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The Namibian Scoring System (NASS) version 2 rapid bio-assessment method for rivers

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This paper presents a rapid bio-assessment method for assessing the ecological condition of streams and rivers in Namibia. The method uses the composition and abundance of aquatic invertebrates, which are identified in the field, mostly to family level. The method is based on the South African Scoring System version 5 (SASS5), which has been modified to account for additional tropical invertebrate taxa that occur in northern Namibia. The method was applied to the Zambezi River near Katima Mulilo and NASS results were found to fluctuate predictably with changes in water level. Training of Namibian personnel to apply the method, as part of the National Water Quality Monitoring Programme, is recommended.

Keywords: aquatic invertebrates, biomonitoring, biotic index, Caprivi, Namibia, river health, SASS5, Zambezi

Introduction

Namibia is the driest country in southern Africa and is consequently depauperate in terms of perennial rivers — with the central regions of the country completely devoid of such features. Around the edges of the country there are perennial rivers and most of these form international boundaries. The Orange River forms the southern border with South Africa, the Kunene and and Kavango Rivers run along the northern border with Angola, while the Zambezi River forms the north-eastern border with Zambia. The knowledge base concerning the functioning, species composition and health of these riverine ecosystems is relatively poor and while a number of focussed studies have been undertaken on each of these rivers (Bethune 1991, 1992, 1996, Taylor 1999, De Moor *et al.* 2000), there has been no routine monitoring of the prevailing water quality or biological health of these systems. It is therefore impossible to state what the environmental health of these systems now is, or how it may change in the future. Without this vital information it is difficult for stakeholders, ranging from individuals to government ministries, to make sound decisions for the future sustainable use and protection of these systems. Water is Namibia's most valuable and limiting resource. The pressures on perennial rivers are considerable and will increase as the human population and need for resources increase.

Aquatic invertebrates provide useful indicators of water quality and river health and numerous biological indices based on the composition of aquatic invertebrates have been developed worldwide. These include the Belgian Biotic Index (De Pauw and Vanhooren 1983), the Rapid Bioassessment Protocol (Plafkin *et al.* 1989), the British Monitoring Working Party Score (Wright *et al.* 1988), Chutter's Biotic Index (Chutter 1972) and the South African Scoring System (SASS) (Chutter 1994, 1998). Reviews of these and other methods are provided in Rosenberg and Resh (1993) and Wright *et al.* (2000). Most of these indices attempt to provide a standard assessment of aquatic conditions, but because the composition of aquatic invertebrates varies naturally from place to place, the indices can be applied only within the region for which they were developed.

An early version of the South African Scoring System (SASS4) was tested in the perennial rivers of northern Namibia (Chutter 1997). From this study it was concluded that, whilst the SASS method could be used in the area, it should be modified to account for additional taxa found in the area. There are several species of aquatic invertebrates that have their southern distribution limit in northern Namibia. Examples include the snails *Pila occidentalis* (Mousson), *Lanistes ovum* (Peters), *Gabbiella kisalensis* (Pisbry and Bequaert), *Etheria elliptica* (Lamarck) and *Cleopatra elata* (Dautzenberg and German) (Brown 1994). Some of these snails, particularly *P. occidentalis, L. ovum* and *G. kisalensis,* are common in northern Namibia (Taylor 1999). The SASS method was therefore modified to account for the additional taxa found in the area (Taylor 1999).

The revised method, referred to as the Namibian Scoring System (NASS), was used to collect the first baseline biomonitoring data of aquatic invertebrates in the Caprivi region of Namibia (Taylor 1999). However, in 2002 NASS became outdated following significant changes to and improvements

of the SASS method, resulting in version 5 (Dickens and Graham 2002). This paper presents a revised (second) version of the Namibian Scoring System, referred to as NASS2. The method is based on SASS5, modified for use in Namibian rivers. Invertebrate data collected from the Zambezi River at the rapids near Katima Mulilo are used to illustrate the method.

