ammonium salts via decomposition by heterotrophic bacteria. Ammonium ions (NH_4^+) may be subject to plant uptake, but more commonly they will be subject to nitrification by autotrophic bacteria in which they are oxidized to nitrite (NO_2^-) by Nitrosomonas and finally to highly soluble nitrate (NO_3^-) by Nitrobacter. The NO_3 ions will be taken up by plants and the excess hydrogen ions produced by the hydrogen ions will be consumed in the completion of the hydrogen cycle.

Changes in nutrients in streams have been widely known to affect aquatic organisms (Puckett, 1995). The inflow of nutrients into streams in areas associated with agricultural development may have wide effects on aquatic organisms in lowveld areas given the variations in weather patterns and changing habitat conditions. The general change in biotic associations along the length of the streams tends to be one of transition (Dallas, 2004, Novotny *et al*., 2005). Higher SASS indices (ASPT, SASS) suggest that Runde River health has not been compromised and this is important for the maintenance of good water quality and preservation of aquatic species. Factors which exhibit a progressive change in value along the length of the river are: current, velocity, substratum, flow, temperature, dissolved oxygen, dissolved nutrients and other organisms (Dallas, 2004).

Total phosphate showed a seasonal effect. Total phosphate indicate the deposition of wastewater-derived sediments flushed out from the sewer system during storm events. The concentrations of total phosphate in ppm were not significantly different between the seasons suggesting that sewage discharge into the river systems may occur throughout the dry and wet seasons (Table 1). Cumulative sewer overflows have been identified as a major source of biodegradable organic pollution that also impact on dissolved oxygen concentration in the receiving streams. Hot summer temperatures preclude phosphorous transportation due to drying up of sewage discharge channels. High levels of nutrients especially nitrogen and phosphates are undesired in freshwater resources because they can result in blooms of aquatic plants such as algae. Flourishing of aquatic plants may result in changes of aquatic systems.

ASPT data has been shown to be more dependent on site. ASPT becomes more sensitive to site because of the nature of the receiving waters at sites. Gratwick (1998/1999) found no statistically significant differences in ASPT with season. Statistically, season has no effect on SASS Scores ($p>0.05$). As a result, this study shows no dependency of SASS Scores on season. Gratwick (1998/1999) showed that SASS Scores changed with the season. In “clean” rivers, ASPT gives more reliable results, while in “polluted” rivers, SASS Score may be more reliable (Chutter, 1998). Season is a key component in determining the distribution of aquatic communities largely by regulating flow and concentrations of chemicals. In addition, most of the chemical, physical and biological properties of water are temperature-dependent and consequently season-dependent. The link between abiotic process and biotic pattern is an important river management consideration.

Nutrients such as total nitrogen, nitrate nitrogen and total phosphates do not show differences between the wet and dry seasons. Under low flow conditions, the magnitude and impacts of wastewater discharges and contaminated agricultural return flows are likely to be most severe, in the absence of dilution due to rainfall events and related runoff phenomena. Ammonia nitrogen showed significant differences in the wet season between the polluted and unpolluted sites. Average Species per Taxon were significantly different between the wet and dry season. SASS showed significant different differences between in the wet season between the wet and dry seasons.

As measures of water quality nutrients are not significantly differently ($P<0.05$) between seasons caution must be made of their use because chemical data only show the water quality at that point in time the water samples were collected. ASPT scores emerged as the most useful measures of water quality and these are followed by SASS scores. Of the chemical, physical, and biological integrity, biological integrity may be the most important since organisms not only integrate the full range of environmental influences (chemical, physical, and biological), but complete their life cycles in the water and, as such are continuous monitors of environmental quality.

SASS scores indicate a water quality or habitat integrity problem e.g when the scores are low but would not indicate the cause of the problem. Toxicological studies provide complimentary information which can contribute to identifying the causes of low biomonitoring scores. If SASS is not comprehensively applied, the water resources may continue to deteriorate. Traditional measures of water quality such as chemical data or concentrations of toxic contaminants, are indirect ways to determine the health of a water body. They allow one to draw conclusions concerning expected effects on aquatic life but do not consider directly the biological responses in the stream. By inventorying SASS indices and comparing results to those found in another season, it is possible to determine whether or not agricultural effluents are having an effect on aquatic organisms by focusing on changes in SASS indices.

CONCLUSIONS

In this study, nutrient data show that water quality is dynamic and the nutrients change with season because of real changes in nutrient concentrations. Levels of total nitrogen, nitrate nitrogen and total phosphates are not significantly different between the control and test stations suggesting that eutrophication of the Runde River may not be at present a threat to the river ecology. Season seemed not to have a significant effect on SASS scores. ASPT scores were different by site. In this study, nutrient data show that water quality is dynamic and the nutrients change with season because of real changes in nutrient concentrations. The results indicate that SASS indices provide a better measure of water quality since they integrate seasonal influences on changes in water bodies than chemical data that reflect conditions at the time the water samples were taken. The study of seasonal effects on nutrients and water quality has the potential to develop our conceptual understanding of the impact of discharges on the fluvial ecology for an environment that is naturally challenging for organisms, given the temporal variation in river flow, temperature and suspended solids.

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