THE MACROINVERTEBRATE COMMUNITIES OF TWO UPLAND STREAMS IN EASTERN ZIMBABWE WITH REFERENCE TO THE IMPACT OF FORESTRY

by

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ABSTRACT

Benthic macroinvertebrates and physico-chemical parameters of the water were examined from two fast flowing streams, the Nyahode River which drains a pine monoculture catchment and the Haruni River which drains an undisturbed deciduous forest catchment in the Chimanimani Mountains, Eastern Zimbabwe. Benthic samples and environmental data were collected in October 2004, December 2004 and January 2005. The water quality was similar in many respects but turbidity was significantly higher ($p<0.05$) in the Nyahode River compared to the Haruni River (mean 17.1 NTU and 6.0 NTU respectively). Conductivity was almost three times higher in the Nyahode (66 $\mu S\ cm^{-1}$) than the Haruni (24 $\mu S\ cm^{-1}$). The impact of forestry on faunal composition was evident on Ephemeroptera (*Euthraulus, Afronurus* and *Dicercomyzon*), Plecoptera (*Neoperla spio*) and Trichoptera (*Macrostemum capense*) (EPT) richness. Absence of shredders from both streams is a result of the low retention of Course Particulate Organic Matter (CPOM) in the streams due to the rapid flows whilst dominance of filterers suggests that the retention of organic material seems to be limited to Fine Particulate Organic Matter (FPOM). These results indicate that unless reference conditions are established first, results from biotic indices could be completely misleading because absence of some taxa could not be due to human impact but is just a natural phenomenon. Many of the taxa collected from both rivers were sensitive to water quality change (ASPT, 5.6 to 7.8) indicating good water quality which is attributable to the currently underdeveloped nature of the catchment.

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Back home, Mom, Dad, Ben, Savo, Loveness, Noria, Idah and Emelda created the necessary environment with unflagging optimism. As for Gamuchirai . . . she knows; she knows.

“In the end, we conserve only what we love. We will love only what we understand.”

Baba Dioum, Senegalese poet.

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INTRODUCTION

Headwater streams are important in the function of riverine ecosystems (Vannote *et al.*, 1980) and aquatic invertebrates living in them are involved in many different ecological processes. These functions include their influence on energy flows, nutrient cycling and the turnover of organic material, whether produced in the system or entering from the riparian zone (Wallace and Webster, 1996). Benthic invertebrates are estimated to process 20 – 73% of the leaf litter that falls into headwater streams thereby releasing bound nutrients into solution. In addition to breaking down leaf litter, grazers, shredders, deposit and suspension feeders also consume algae, fungi, bacteria and protozoans along with the detrital material (Malmqvist, 2002). Since benthic macroinvertebrates are important prey for both aquatic and terrestrial consumers (Huryn and Wallace, 2000), they therefore link the microbial loop with upper trophic levels. This prevents nutrients taken up by microbes, which are not readily available to upper trophic levels, from being lost from the ecosystem. Benthic macroinvertebrates also accelerate the transfer of nutrients from the sediments to the overlying water in lakes (Clarke *et al.*, 1997) as well as to the riparian zones along streams (Wallace *et al*., 1997).

Determinants of macroinvertebrate community composition

Macroinvertebrate communities can be described in a variety of ways such as (1) their species composition, (2) their trophic organization, i.e. the number of species in different trophic groups, and (3) the structure and functioning of their food-webs, i.e. the patterns of flow of energy and matter through the ecosystem. Understanding the factors that control ecosystem structure and function is necessary if satisfactory conservation and management practices are to be implemented. A key to this understanding is an appreciation of the environmental factors that operate at different spatial scales such as geographical regions, catchments, single streams or segments of streams, reaches and microhabitats (Minshall and Robinson, 1998).

At a broader scale, previous biogeographical events, geology, climate and associated vegetation (Heino *et al*., 2003) are thought to be the main determinants of stream habitat characteristics, and macroinvertebrate assemblages often show correspondence to such large-scale factors across ecoregions or other regional delineations (Corkum, 1989). Other studies have also shown that, on the contrary, catchment scale characteristics such as climate, land use and water chemistry are more useful than regional factors in predicting stream macroinvertebrate assemblage structure (Hawkins and Vinson, 2000). On a more local scale, differences in specific habitat characteristics for example riparian conditions, and local biotic interactions have been found to contribute substantially to variations in macroinvertebrates assemblages within a stream (Lamert and Allan, 1999). Furthermore, both biotic and abiotic factors at the site the animals live in are important in defining the niche space of individual species (Minshall and Robinson, 1998). Water temperature, flow and substrate are amongst the most important abiotic factors while food resources, competition and predation are important biotic factors, especially at the microhabitat scale (Resh *et al*., 1988; Lancaster *et al*., 1991).

Habitat heterogeneity, which is essential for species richness and assemblage structure, occurs across both spatial and temporal scales among, along and within streams (Minshall and Robinson, 1998). Physical characteristics such as stream size, order, width, depth and distance from source (Malmqvist and Mäki, 1994), slope (Higler and Verdonschot, 1991), velocity (Malmqvist and Mäki, 1994) and substrate (Minshall, 1984) are important variables that explain most observed variations in species data. Stream size, which generally increases with distance from the source, presumably influences macroinvertebrates through an increase in habitat diversity. Velocity directly affects the size of particles in the substrate and together with slope determines the diversity of microhabitats available for invertebrate colonization (Malmqvist, 2002). Chemical factors include dissolved oxygen, pH, hardness and nutrients (Harper, 1992).

Management of water resources

Almost all the river systems in Southern Africa have been modified by human activities in one way or another. The problem of water supply in a climate with mostly unpredictable and highly variable rainfall has been aggravated by a rapidly increasing population. About 38% of Southern Africa can be classified as semi-arid with an average rainfall less than 600mm per year (Conley, 1995). Because rainfall is highly seasonal, and varies from year to year, the flow in most streams shows seasonal variation and this pattern is likely to become more pronounced as water is removed from them to meet the demands of the human population. In many parts of the region, the problems of water supply have already become a reality with countries like Botswana, Namibia and South Africa facing the prospect of inadequate water supply within the next 30 years, by which time water demand in the region is expected to have doubled (Hyenes *et al.,* 1994; McCullum, 1994).

Urbanization, agriculture and afforestation adversely affect the quality and quantity of water resources in many parts of southern Africa. The growth of urban areas has led to the degradation of water quality in streams and lakes near towns in Africa because of increased volumes of urban storm-water run-off, and discharge of domestic and industrial effluents (Walsh *et al*., 2001).

Inappropriate agricultural practices have caused massive sedimentation of the region's rivers and it is estimated that about 12×10^7 tons of sediment enters rivers in southern Africa each year (Chabwela, 1991). This has adversely affected many of the region's rivers and some that used to be perennial: these no longer flow during the dry season because of excessive abstraction upstream and siltation (O'Keeffe and Davies, 1991).

In their pristine state, headwater streams are often narrow and well-shaded by riparian vegetation along their banks. Such streams are strongly influenced by the riparian vegetation and the composition of the macroinvertebrate community should follow a predictable pattern along the longitudinal gradient of the stream (Vannote *et al*., 1980). Shading and low temperatures limit algal growth. The growth of macrophytes is affected by high water velocity, unsuitable substrates and low nutrient concentrations (Vannote *et al*., 1980). Detritivorous macroinvertebrates rely on allochthonous inputs as the major energy source while autotrophically structured communities become more important downstream as the role of primary productivity increases with increasing stream size (Vannote *et al*., 1980).

The quality and diversity of detritus available to macroinvertebrates depends on what is available in the riparian zone and the retentiveness of the stream (Pozo *et al*., 1997; Jones, 1997). The more diverse the riparian zone, the greater is the range of detritus and hence the longer the period of potential food supply. The removal of riparian vegetation may influence in-stream communities by causing a widespread loss of macroinvertebrate habitats through increased sedimentation. Riparian degradation may also lead to elevated water temperatures in summer, which may affect thermally sensitive taxa (Quinn *et al.,* 1994). The natural riparian cover is a source of food for stream dwelling biota that depend on allochthonous inputs besides serving as a habitat (Vannote *et al*., 1980).