Methods

This study was based on a review of available data, discussions with various people mentioned in the acknowledgements and a field visit to the East Caprivi on 16–22 October 2001. The field visit formed part of the Environmental Assessment of the proposed Caprivi sugar development and was used, *inter alia*, to collect data on aquatic invertebrates in the Zambezi River at the Wenela rapids, immediately upstream of Katima Mulilo (Palmer *et al.* 2003). The NASS results recorded at Wenela during this study were compared to the results collected at the same site by Chutter (1997) and Taylor (1999). This was done after converting previous NASS1 results to NASS2 equivalents, and restricting the comparison to results of similar biotopes sampled (i.e. stones-in-current and marginal vegetation only).

NASS2

The sampling procedure for NASS2 is exactly as described for SASS5 (see Dickens and Graham 2002) and is not repeated here. Essentially, the method involves sampling three separate biotopes: 1) stones and bedrock in- and out-of-current, 2) vegetation in- and out-of-current and 3) gravel, sand and mud, using a 1mm mesh net for standard lengths of time and/or areas. The contents of the net are then tipped into a white tray containing clean water, and the invertebrate taxa collected are identified to a standard resolution (mostly to family level).

Each NASS taxon has been allocated a score that reflects its overall sensitivity to water quality and habitat degradation, where 1 = highly tolerant and 15 = highly sensitive. An example of a NASS2 scoring sheet is shown in Table 1. The scores for each taxon recorded are added to give a Total Score and then divided by the total number of taxa found to provide an Average Score Per Taxon (ASPT). The ASPT provides a reliable and simple indicator of the ecological conditions in a river or stream.

The assumptions and limitations of NASS2 are the same as those described for SASS5 (Dickens and Graham 2002). These are not repeated here, except to highlight that NASS was developed specifically for flowing rivers, and the method is not applicable to standing waters, ephemeral systems or estuaries. Furthermore, NASS is based on the most commonly-occurring taxa only, and is not designed to record all taxa that may be found in an area. Furthermore, the resolution mainly to family level means that important taxa, such as disease vectors, may not be detected.

The diversity and abundance of invertebrates found at a site usually reflects the diversity and quality of biotopes available. So, to enhance the interpretation of biomonitoring data, the quality of each biotope sampled is assessed in terms of its suitability for aquatic invertebrates using a simple, five-point scale where 1 = very poor and 5 = highly suitable.

Identification is usually done in the field, but samples may also be returned to the laboratory for sorting and identification, using stereo micropscopes and published keys and literature. Identification should always be done using live specimens. In order to achieve this off-site, specimens can be kept alive for a few days by chilling them in a refrigerator or cooler box (i.e. at 4°C) and by keeping them relatively dry.

Comparison between NASS2 and SASS5

For NASS and SASS to be comparable, they should each have a similar number of taxa. NASS2 includes a total of 90 taxa, of which 83 are shared with SASS5, whereas SASS5 contains 96 taxa, of which six are restricted to the south-western Cape (Table 2). NASS2 includes seven additional families that are not included in SASS5, *viz*: three families of Mollusca (Ampulariidae, Bithyniidae and Etheriidae), two families of mayflies (Machadorythidae and Ephemerythidae), one spongillafly (Sisyridae) and one snout beetle (Curculionidae) (Table 2).

Ampulariidae and Bithyniidae are both common in the rivers in northen-eastern Namibia (Taylor 1999), while the freshwater oyster (family Etheriidae) occurs in the lower Cunene River (De Moor *et al.* 2000). These molluscs are large and easy to identify in the field and are therefore suitable NASS candidates. However, Appleton (1996) indicates that Etheriidae prefer deep waters and therefore tend to be overlooked. The NASS scores that have been allocated to these taxa are the best estimate based on the available data, and it is likely that the scores may need to be modified as new information becomes available.