The replacement of native vegetation with exotic species through afforestation fundamentally alters landscape characteristics and contributes to environmental change in headwater catchments (Vuori *et al*., 1998). The degrading influence of silvicuture through scarification and fertilization of forest soil may have long-term effects on the discharge, water quality, and temperature and substrate composition of streams (Holoplainen and Huttmen, 1998; Vuori *et al*., 1998). Forestry practices alter the water balance, geomorphology and vegetation cover of the riparian zone (Pozo *et al*., 1997). Afforestation can reduce the flow in streams; *Pinus radiatus*, for example, reduced stream flow by 40 – 60% while *Eucalyptus grandis* reduced it by 90 – 100% (Benkes and Kromhout, 1963; Smith and Scott, 1992).

Drainage basins that have been extensively converted to timber production often have low spatial diversity because of the shift from natural, heterogenous patches with gradual ecotone gradients to more homogenous timber plots with abrupt transitions. The replacement of the riparian vegetation with a less diverse community alters the input of terrestrially-derived organic matter and alters the patterns of runoff increasing the concentrations of suspended sediments and nutrients entering in the stream. This can trigger shifts in the functional feeding group, composition and abundance of instream biota.

The effects of afforestation have created concern among limnologists (Graca, 1993) because changes in the composition of the riparian canopy may affect stream assemblages, especially those inhabiting wood. This is because the surface sculpturing and surface area available for animals varies among different wood species (Carlson *et al*., 1990; O'Connor, 1991). The rates of breakdown and palatability of different species also varies; eucalyptus litter, for example, is of poor quality and breaks down slowly because of its high phenolic and tannin content and waxy cuticle (Boullon, 1991). Conifers also break down slowly and are unsuitable food for macroinvertebrates owing to the high nitrogen: carbon ratios and high concentrations of secondary chemical compounds (Anderson and Sedell, 1979; Aumen *et al*., 1983).

The combined effects of human activities mean that aquatic habitats arguably represent some of the most threatened ecosystems in southern Africa (Davies and Day, 1998). An ecological approach to water management requires the recognition of ecological entities (Hawkes, 1975). Recently there has been a shift from assessing the health of aquatic ecosystems by chemical and physical monitoring to an ecosystem approach that addresses the complexity of ecological interactions, the importance of humans to ecosystems and the need for a balanced view of resource management (Karr, 1991; Calow, 1992). Structural and functional attributes of biotic communities, such as taxa richness, diversity, density and indicator taxa, are important indicators of the health and integrity of rivers (Milner, 1996).

Macroinvertebrates have been widely used in aquatic bioassessment through the formulation of biotic indices or the development of predictive models (Rosenberg and Resh, 1993). They offer a number of advantages in bioassessment as they can be used to locate polluted areas owing to their limited mobility and their inability to escape adverse conditions. Because they are always present in the water, intermittent pollution, which may be missed by chemical analysis, can be detected.

Research into stream ecology in Zimbabwe has lagged behind that of countries such as South Africa (Harrison and Elsworth, 1958; King *et al*., 1988; Vivier and Cyrus, 1999) and Namibia (de Moor *et al.,* 2000). Biotic indices such as the South African Scoring System (SASS) have been developed using macroinvertebrates (Chutter, 1994, 1998). These indices are also used in environmental impact assessments of projects such as dam construction (de Moor *et al.,* 2000).

Documented ecological work done on Zimbabwean streams includes that of Harrison (1966) but some applied studies have been carried out, mostly in relation to water quality. These studies include work on streams in the Harare area where the SASS system has been successfully applied (Gratwicke, 1998, 1999; Moyo & Phiri, 2002; Ravenganai *et al*., 2005). However all applied studies in Zimbabwe lack pre-impact assessment and baseline data for comparisons. Given the threats faced by many streams in Zimababwe, there is a need for an appropriate and scientifically validated bioassessment tool.

The present study investigated the structure and composition of macroinvertebrate communities in two streams in the Chimanimani area (the Haruni and the Nyahode Rivers). The study was aimed at establishing baseline information on macroinvertebrates and to determine the effect of afforestation. The headwater streams in this mountainous area have steep gradients and flow through shallow channels with a dense riparian canopy, suggesting a tight terrestrial-aquatic linkage. Forestry is the principal form of land use and the catchment of the Nyahode is almost entirely dominated by conifer plantations, in contrast to the Haruni River which flows through natural deciduous woodland.

Ideally, comparisons of disturbed and undisturbed streams should include streams with similar climatic, hydrologic and geomorphic characteristics (Resh *et al*., 1988). The Haruni and Nyahode Rivers are located within 20km of each other in an area with a similar climate and geology. This ensured that faunal comparisons were not unduly influenced by recolonisation mechanisms since the rates of immigration and the species pool is likely to be very similar in both rivers.

The objectives of this study were: (1) to determine the species composition of the macroinvertebrates in the two rivers, (2) to examine the influence of the conversion of riparian vegetation from deciduous to pine by comparing the macroinvertebrate communities in the two rivers. The hypothesis that was tested was: (1) the structure and function of the benthic communities would reflect the impact of forestry activities through changes in the relative abundance of functional feeding groups (particularly shredders).

METHODS

Study area

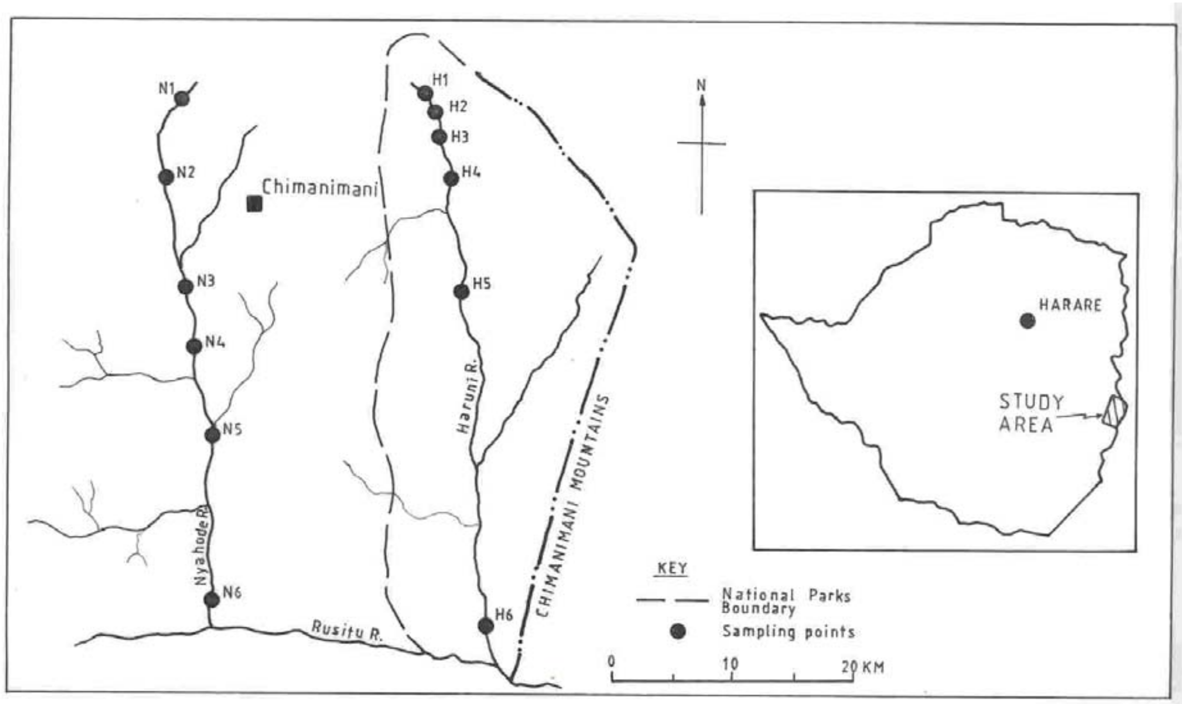

Fig 1: The location of the Haruni and Nyahode Rivers. Insert is the map of Zimbabwe showing the location of the study area.

The Haruni and Nyahode Rivers are located in the eastern highlands of Zimbabwe between latitudes 19^o 45' – 20^o 03'S and longitudes 32^{o}45' – 33^{o}02'E and are both tributaries of the Rusitu River (Fig 1). The catchment receives between 1400mm and 2000mm of rainfall annually. Both streams exhibit high streambed roughness with the predominant substratum being a mixture of cobble, pebble and boulders. The Nyahode River flows through plantations of pine trees (*Pinus patula, P. taeda* and *P. elliottii*) and gum trees (*Eucalyptus grandis, E. saligna* and *E. cloeziana*). Following conversion to pine plantations, invading hardwoods have been periodically removed by cutting and thus the riparian growth typical of the headwater streams in this subcatchment is greatly reduced along this stream. There is also subsistence farming on steep slopes along the river rendering the soil more susceptible to erosion. The Haruni River, on the other hand, flows through a remote and sparsely populated area and has a diverse riparian zone dominated by *Albizia gumifera* and *Khaya nyasica,* while other indigenous trees include *Brachystegia spiciformis, Compretum mole, Ficus capensis, Bridelia micrantha, Combretum zeyheri, Parinari curatelifolia, Alsophila dregei, Celtis africana, Bridelia petersiana, Syzigium cordatum, Cussonia spicata, Phoenix reclinata, Revofia caffra,* and *Uapaca kirkiana.* The only exotic species encountered along the river is *Psidium guajava*, a widespread invasive species in the eastern highlands that is effectively dispersed by birds and other animals that eat its fruit.

Sampling for water quality variables and macroinvertebrates was done at 12 stations (Fig 1). Sampling stations were selected according to their accessibility. Samples were collected in October 2004, December 2004 and January 2005 to give the maximum variation in flow rates.

Physico-chemical conditions

The following physico-chemical variables: water pH, conductivity and temperature, depth and stream width were recoreded on site. A pH meter (model 330 SEI-1) and a conductivity meter (model LF 340/SET) were used. The mean velocity of the water was measured with an FP20 velocity meter while turbidity was determined photometrically from unfiltered water samples and expressed in nephelometric turbidity units (NTU) using a HACH DR/2010 spectrophotometer. Dissolved oxygen was determined by the Winkler method.

Habitat quality was determined by the HABS1 criteria used by the South African Scoring System (SASS) (Thirion *et al*., 1995). The extent of habitat smothering (or blanketing) was assessed visually and categorised by assigning a score based on the amount of fine soil deposited on rocks or macrophytes, as follows: 0 (nil), 1 (slight), 3 (moderate) and 5 (extensive). Embeddedness was used as a measure of siltation and was determined by measuring the depth to which rocks were buried in the surrounding matrix and expressing it as a percentage of the total area of rock. Canopy cover (%) and the percentage of native trees in the riparian zone were determined at each station. Trailing bank vegetation, defined as terrestrial vegetation in direct contact with the water under base-flow conditions, was estimated visually as nil (1), slight (2), moderate (3) or extensive (4).

The contribution of the following biotopes: bedrock, boulders (> 256mm), cobbles (64 – 256mm), pebbles (16 – 64 mm), gravel (2 – 16mm), sand (0.06 – 2mm) and (silt and clay < 0.06mm), marginal vegetation and aquatic vegetation, was visually assessed at each site and expressed as a percentage. The sum of all the substrate categories at a site must equal 100%. Habitat diversity was determined using the Shannon-Wiener diversity index.

Macroinvertebrates

Three samples of macroinvertebrates were taken at each sampling station with thirty minutes being spent collecting animals at each station. All the samples were semiquantitative with the macroinvertebrates being disturbed by kicking the substrate and then being collected in a square hand net with a mesh size of 250 µm (Chutter, 1994). Using forceps, invertebrates were taken directly from submerged rocks taken out of the water, and isolated from detritus that had been passed through 1-mm and 250-µm nested sieves. All samples from each station were pooled into a single composite sample and preserved in 70% alcohol. Specimens were sorted under a dissecting microscope and counted in the laboratory. All specimens were identified to the lowest possible taxonomic level, mostly to genus except for the Chironomidae (to subfamily) the Elmidae (to family) and the Turbellaria (to class) using keys in Day *et al*., (2002), de Moor *et al* (2002, 2003) and Day and de Moor (2002). The animals were assigned to habit (i.e. burrower, sprawler, swimmer, or diver) and functional feeding groups (FFGs) according to the guidelines in Merrit and Cummins (1996) and Merrit *et al*., (1996).

Data analysis

Samples from each river for the entire study period were pooled by site to give the total number of taxa (taxonomic richness), Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness and intolerant taxa richness for the two rivers. Student's t-test was used to test for any significant differences in environmental and biotic data between two rivers.

The water quality of the two rivers was assessed using the South African Scoring System version 4 (SASS4) (Chutter, 1994, 1998) in which macroinvertebrates are identified to family level and each family is assigned a tolerance level, from 1-15 to indicate their resistance to pollution (Chutter, 1994, 1998). Tolerant taxa are given low scores and sensitive ones high scores. The total score for each site was calculated by summing the individual taxon scores. The Average Score Per Taxon (ASPT) was calculated by dividing the total SASS4 score by the number of taxa in the sample.. The higher the SASS4 score and/or the ASPT value, the better the water quality is deemed to be (assuming that habitat availability is not limiting). A habitat assessment was therefore done at each site to isolate the effects of missing habitat from environmental perturbations. Interpretations were based on guidelines described by Thirion *et al*., (1995) (Appendix 1).

RESULTS

Environmental variables

Both the Haruni and Nyahode were fast-flowing mountain streams about the same size, with an average width of 860 and 900 cm and an average depth of 28 and 35 cm, respectively, and with a the mean velocity in both around 1.0 ms^{-1} (Table 1). The mean turbidity of the two rivers was similar (Haruni = 22.5 NTU, Nyahode = 17.1 NTU) but this was misleading because the water at the first five stations on the Haruni was clear with a mean turbidity of 6.0 NTU. Effluent from a tributary upstream of H6 caused high turbidity (mean = 105.0 NTU) (Table 1). There were significant differences in turbidity between the Nyahode and Haruni (stations 1-5) (t-test, df = 9, $P < 0.01$) while station H6 on the Haruni was significantly different from both the other stations and those on the Nyahode River (t-test, df = 34, $p < 0.001$). The conductivity of the two rivers was also significantly different (t-test, df = 9, $p < 0.001$) with the mean conductivity in the Nyahode (66 $\mu S\ cm^{-1}$) being almost three times higher than that of the Haruni (24 $\mu S\ cm^{-1}$) (Table 1).

The conductivity at station H6 was not significantly different (t-test, df = 4, $p > 0.05$) from that of the station immediately upstream (H5) in spite of the high turbidity at this station (Table 1), suggesting that the gold panning produced suspended rather than dissolved material. Although the mean pH of the two rivers was significantly different (t-test, df = 9, $p < 0.01$) the Haruni differed from the Nyahode in that its headwaters were acidic and it became more alkaline at its lower stations, while the water in the Nyahode was slightly alkaline throughout.

Table 1: Average values for environmental variables and some habitat characteristics along the Haruni (H) and Nyahode (N) Rivers during the study period. HABS1 = Habitat Assessment score, ETBV = Extent of Trailing bank vegetation.

	Haruni River Stations							Nyahode River Stations						
	H1	H2	H3	H4	H5	H6	Mean	N1	N2	N3	N4	N5	N6	Mean
Mean breadth of water surface (cm)	106	167	397	827	693	2967	859	51	149	316	1027	1210	2640	899
Mean water depth (cm)	20	38	45	43	29	50	38	17	42	26	40	52	27	34
Velocity (m s^{-1})	1.3	0.7	0.8	0.9	1.0	1.1	1.0	0.1	0.4	0.8	0.8	0.8	1.7	0.8
Water temperature (ºC)	19.6	21	22.5	21.7	21.4	24.4	21.8	21.6	19.1	20.8	20.3	22.3	23.5	21.3
pH	6.8	6.5	6.8	6.9	7.2	7.2	6.9	7.9	7.2	7.4	7.4	7.2	7.7	7.5
Conductivity (µS cm^{-1})	11.0	9.0	23.0	25.0	38.0	36.0	24.0	43.0	66.0	68.0	73.0	73.0	74.0	66.0
Turbidity (NTU)	2.2	6.5	6.4	8.1	6.7	105.0	22.5	16.3	15.7	12.0	13.9	19.1	25.3	17.1
DO (mg/l)	7.9	7.3	8.8	6.4	7.5	7	7.5	7.1	6.9	7.0	7.5	6.6	8.8	7.3
% embededness	0	26	23	21	13	42	21	100	55	37	30	25	70	53
Blanketing (0 – 5)	0	1	0	0	0	5	1	5	4	1	1	4	4	3
Riparian native trees (%)	100	100	100	99	100	100	99.8	0	5	0	10	20	5	6.7
Riparian total trees (%)	95	60	95	95	95	90	88.3	0	15	30	80	40	15	30.0
% canopy cover	10	0	80	20	70	20	33.3	0	5	0	0	20	0	4.2
ETBV (0 - 4)	1	2	2	1	3	1	1.7	4	4	2	2	3	0	2.5
Habitat diversity (H')	0.21	0.84	1.10	0.58	1.70	0.30	0.80	0.33	0.88	0.78	0.95	1.10	0.20	0.70
HABS1 score	50	85	80	85	90	90	80.0	40	65	80	85	90	55	69.0

The state of the substrate, indicated by the degree of embeddedness and the extent of blanketing also differed in the two rivers (Table 1). Embeddedness in the Haruni (Stations H1 to H5) ranged from 0 to 26% (mean = 16.6%) compared to 25 to 100% (mean = 47.8%) in the Nyahode; the means were significantly different (t-test, $df = 9$, $p < 0.05$). There was no obvious pattern of variation in embeddedness amongst the stations in each river. The extent of blanketing, measured on a scale of 1-5, was low in the upper five stations of the Haruni (mean = 0.2) but high at station H6 where a value of 5.0 was recorded as a result of the sediment produced by the gold panners. Blanketing in the Nyahode was higher overall (mean = 3.0), which was a consequence of land use in the catchment.