Machadorythidae and Ephemerythidae were formerly considered genera within the family Tricorythidae, but their status has recently been elevated to family level (McCafferty and Wang 2000). Their inclusion in NASS2, as well as that of the spongillafly (Sisyridae), is partly to increase the number of taxa to compensate for taxa recorded in SASS5 that are not found in the Namibian Rivers. Machadorythidae are present in the Cunene River (De Moor *et al.* 2000) and Angola (Demoulin 1959), while Ephemerythidae are common tropical taxa that are expected to occur in northern Namibia, although they have not yet been recorded here. Ephemerythidae occur in a wide variety of habitats, from stones-in-current to leaf litter in back-water eddies, both in cooler upland streams and warmer lowland rivers (Barber-James and Lugo-Ortiz 2003). This suggests that they are a tolerant taxon and so they have been allocated a NASS score of 6 (Barber-James pers. comm.).

The snout beetle *Cyrtobagous singularis* (Hustache) was introduced from South America into the Chobe River System (Schlettwein 1985) in an unsuccessful attempt to control the pest waterweed *Salvinia molesta.* In 1982 a closely-related snout beetle, *Cyrtobagous salviniae* (Calder and Sands), was released into the caprivi waterways and has since proved successful in controlling the extent of infestation of this weed (Schlettwein 1986, Schlettwein *et al.* 1991).

Table 1: The Namibian Scoring System Version 2 (NASS2) scoring sheet, showing the sensitivity score allocated to each NASS taxon. Data for each of the three biotopes sampled are entered into separate columns as follows: S = Stones; VG = Vegetation and GSM = Gravel, Sand and Mud. The total abundance rating for each taxon is indicated in the fourth column. Scores are added separately for each biotope and the total, and divided by the number of taxa to provide an Average Score per Taxon (ASPT)

Namibian Scoring System Version 2

Date:	Taxon	Score	S	VG	GSM	TOT	Taxon	Score	S	VG	GSM	TOT	Taxon	Score	S	VG	GSM	TOT
	PORIFERA (SPONGE)	5					**HEMIPTERA (BUGS)**						**DIPTERA….**					
Grid References:	**COELENTERATA (CNIDARIA)**	1					Belostomatidae* (Giant water bugs)	3					Empididae (Dance flies)	6				
	TURBELLARIA (FLATWORMS)	3					Corixidae* (Water boatmen)	3					Ephydridae (Shore flies)	3				
	ANNELIDA						Gerridae* (Pond skaters/Water striders))	5					Muscidae (House flies, Stable flies)	1				
Site code:	Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Psychodidae (Moth flies)	1				
River:	Leeches	3					Naucoridae* (Creeping water bugs)	7					Simuliidae (Blackflies)	5				
Name of sampler:	**CRUSTACEA**						Nepidae* (Water scorpions)	3					Syrphidae* (Rat tailed maggots)	1				
Site description:	Crabs*	3					Notonectidae* (Backswimmers)	3					Tabanidae (Horse flies)	5				
	Atyidae (Shrimps)	8					Pleidae* (Pygmy backswimmers)	4					Tipulidae (Crane flies)	5				
	Palaemonidae (Prawns)	10					Veliidae/M...veliidae* (Ripple bugs)	5					**GASTROPODA (SNAILS)**					
	HYDRACARINA (MITES)	8					**NEUROPTERA**						Ampulariidae (Pilidae)	3				
Temp:.....…°C pH:……..…...	**PLECOPTERA (STONEFLIES)**						Sisyridae	4					Ancylidae (Limpets)	6				
	Perlidae	12					**TRICHOPTERA (CADDISFLIES)**						Bithyniidae	3				
DO:……mg/l Cond:…..……mS/m	**EPHEMEROPTERA (MAYFLIES)**						Dipseudopsidae	10					Bulininae*	3				
Biotopes sampled:	Baetidae 1sp	4					Ecnomidae	8					Hydrobiidae/					
SIC .....…..... Time...…..... minutes	Baetidae 2 sp	6					Hydropsychidae 1 sp	4					Pomatiopsidae*	3				
SOOC…….....	Baetidae > 2 sp	12					Hydropsychidae 2 sp	6					Lymnaeidae* (Pond snails)	3				
Bedrock.....….	Caenidae (Squaregills/Cainfles)	6					Hydropsychidae > 2 sp	12					Physidae* (Pouch snails)	3				
Aquatic veg'n..... Dom. sp.....	Ephemeridae	15					Philopotamidae	10					Planorbinae* (Orb snails)	3				
MvegIC…..……Dom. sp.....	Ephemerythidae	6					Polycentropodidae	12					Thiaridae* (=Melanidae)	3				
MvegOOC……... Dom. Sp……..	Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Viviparidae*	3				
Gravel…..……	Leptophlebiidae (Prongills)	9					**Cased caddis:**											
Sand……..……	Machadorythidae	11					Calamoceratidae	11					**PELECYPODA (BIVALVES)**					
Mud……..……	Oligoneuridae (Brushlegged mayflies)	15					Hydroptilidae	6					Corbiculidae	5				
Hand picking/Visual observation: Simul. Pupae	Polymitarcyidae (Pale Burrowers)	10					Lepidostomatidae	10					Etheriidae (Freshwater oyster)	6				
Flow:	Prosopistomatidae (Water specs)	15					Leptoceridae	6					Sphaeriidae (Pills clams)	3				
Turbidity:	Tricorythidae (Stout Crawlers)	9					Pisuliidae	10					Unionidae/Mutelidae (Perly mussels)	6				
Riparian land use:	**ODONATA (DRAGONFLIES & DAMSELFLIES)**						**COLEOPTERA (BEETLES)**						**NASS2 score**					
	Calopterygidae (=Agriidae)	10					Curculionidae* (Snout beetle)	5										
Disturbance in the river: eg. sandwinning,	Chlorocyphidae	10					Dytiscidae/Noteridae* (Diving beetles)	5					**No. of taxa**					
cattle trampling, floods etc.	Synlestidae (Chlorolestidae)(Sylphs)	8					Elmidae/Dryopidae* (Riffle beetles)	8										
	Coenagrionidae (Sprites and blues)	4					Gyrinidae* (Whirligig beetles)	5					**ASPT**					
Signs of pollution: eg. smell and colour of	Lestidae (Emerald Damselflies)	8					Haliplidae* (Crawling water beetles)	5										
water, petroleum, dead fish, etc.	Platycnemidae (Brook Damselflies)	10					Helodidae (Marsh beetles)	12					**Other biota:**					
	Protoneuridae	8					Hydraenidae* (Minute moss beetles)	8										
	Zygoptera juvs.	6					Hydrophilidae* (Water scavenger beetles)	5										
Other observations:	Aeshnidae (Hawkers & Emperors)	8					Limnichidae	10										
	Corduliidae	8					**DIPTERA (FLIES)**											
	Gomphidae (Clubtails)	6					Athericidae	10										
	Libellulidae (Darters)	4					Ceratopogonidae (Biting midges)	5										
	LEPIDOPTERA (MOTHS)						Chironomidae (Midges)	2										
	Crambidae (Pyralidae)	12					Culicidae* (Mosquitoes)	1										

Procedure: Kick stones in current & bedrock for 2 to 5 mins. Kick SOOC & bedrock +/- 1m2. Sweep vegetation (IC & OOC) for 2m total. Stir & sweep gravel, sand, mud for 30 secs total. * = airbreathers

Hand picking & visual observation for 1 min - record in biotope where found. Tip net contents into tray. Remove leaves, twigs & trash. Check taxa present for 15 mins and stop if no new taxa seen after 5 mins.

Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone and rock; VG = All vegetation; GSM = Gravel, sand, mud

Rate invertebrate biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Table 2: Comparison of taxa not shared between the Namibian Scoring System version 2 (NASS2) and the South African Scoring System version 5 (SASS5). Asterisks (*) indicate species restricted to the south-western Cape

Taxa exclusive to SASS5	Taxa exclusive to NASS2
Amphipoda	Ampulariidae
Barbarochthonidae*	Bithyniidae
Blepharoceridae	Curculionidae
Corydalidae	Ephemerythidae
Dixidae	Etheriidae
Glossosomatidae*	Machadorythidae
Hydrosalpingidae*	Sisyridae
Notonemouridae	
Petrothrincidae*	
Psephenidae	
Sericostomatidae*	
Sialidae	
Teloganodidae*	

Although this beetle is exotic, it now forms an integral component of the northern Namibian aquatic fauna and by including the family Curculionidae in the NASS, their distribution and abundance in Namibia will be monitored as part of routine NASS sampling.