The differences in land use between the two catchments was reflected in the composition of the riparian vegetation, which consisted almost entirely of native species along the Haruni, while native species made up only 7.5% of the vegetation along the Nyahode (Table 1). Similarly, the density of riparian trees was greater along the Haruni (88.3%) than along the Nyahode (30%). The Haruni was also more heavily shaded with a canopy cover of 33.3%, compared to only 4.2% on the Nyahode.

The extent of trailing bank vegetation (ETBV) was lower along the Haruni (1.7) than along the Nyahode (2.7) (Table 1). There was little variation in habitat diversity in the two rivers (means = 0.8 in the Haruni and 0.7 in the Nyahode) while the HABS1 scores were 80 and 69, respectively.

Macroinvertebrate communities

Forty-six families and 96 genera of macroinvertebrates were recorded from the two rivers (Table 2: raw data listed in appendix 3 to 5). Insects accounted for >95% of the benthic invertebrates and included 20 genera from six families of Ephemeroptera, 10 genera of Trichoptera from four families, 15 genera of Coleoptera from seven families, 26 genera of Odonata from seven families, 18 genera of Hemiptera from nine families, 12 Diptera from seven families and one Plecopteran species. Non-insect taxa included the freshwater crab *Potamonautes* sp. (Potamonautidae), Hydracarina, and gastropods including Ancylidae (*Burnupia* sp), Lymnaeidae (*Lymnaea* sp) and Thiaridae (*Melanoides tuberculata*).

Table 2. Average number ($30min^{-1}$) sample of macroinvertebrate taxa collected along the Haruni (H) and Nyahode (N) Rivers for the entire study Period. Where an average of less than 1 was obtained, it was rounded off to 1 in order to maintain the number of taxa collected.TV = tolerance value, FFG = functional feeding group (sc = scraper, cl = collector, ft = filterer, pr = predator. Habit abbreviations are: bu = burrower, cn = clinger, cb = climber, sp = sprawlerdv = diver and sw = swimmer

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See attached Excel file

H6 was not included in the comparative studies between the Haruni and Nyahode because it is no longer natural due to the effects of gold panners upstream of that site. Taxonomic richness, EPT richness and Ephemeroptera taxa richness were significantly greater (t-test,df = 9, $p < 0.05$; t-test) along the Haruni compared with that along the Nyahode (Table 3). The number of taxa gradually increased along the Haruni and peaked at H5 followed by a 22.5% decrease at H6. The pattern was similar, although less distinct in the Nyahode (Table 3).

Table 3: The mean macroinvertebrate indices for the Haruni (H) and Nyahode (N) Rivers. EPT = Ephemeroptera, Plecoptera, Trichoptera taxa richness. (-) means absent.

	Taxonomic richness	EPT taxa richness	Ephemeroptera taxa richness	Plecoptera taxa richness	Trichoptera taxa richness	Intolerant taxa richness
H1	48	18	10	1	7	9
H2	52	12	8	1	3	4
H3	59	17	9	1	7	7
H4	59	17	9	1	7	8
H5	71	20	12	1	7	11
H6	55	20	12	1	7	6
Mean	57.3	17.3	10.0	1	6.3	7.5
N1	34	6	5	-	1	4
N2	49	10	6	-	4	7
N3	34	6	4	-	2	3
N4	46	12	8	1	3	5
N5	47	15	8	1	6	7
N6	32	13	6	1	6	5
Mean	40.3	10.3	6.2	0.5	3.7	5.0

Intolerant taxa richness

Intolerant taxa (tolerance values = 10 to 15) are the first to be eliminated by disturbance because they are specialists and sensitive to changes in habitat or water quality. The greatest number of sensitive taxa was recorded from the Haruni and was much lower in the Nyahode (Table 3). Tolerant taxa (sensitivity value = 1 to 5) were more numerous in the Nyahode than in the Haruni (Fig 2).

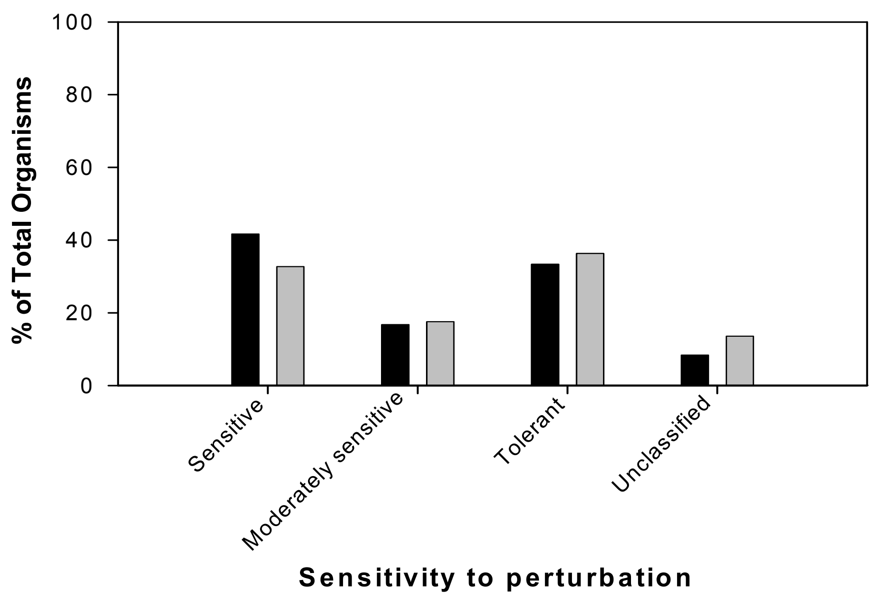

Fig 2: Proportions of tolerance ranges in animals from the Haruni (Black) and Nyahode (Grey) Rivers. These metrics were not significantly different (t-test, df = 9, p>0.05) between the two rivers.

Macroinvertebrate trophic organization

The invertebrates of the two rivers did not differ significantly in the composition of functional feeding groups (t-test, df=9, p>0.05). Predators were the predominant group followed by scrapers and filterers (Table 4) whereascollectors were the scarce. No shredders were recorded from either river.

Table 4: Proportion of the functional feeding groups (FFGs) in the Haruni and Nyahode Rivers.

Station	Predators	Collectors	Filterers	Scrapers	Unclassified
H1	27.6	3.5	20.6	28.2	20.1
H2	39.0	2.9	8.8	21.3	28.0
H3	33.3	2.9	18.1	27.5	18.2
H4	28.8	2.4	30	26.5	12.3
H5	30.2	2.9	17.9	33.7	15.3
H6	14.4	2.9	36.4	21.5	24.8
Mean	28.9	2.9	22.0	26.5	19.9
N1	51.4	23.4	4.5	<0.1	20.7
N2	34.4	12.0	18.1	20.8	14.7
N3	18.8	4.8	20.6	43.4	12.4
N4	21.5	7.9	18.2	37.6	14.8
N5	35.1	3.2	11.3	11.3	39.1
N6	13.8	0.8	21.5	22.3	41.6
Mean	29.2	8.7	15.7	22.6	23.9

Water quality findings

Many of the taxa collected from both rivers were sensitive to water quality change (ASPT scores, 5.6 - 7.8) (Table 5) indicating good water quality which is attributable to the currently underdeveloped nature of the catchment. Although a number of Nyahode River sites were classified as having excellent water quality, the Haruni River had higher SASS4 and ASPT values indicating that the Haruni River contained many more sensitive taxa compared to the Nyahode River and this is attributable to differences in the levels of human activities in the two sub-catchments. Although H6 was affected by gold panning activities, the SASS4 system classified water quality at that site as being excellent (Table 5).

Table 5: Habitat assessment (HABS1) scores, SASS4 scores and ASPT values for the Haruni and Nyahode Rivers with water quality and habitat quality given in brackets.

Haruni River	HABS1 score	SASS4 score	ASPT
H1	50 (POOR)	210 (EXCELLENT)	7.5 (EXCELLENT)
H2	85 (GOOD)	209 (EXCELLENT)	7.1 (EXCELLENT)
H3	80 (GOOD)	234 (EXCELLENT)	7.3 (EXCELLENT)
H4	85 (GOOD)	211 (EXCELLENT)	7.8 (EXCELLENT)
H5	90 (GOOD)	245 (EXCELLENT)	7.4 (EXCELLENT)
H6	90 (GOOD)	198 (EXCELLENT)	6.8 (GOOD)
Nyahode River			
N1	40 (POOR)	95 (FAIR)	5.6 (GOOD)
N2	65 (FAIR)	146 (EXCELLENT)	6.1 (GOOD)
N3	80 (GOOD)	144 (EXCELLENT)	6.3 (GOOD)
N4	85 (GOOD)	182 (EXCELLENT)	6.7 (GOOD)
N5	90 (GOOD)	200 (EXCELLENT)	7.4 (EXCELLENT)
N6	55 (POOR)	135 (GOOD)	7.5 (EXCELLENT)

EPT taxa richness and Taxonomic richness decreased with increasing siltation (% embeddedness) (Fig 6a and 6b). These results indicate that macroinvertebrates living in the riffle habitats of mountain streams are strongly sensitive to addition of fine sediments which may smother or abrade the animals and also reduce habitat quality (blanketing).

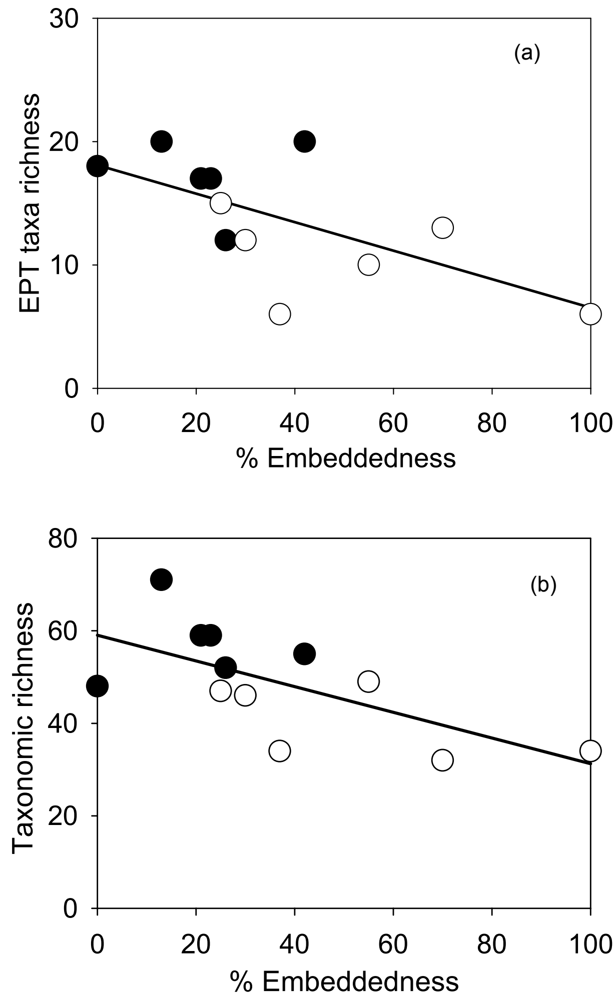

Fig 3: Relationships between (EPT) taxa and taxonomic richness with percent embeddedness along the Haruni (●) and Nyahode (○) Rivers. The regressions were fitted by: (a) $y = 18.1 - 0.12\,x$, $r^2 = 0.42$, $p < 0.05$; (b) $y = 59.1 - 0.28x$, $r^2 = 0.42$, $p > 0.05$.

DISCUSSION

Although studies elsewhere have attributed absence or lowered macroinvertebrate diversity in streams draining confer plantations to water chemistry differences (Omerod *et al*., 1993), water chemistry differences between the Haruni and Nyahode were minimal (with the exception of conductivity). Many of the macroinvertebrate taxa collected from both the Haruni and Nyahode Rivers were sensitive to water quality change (ASPT scores, 5.6 – 7.8) (Table 5) indicating good water quality which is attributable to the current underdeveloped nature of the catchment. However, although a number of Nyahode River stations were classified as having excellent water quality, the Haruni River had higher SASS4 and ASPT scores (Table 5) indicating that the Haruni contained more sensitive taxa compared to the Nyahode. This is mainly due to differences in land-use and the levels of human activities between the two sub-catchments which could have reduced the number of intolerant taxa in the Nyahode.

In the light of the environmental variables investigated in this study it appears that the organizational structure of macroinvertebrates in the upland streams was primarily determined by habitat characteristics. As there were no algal mats and quiet backwaters, animals of the stony bed (clingers) (Table 2) adequately represented the invertebrate fauna of the rivers. The abundance of clingers is attributable to the fast flowing water and the violent spates characteristic of these mountain streams. Baetidae, Heptagenidae, Leptophlebiidae, Trichorythidae, Perlidae, Psephenidae, Hydropsychidae and Ancylidae were practically limited to the stones in current habitat while Coenagrionidae appeared to be vegetation specialists as they were found only at sites with extensive trailing bank vegetation. Swimmers, divers, sprawlers and burrowers were only important at a small pool at station N1 where the substrate was 100% silt and the velocity was very low (Table 1).

The localised influence of habitat availability on functional feeding-group composition was also apparent in this subcatchment. The importance of the invertebrate predators (i.e. mainly Coenagrionidae) from both streams is related to the presence of extensive trailing bank vegetation, an important habitat for these climber taxa, at most of the sites sampled. Complete absence of Coenagrionidae from N6 is a result of the absence of marginal vegetation at that site. Furthermore, the occurrence of scrapers at all the Haruni sites and from N2 to N6 is attributable to the presence of rocky substratum for attachment of periphyton and also the lack of a complete canopy cover at all these sites which thus enhanced adequate light to penetrate and support periphyton growth. No scrapers were recorded at the first Nyahode site. This is not surprising as the fine silt at this site does not support extensive standing crops of periphyton.

The high proportions of stony bed habitat throughout the Haruni and also at N3 – N6 also provided ample habitat for filterers and thus their higher abundances in the two streams. Riffle habitats are characterized by rapid velocity relative to other habitat types (Wallace *et al.*, 1992). Collector-filterers are well suited to exploit these conditions using holdfast structures and refugia to maintain position while capturing entrained food resources with catchnets or modified appendages (Merrit and Cummins, 1996). Their importance in the two rivers suggests that the retention of organic material in both streams seems to be limited to fine particulate organic matter (FPOM) (Vannote *et al.*, 1980).

Taxonomic richness generally increased in a downstream direction along the Haruni River (Table 3). This is possibly due to an increase in habitat diversity along the same gradient (Table 1). Townsend and Hildrew (1994) suggested an increase in species richness with increased spatial heterogeneity either due to a greater variety of niches or because of reduced competition in a patchy environment. The decrease in taxonomic richness at H6 is a result of increase in turbidity and silt load due to gold panning activities in a tributary upstream of the station. The decrease in biotic diversity at N6 could be a result of increased human activities, increased temperatures (due to reduced canopy cover), absence of trailing bank vegetation and reduced habitat diversity. Due to increased human activities at N6, there was little riparian vegetation below the height of 1.5m, and the recruitment of young plants of larger trees was rare. The paucity of riparian vegetation, which provides important refuge for adult insects, must therefore also influence their diversity.

Previous work has shown that long-term alteration of riparian vegetation is certainly a chronic landscape-level disturbance (Haapala and Muotka, 1998; Vuori *et al*., 1998; Holopainen and Huttunen, 1998). Therefore the subtle differences in macroinvertebrate communities between the Haruni and Nyahode rivers were not expected. It was hypothesised that forestry activities would negatively affect the composition of shredders in the Nyahode River by reducing the quality and quantity of allochthonous organic matter inputs. This hypothesis could not be tested because the Haruni River was also notable for very low course particulate organic matter (CPOM): the principal diet for shredders, on the river bed despite the fact that the river was entirely forested. This is probably because of the flashy flow which means that the organic matter does not accumulate for long, and moreover, the river lacks the large woody structures that tent to retain leaf material as observed elsewhere (Winterbourn *et al*., 1981). The absence of shredders from the benthic samples in this study is therefore not surprising given the low retention capacity associated with the fast flowing nature of the stream. Absence of shredders from the Nyahode cannot therefore be attributed afforestation impacts as shredders were also absent from the reference stream due to high velocities.