The beetle family Noteridae is also included in the NASS system, but in the field they are difficult to distinguish from members of the Dytiscidae, and therefore the two families are grouped together.

The new families included in the NASS system are low-scoring taxa, mostly from the order Gastropoda. The lack of additional high-scoring taxa is probably related to the tropical nature of the rivers in the area. Water temperatures are usually high during the summer months (c. 25°C+), and oxygen levels are likely to be low. The fauna occurring in the area is therefore adapted to periods of low dissolved oxygen. Many species of snails are able to obtain air directly from the water surface. This attribute led them to be classified as less sensitive organisms, with low NASS scores (3 for the majority of the snail families). High-scoring taxa that are more sensitive to changes in dissolved oxygen are probably less common in Namibia's northern rivers than elsewhere in southern Africa.

SASS5 taxa that are excluded from NASS2 include families that are restricted to the south-western Cape (five families of cased caddisflies, one family of mayfly and one family of stonefly), families that are usually associated with mountain streams and are unlikely to be found in Namibia (e.g. Corydalidae, Sialidae, Psephenidae and Blepharoceridae), and taxa that are rare or unknown in surface waters in Namibia (e.g. Amphipoda and Dixidae) (Table 2).

Because of the similarities between NASS2 and SASS5, biomonitoring results from the lower Orange River, which forms Namibia's southern border with South Africa, will be essentially identical using either index, as invertebrate taxa recorded in the lower Orange are included in both the SASS and NASS data sheets, and the same scores have been used. This highlights the value of NASS for sharing data and for regional co-operation in the management of the lower Orange River. The only difference is the inclusion of Spongillafly (Sisyridae) in NASS2.

NASS2 scores in the Zambezi River

A summary of NASS results recorded in the Zambezi River near Katima Mulilo indicates that scores are seasonally predictable, with consistently higher scores during periods of low flow (September to December) than during periods of high flow (February to April) (Figure 1). These fluctuations may be expected in the Zambezi River because of differences in habitat availability, the duration of inundation and in particular, the difficulty of sampling the stones-in-current biotope during periods of high flow. It is unlikely that NASS scores in smaller, more accessible rivers, would fluctuate as much. This was supported by the results recorded by Taylor (1999) from the Kwando River. The Kwando River was not subject to high levels of inundation between February 1997 and June 1998 and all biotopes remained accessible during this period. Scores varied very little throughout this period, highlighting that NASS provides a reliable indicator that is not usually affected by natural seasonal changes.

A comparison of NASS1 results and NASS2 equivalent results for specific biotopes in the Zambezi River near Katima Mulilo shows that the NASS1 scores were similar to NASS2 scores (Table 3).

The range of aquatic biotopes sampled near Katima Mulilo in October 2001 was very high and included riffles, sediments and marginal vegetation — mainly *Phragmites mauritianus* (Kunth) and *Ludwigia stolonifera* (Guill and Perr). Flow in the river at the time was low (250m^3/s), the water was clear and stones in riffles were covered with epilithic algae (>80% cover). The diversity of invertebrate taxa was high (total of 30 NASS2 taxa) and comprised many sensitive taxa (ASPT 6.6). Sand bars at the Wenela site were dominated by Gomphidae, while backwater areas provided habitat for a wide variety of invertebrate fauna, particularly mayflies (Ephemeroptera) and Veliidae. The rapids supported a wide variety of flow-dependant aquatic organisms that are rare in Namibia, but well represented in other parts of the Zambezi River where there are similar biotopes. No single taxon dominated the riffle fauna, although the families Baetidae, Ecnomidae and Philopotamidae were all common. The data indicate that water quality in the Zambezi River near Katima Mulilo is in excellent condition.