Absence of the Ephemeropteran taxa (*Dicercomyzon, Afronurus, and Euthraulus*) and the Plecopteran (*Neoperla spio*) from the extensively forested headwater sites of the Nyahode River and their paucity downstream suggest an impact by pine vegetation. The Trichoptera (*Macrostemum capense*), which was collected from five of the Haruni stations, was completely absent from the Nyahode due to forestry activities (Table 2). These taxa are possible indicators of forestry impacts.

Forestry activities in the Nyahode catchment increased the turbidity and addition of fine sediments into the Nyahode River compared to the Haruni River (Table 1). Results from this study successfully indicated that Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa and Taxonomic Richness were intolerant of siltation (Figs 3a and 3b). The sensitivity of EPT taxa to siltation has been reported before (Rosenberg and Resh, 1993). Siltation results in the accumulation of fine sand and inorganic silt on the gills (Lemley, 1982) while increased turbidity has been shown to increase macroinvertebrate drift (i.e. the rate at which animals move by floating downstream) (Chutter, 1968; Doeg and Millege, 1991). Increased turbidity also affects benthic animals by reducing light penetration which further reduces primary productivity. Ryan (1991), for example found turbidity levels as low as 5 NTU reducing primary productivity by 3-

13%. The lowered EPT taxa richness, taxonomic richness and intolerant taxa richness along the Nyahode compared to the Haruni could therefore be a result of increased turbidity and siltation in this stream.

The present study has successfully established baseline ecologixcal data of macroinvertebrates in the Chimanimani area. This information is vital for monitoring and management of water resources in this subcatchment as it can be used in comparative studies assessing the impacts of anthropogenic activities in the subcatchment. The natural environmental gradients such as flow regime and the physical habitat were the major determinants of macroinvertebrate community composition in the upland streams of this subcatchment. The impact of forestry on faunal composition through increase in turbidity and fine sediment loading (siltation) was evident in those taxa belonging to the Ephemeroptera (*Afronurus, Euthraulus* and *Dicercomyzon*), Trichoptera (*Macrostemum capense*) and Plecoptera (*Neoperla spio*). It can be concluded from the factors discussed above that afforestation practices in the Chimanimani area did not have profound negative impacts on the macroinvertebrate community. Further investigation is however necessary in order to determine the factors that are responsible for the persistence of the macroinvertebrates in the afforested stream and also to establish causes for differences in conductivity levels.

REFERENCES

Anderson NH and Sedell JR (1979) Detritus processing by macroinvertebrates in stream ecosystems. *Annual Reviews on Entomology*, **24**, 351-377.

Aumen NG, Bottomley PH, Ward GM and Gregory SV (1983) Microbial decomposition of wood in streams: distribution of microfauna and factors affecting [14C] lignocellulose mineralization. *Applied Environmental Microbiology*, **46**, 1409-1416.

Benkes CH and Kromhout C (1963) The effect of afforestation with Pinus radiate on summer baseflow and total annual discharge from Jonkershoeck catchments. *Forestry South Africa*, **3**, 43-65.

Boullon AJ (1991) Eucalyptus leaf decomposition in an intermittent stream in south-eastern Australia, *Hydrobiologia*, **211**, 123-136.

Calow P (1992) Can ecosystems be healthy? Critical consideration of concepts. *Journal of Aquatic Ecosystem Health*, **1**, 1-5.

Carlson JY, Andrus CW and Frochlich HA (1990) Woody debris, channel features and macroinvertebrates of streams with logged and undisturbed riparian timber in northern Oregon, USA. *Canadian Journal of Fisheries and Aquatic Sciences*, **47**, 1103-1111.

Chabwela H (1991) *Wetlands: A conservation programme for Southern Africa*. IUCN and SADC, Harare.

Chutter FM (1968) The effects of silt and sand on invertebrate fauna of streams and rivers. *Hydrobiologia*, **34**, 57 – 76.

Chutter FM (1994) The rapid bioassessment of streams and river water quality by means of macroinvertebrate communities in South Africa. In: Uys MC (ed) Classification of rivers and environmental health indicators (pp. 217-234). Research Commission Report No. TT63/94, South Africa.

Chutter FM (1998) Research on the Rapid Biological Assessment of Water Quality Impacts in Streams and Rivers. Report to the Water Research Commission, Pretoria. WRC Report No. 422/98.

Clarke KD, Knoechel R and Ryan PM (1997) Influence of trophic role and life-cycle on timing and magnitude of benthic macroinvertebrate response to whole lake catchment. *Canadian Journal of Fisheries and Aquatic Sciences*, **54**, 89-95.

Conley AH (1995) *A synoptic view of water resources in Southern Africa*. Paper to South African Department of water Affairs and Forestry, Pretoria, pp32.

Corkum LD (1989) Patterns of benthic invertebrate assemblages in rivers of northwestern North America. *Freshwater Biology*, **21**, 191-205.

Davies BR and Day JH. (1998) Vanishing waters. Department of extra-mural studies, University of Cape Town, pp487.

Day JA and de Moor IJ (2002) Guides to the Freshwater Invertebrates of Southern Africa, Volume 6: Arachnida and Mollusca. Prepared for the Water Research Commission, June 2002. Report No. TT 182/02.

de Moor FC, Barber-James HM, Harrison AD and Lugo-Ortiz CR (2000) The macroinvertebrates of the Cunene River from the Ruacana Falls to the river mouth and assessment of the conservation status of the river. *African Journal of Aquatic Sciences*, **25**, 105-122.

de Moor IJ, Day JA and de Moor FC (2003) Guides to the Freshwater Invertebrates of Southern Africa, Volume 8: Insecta II, Hemiptera, Megaloptera, Trichoptera and Lepidoptera. Prepared for the Water Research Commission, September 2003. Report No. TT 214/03.

de Moor IJ, Day JA and de Moor FC (2003) Guides to the Freshwater Invertebrates of Southern Africa, Volume 7: Insecta I, Ephemeroptera, Odonata and Plecoptera. Prepared for the Water Research Commission, April 2003. Report No. TT 207/03.

de Moor IJ, Harrison JA and Day JA (2002) Guides to the Freshwater Invertebrates of Southern Africa, Volume 9: Diptera. Prepared for the Water Research Commission, February 2003. Report No. TT 201/02.

Doeg TJ and Milledge GA (1991) Effects of experimentally increasing concentrations of suspended sediment on macroinvertebrate drift. *Australian Journal of Marine and Freshwater Research*, **42**, 519 – 526.

Graca MAS (1993) Patterns and processes in detritus based stream systems, *Limnologica*, **23**, 107-114.

Gratwicke B (1998) An introduction to aquatic biological monitoring. *Zimbabwe Science News*, **32**, 75 – 78.

Gratwicke B (1999) The effect of season on a biotic water quality index: A case study of the Yellow Jacket and Mazowe Rivers, Zimbabwe. *South African Journal of Aquatic Sciences*, **24**, 24 – 35.

Haapala A and Muotka T (1998) Seasonal dynamics of detritus and associated macroinvertebrates in channelised boreal stream. *Archiv fur Hydrobiologie*, **142**, 171-189.

Harper (1992) Eutrophication of freshwaters. Principles, Problems and Restoration.. Chapman and Hall, London.

Harrison AD (1966) Recolonisation of a Rhodesian stream after drought. *Archiv fur Hydrobiologie*, **62**, 405-421.

Harrison AD and Elsworth JF (1958) Hydrobiological studies on the Great Berg River, Western Cape. *Transactions of Rhodesian Society of Southern Africa*, **35**, 125-276.

Hawkes HA (1975) River zonation and classification. In: Whitton BA (ed) *River ecology. Studies in river ecology*. Univ. California.

Hawkins CP and Vinson MR (2000) Weak correspondence between landscape classifications and stream invertebrate assemblages. Implications for bioassessment. *Journal of the North American Benthological Society*, **19**, 501-517.

Heino J, Muotka T and Paavola R (2003) Determinants of macroinvertebrate diversity in headwater streams: regional and local influences.

Higler LWG and Verdonschot PFM (1991) Caddis larvae as slaves of stream hydraulics. In: Tomaczewski C (ed) *Proceedings of the 6th International Symposium on Trichoptera.* pp 57-62. Adam Mickwiecz University Press, Poznaň.

Holopainen AL and Huttnen P (1998) Impact of forestry practices on ecology of algal communities in small brooks in the Nurmes experimental forest area. *Finland Boreal Environmental Research*, **3**, 63-73.

Huryn AD and Wallace JB (2000) Life history and production of stream insects. *Annual Reviews of Entomology*, **45**, 83-110.

Hyens P, Masundire H and Sekwale M (1994) Freshwater Resources. In: In: Chnje M., and Johnson P. (eds) *State of the environment in Southern Africa*. SARDC, IUCN and Southern African Development Community. Penrose Press, Johannesburg, pp 181-206.

Jones JB (1997) Benthic organic matter storage in streams: influence of detrital import and export, retention mechanisms and climate. In: Webster JR and Meyer JL (eds) *Stream Organic Matter Budgets*, pp 109-119. *Journal of the North American Bethological Society*, **16**, 3-161.

Karr JR (1991) Biological Integrity: a long neglected aspect of water resource management. *Ecological Applications* **1**: 66-84.

King JM, Day JA, Hurly PR, Heshall-Howard M-P and Davies BR (1988) Macroinvertebrate communities and environment in a southern African mountain stream. *Canadian Journal of Fish and Aquatic Sciences*, **45**, 2168-2181.

Lancaster J, Hildrew AG and Townsend CR (1991) Invertebrates predation on patchy and mobile prey in streams. *Journal of Animal Ecology*, **60**, 625-641.

Lemley AD (1982) Modification of benthic insect communities in polluted streams. Combine effect of sedimentation and nutrient enrichment. *Hydrobiologia*, **87**, 229 - 245.

Malmquivst B (2002) Aquatic invertebrates in riverine landscapes. *Freshwater Biology*, **47**, 679-694.

Malmquivst B and Mäki M (1994) Benthic macroinvertebrate assemblages in north Swedish streams: environmental relationships. *Ecography*, **17**, 9-16.

McCullum J (1994) Freshwater resources. In: Chenje M., and Johnson P. (eds) *State of the environment in Southern Africa*. A report by the Southern Africa Research and Documentation Centre in Collaboration with IUCN – the World Conservation Union and the Southern African Development Community.

Merrit RW and Cummins KW (1996) An introduction to the Aquatic insects of North America. 3rd edition. Kendal/Hunt Publishing Co., Dubuque, IA.

Merrit RW, Wallace JR, Higgins MJ, Alexander MK, Berg MB, Morgan WT, Cummins KW and Vanderneeden (1996) Procedures of the functional analysis of invertebrate communities of the Kissimee River – floodplain ecosystem. *Florida Scientist*, **59**, 216-274.

Milner AM (1996) System Recovery. In: Petts GE and Calow P (eds) *River Restoration.* Blackwell Science. pp205-226.

Minshall GW (1984) Aquatic insect-substratum relationships. In: Resh VH and Rosenberg DM (eds) *The Ecology of Aquatic Insects*, pp 358-400. Praeger Publishers, New York.

Minshall GW and Robinson CT (1998) Macroinvertebrate community structure in relation to measures of lotic habitat heterogeneity. *Archiv fūr Hydrobiologie*, **141**, 129-151.

Moyo NAG and Phiri C (2002) The degradation of an urban stream in Harare, Zimbabwe. *African Journal of Ecology*, **40**, 401-406.

O'Connor NA (1991) The effects of habitat complexity on the macroinvertebrates colonizing wood substrates in a lowland stream. *Oecologia*, **85**, 504-512.

O'Keeffe JH and Davies BR (1991) Conservation and Management of the rivers in the Kruger National Park: Suggested methods for calculating instream flow needs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **1**, 55-71.

Omerod SJ, Rundle SD, Lloyd EC and Douglas AA (1993) The influence of riparian management on habitat structure and macroinvertebrate communities of upland streams draining plantation forests. *Journal of Applied Ecology*, **30**, 13-24.

Peterson RH and Van Eeckhaute L (1992) Distributions of Ephemeroptera, Plecoptera and Trichoptera of three montane catchments differing in pH. *Freshwater Biology*, **27**, 65-78.

Pielou EC (1975) Ecological Diversity, Wiley, New York. pp165.

Plafkin JL, Barbour MT, Porter KD, Gross SK, and Hughes RM. (1989) *Rapid bioassessment protocols for use in Streams and Rivers. Benthic macroinvertebates and fish*. EPA/444/4-89/001, United States Environmental Protection Agency, Washington, USA.

Pozo J, González E, Díez JR, Molinero J and Elósegui A (1997) Inputs of particulate organic matter to streams with different riparian vegetation. *Journal of North American Bethological Society*, **16**, 602-611.

Quinn JM, Steele GL, Hickey CW and Vickers ML (1994) Upper thermal tolerances of twelve common New Zealand stream invertebrate species. *New Zealand Journal of Marine and Freshwater Research*, **28**, 391 – 397.

Ravenganai S, Love D, Love I, Gratwicke B, Mandingaisa O and Owen RJS (2005) Impact of Iron Duke Pyrite Mine on water chemistry and aquatic life – Mazowe Valley, Zimbabwe. *Water SA*, **31**, 219-228.

Resh VH, Brown AV, Covich AP, Gurtz ME, Li HW, Minshall GW, Reice SR, Sheldon AL, Wallace JB and Wissmar RC (1988) The role of disturbance in stream ecology. *Journal of the North American Benthological Society*, **7**, 433-455.

Reynolds CS, Carling PA and Beven KJ (1991) Flow in river channels: new insight into hydraulic retention. *Archiv fur Hydrobiologie*, **121**, 171-9.

Rosenberg DM and Resh VH (1993) Freshwater biological monitoring and benthic macroinvertebrates. Chapman and Hall Publishers, New Tork, London, pp488.

Ryan PA (1991) Environmental effects of sediments on New Zealand streams: A review. *New Zealand Journal of Marine and Freshwater Research*, **25**, 207-221.

Smith RE, and Scott DF (1992) The effects of afforestation on low flows in various regions of South Africa. *Water SA*, **18**, 185-194.

Thirion CJ, Mocke A and Worst R (1995) Biological monitoring of streams and rivers using South African Scoring System (SASS) – a user manual. Department of Water Affairs and Forestry Institute for Water Quality Studies. South Africa , Report No. N0000/00/REQ/1195.

Townsend CR and Hildrew AG (1994) Species traits in relation to habitat template for River systems. *Freshwater Biology*, **31**, 265-275.

Vannote RL, Minshall GW, Cummins KW, Sedell JR, and Cushing CE. (1980) The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences*, **37**, 130-137.

Vivier L and Cyrus DP (1999) The zoobenthic fauna of the Nhlabane coastal lake system, Kwazulu Natal, South Africa, 20 years after construction of a barrage. *Water SA*, **25**, 533-542.

Vuori KM, Joensum I, Latvala J, Jutila E and Ahvonen A (1998) Forest drainage: a threat to benthic diversity of boreal headwater streams? *Aquatic Conservation: Marine and Freshwater Ecosystems*, **8**, 745-759.

Wallace JB and Webster JR (1996) The role of macroinvertebrates in stream ecosystem function. *Annual Reviews of Entomology*, **41**, 115-139.

Wallace JB and Merrit RW (1980) Filter-feeding ecology of aquatic insects. *Annual Reviews of Entomology*, **25**, 103-132.

Wallace JB, Eggert SL, Meyer JL and Webster JR (1997) Multiple trophic levels of forest stream linked to terrestrial litter inputs. *Science*, **227**, 102-104.

Wallace JB, Webster JR and Lowe RL (1992) High gradient streams of the Appalachians. In: Hackey CT, Adams SM and Martin WA (eds) *Biodiversity of the southeastern United States: aquatic communities*. John Wiley & Sons, New York, NY, pp 135-191.

Walsh CJ, Andrew KS, Breen PF and Jason AS (2001) Effects of urbanistion on Streams of Melbourne Region, Victoria, Australia.1. Benthic macroinvertebrate communities *Freshwater Biology*, **46**, 431-566.

Winterbourn MJ, Rounick JS and Cowe B (1981) Are New Zealand stream ecosystems realy different? *New Zealand Journal of Marine and Freshwater Resources*, **15**, 321-328.

APPENDICES

Appendix 1: The SASS4 categories used for classification of habitat and water quality. (Source: Thirion *et al*., 1995). HABS1 = habitat assessment score, ASPT = Average Score Per Taxon and SASS4 = South African Scoring System version 4 score.