Conclusions

Previous applications of the SASS method in Namibia showed that the method can be used to assess the overall ecological state of the north-eastern perennial rivers of the country (Chutter 1997, Taylor 1999). The decision to modify the method to account for additional taxa found in the northern part of the country was based mainly on the abundance of tropical snails that characterise the rivers in this region. Aquatic molluscs are clearly important components of these river systems and any biomonitoring programme in northern Namibia that excludes common aquatic molluscs would be incomplete. The NASS method takes account of these differences, but because of its similarity to SASS, the two

methods will give similar results when applied to the Orange River, which forms the border between Namibia and South Africa. The NASS method is therefore well-suited as a tool for regional co-oporation in water resource management. The method remains to be tested in adjacent territories, particularly Botswana and the Zambezi Catchment as a whole.

It was apparent from the results presented above that in rivers with a strong flood regime such as the Zambezi and Okavango, biomonitoring is best carried out during particular times of the year. The most reliable samples are those taken during the low-flow periods. For rivers with no pronounced flood pattern, where samples are able to be taken at any time of the year, such as the Kwando River, results are less variable, but it is still recommended that sampling be done at the same time each year and, where possible, in conjunction with other sampling in the area so as to increase efficiency and comparability.

The NASS method is relatively simple and can be taught in a few weeks, but it takes some years of training to interpret the results reliably, and users should ideally have a background in entomology. Some on-the-job training took place in the Caprivi during the pilot study in 1997 and 1998, but Namibia still lacks personnel to continue this work. There is therefore a need for further training in biomonitoring within Namibia so that the method can be applied routinely and can form part of the National Water Quality Monitoring Programme.

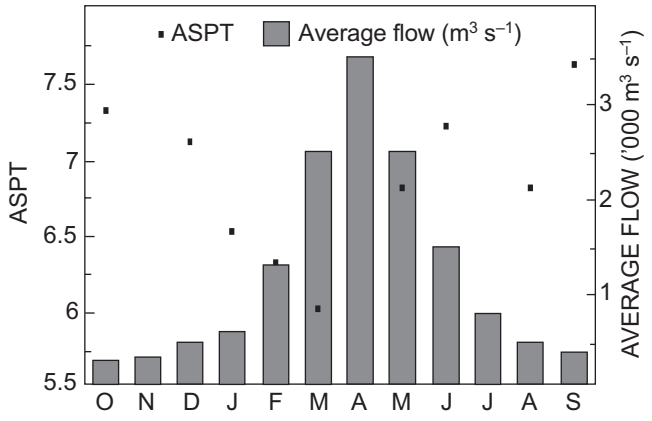

Figure 1: Seasonal changes in biomonitoring (NASS2) results from the Zambezi River near Katima Mulilo, showing average flows and the Average Score per Taxon (ASPT) for Marginal Vegetation habitats only. [Data based on Taylor 1999, Chutter 1997 and this study]

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Table 3: Flow conditions, aquatic invertebrates and biomonitoring results (NASS1 and NASS2) from the Zambezi River near Katima Mulilo. NASS2 results were based on Stones-in-current and Marginal Vegetation biotopes only

	Previous studies [Taylor (1999) and Chutter (1997)]									This study
Date	12.01.97	12.02.97	30.05.97	08.08.97	30.09.97	03.12.97	04.02.98	08.04.98	03.06.98	16.10.01
Flow when sampled (m^3/s)	334	643	1 546	294	193	200	725	4 459	1 753	250
Sample Score										
NASS1	98	94	133	137	183	178	100	42	87	N/A
NASS2	97	93	129	136	182	177	100	42	86	175
Number of Taxa										
NASS1	15	15	19	20	24	25	16	7	12	N/A
NASS2	15	15	19	20	24	25	16	7	12	24
ASPT										
NASS1	6.5	6.3	7.0	6.9	7.6	7.1	6.3	6.0	7.3	N/A
NASS2	6.5	6.2	6.8	6.8	7.6	7.1	6.3	6.0	7.2	7.3

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