HABS1 score	SASS4 score	ASPT	CONDITION
> 100	> 140	> 7	Excellent
80 - 100	100 - 140	5 – 7	Good
60 - 80	60 - 100	3 – 5	Fair
40 - 60	30 - 60	2 – 3	Poor
< 40	< 30	< 2	Very poor

Appendix 2a: Environmental data for all the Haruni River stations and dates.

	H1			H2			H3			H4			H5			H6		
Variable	O	D	J	O	D	J	O	D	J	O	D	J	O	D	J	O	D	J
Temperature (^{o}C)	19.4	19.3	20.1	20.8	21	21.2	21.7	22.5	23.4	21.3	23.1	20.6	20.1	23.4	20.7	24	25.3	24
pH	6.8	6.5	7	6.7	6.6	6.1	6.9	6.7	6.9	6.7	6.9	7.1	7	7.1	7.4	7.3	7.2	7.3
Conductivity (µScm^{-1})	3	10	20	3	11	14	5	24	41	5	24	45	9	38	66	8	31	70
Turbidity (NTU)	1	2.6	3	7.3	6.4	5.7	4.1	9.1	6	3.3	14	7	3.7	11.2	5.3	104	122	88.6
DO (Mg l^{-1})	7.3	7	9.5	6.5	6.9	8.5	9.7	6.9	9.8	6.2	7	5.8	6.2	6.9	9.3	5.6	5.9	9.4
Velocity (ms^{-1})	1.0	1.3	1.5	0.7	0.9	0.8	0.7	0.9	1.0	0.8	0.9	1.1	0.8	0.9	1.3	1.0	1.0	1.4
Blanketing (0 – 5)	0	0	0	3	1	1	0	0	0	0	0	0	1	0	0	5	4	3
% Canopy cover	10	10	10	0	5	5	75	80	85	20	20	20	60	70	80	20	20	20
ETBV (0 – 4)	1	2	2	0	3	4	1	2	3	1	1	2	2	4	4	1	2	2
Habitat divesirty (H’)	0.17	0.25	0.21	0.59	0.9	0.98	1.03	0.99	1.26	0.43	0.57	0.73	1.71	1.73	1.63	0.43	0.37	0.22
% Embededness	0	0	0	24	26	27	28	20	21	25	28	20	15	15	10	45	40	40
Depth (cm)	17	20	25	28	39	48	32	45	58	40	44	46	28	30	30	40	50	60
Width (cm)	50	77	192	150	150	200	340	410	440	800	820	860	660	700	720	2800	3000	3100
% Native trees		100			100			100			95			100			100	
% Riparian trees		95			5			85			80			80			70	

Appendix 2b: Environmental data for all the Nyahode River stations and dates where O = October, D = December and J = January.

	N1			N2			N3			N4			N5			N6		
Variable	O	D	J	O	D	J	O	D	J	O	D	J	O	D	J	O	D	J
Temperature (^oC)	19.8	20.9	24.0	18.2	18.1	21	20.1	20.9	21.3	18.3	19	23.5	21.2	21.2	24.6	23	22.9	24.6
pH	8.3	8.1	7.2	7.3	7.3	7.1	7.4	7.4	7.4	7.4	7.2	7.7	6.7	7.1	7.8	7.8	7.7	7.8
Conductivity	7	40	83	15	75	107	12	61	130	14	69	135	13	63	143	12	70	139
Turbidity (NTU)	16	17	15	12	15	20	11	17	7	13	18	11	20	25	13	29	31	15
DO (Mgl^{-1})	6.2	7.5	7.7	6.1	6.7	8	6.2	6.9	7.9	7.3	7	8.3	4.5	7.1	8.2	11.9	7.6	6.9
Velocity (ms^{-1})	0.1	0.1	0.1	0.2	0.2	0.7	0.7	0.8	0.9	0.8	0.8	0.9	0.8	0.9	0.8	1.7	1.8	1.8
Blanketing (0 – 5)	5	5	5	3	3	3	1	0	0	1	0	1	3	3	1	5	3	3
% Canopy cover	0	0	0	5	5	5	0	0	0	0	0	0	20	20	20	0	0	0
ETBV (0 – 4)	4	4	4	4	4	4	2	2	2	2	2	2	3	3	3	0	0	0
Habitat divesirty (H’)	0.33	0.33	0.3	0.88	0.88	0.88	0.57	0.88	0.88	0.95	0.95	0.95	1.1	1.1	1.1	0.17	0.17	0.17
% Embededness	100	100	100	55	55	55	40	35	35	30	30	30	25	25	25	75	70	65
Depth (cm)	16	20	14	30	43	55	25	25	29	34	34	54	41	55	62	22	25	36
Width (cm)	30	43	80	130	150	168	220	270	460	950	1030	1100	1040	1290	1300	2500	2630	2790
% Native trees		0			10			0			5			30			60	
% Riparian trees		0			15			5			40			70			40	

Appendix 3: Macroinvertebrates collected from the Haruni (H) and Nyahode (N) Rivers in October 2004

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N 2	N3	N4	N5	N 6
Baetidae	*Baetis sp1*	2	1	2	1	37	6		28	38	53	9	1
	Baetis sp2	2		2	2	23	1		16	18	12	3	
	Baetis sp 3								6		5		
	Pseudocloeon sp				1	7	7	2	2	12	19	9	
	Afroptilum sp					1					1		
	Pseudopannota sp						3			1	1	3	
	Demoreptus sp						1						
	Demoulinia sp	5					1				1		
	Acanthiops sp	8											1
Leptophlebiidae	*Aprionyx sp*			1		2							
	Euthraulus sp	1		8		6	5						
	Hyalophlebia sp	3											
	Adenophleboides sp	2											
	Adenophlebia sp	2	1										
Heptagenidae	*Afronurus sp*	2		13	5	17	12				6	6	
	Compsonuria sp				1	6							
Trichorythidae	*Dicercomyzon sp*	6		1	4	33	3					1	
	Trichorythus sp						3					12	44
Caenidae	*Barnardara sp*					2							
	Afrocaenis sp	12	1	3			3	38	20	4	1		
	Caenospella sp			4									
Ephemerythidae	*Ephemerythus sp*					9	1		1				
Perlidae	*Neoperla spio*			1		4	10				3	3	4
Ancylidae	*Burnupia* sp					33			26		31		23
Psephenidae	*Afrobrianax sp*	8	4	12	2	43					6	1	
	Afropsephenus sp										13		
Aeshnidae	*Aeshna* sp	1				3				2		1	
Libelludidae	*Zygonyx* sp	12			3	40	3				4	20	7
	Tholymis sp		1			13							
	Atoconeura sp				2	8		7	3		2	1	
	Trithemis sp												
Corduliidae	*Hemicordulia* sp	1		2		1			1		3	2	
	Syncordulia sp		2			5		5					
	Phyllomacromia sp		3			1							
Coenagrionidae	*Ischnura* sp					1							
	Pseudagrion sp				1	6	3	18	11	2	2	4	
	Agriocnemis sp			1									
	Enallagma sp				1								
	Teinobasis sp							42					
	Ceriagrion sp							14					
Chlorocyphidae	*Platycypha sp*	5		1		2							
Gomphidae	*Ceratogomphus sp*					2							
	Gomphidia sp							2					
	Microgomphidia sp							12					
	Microgomphus sp									3	1		

Appendix 3: Macroinvertebrates collected from the Haruni (H) and Nyahode (N) Rivers in October 2004 (continued).

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N2	N3	N4	N5	N6
Elmidae	Elmidae (adults)	9		5	3	4	11			5	13		4
	Elmidae (larvae) sp 1	1	1			10				1	14		1
	Elmidae (larvae) sp3		1		1	1				4	8		
	Elmidae (larvae) sp 2								2				
Hydraenidae	Hydraenidae (adults)	1							4				
	Parsthetops sp				1								
Helodidae	*Helodes* sp	2				4			2			8	
	Cyphon sp			2	1	6							
Dystiscidae	*Hydrovatus* sp					3							
	Yola sp			1		12			1		12		
	Laccophilus sp					2							
	Hydaticus sp							6					
Gyrinidae	*Orectogyrus* sp			3	2	6		4	1		5	4	
	Dineutus sp	1			3	3	2		12	12	8	8	
Hydrophilidae	*Enochrus* sp		1	1	1	2	1		1		3	2	
	Adults (unid)						1			2	6		1
Hydrometridae	*Hydrometra* sp					2							
Naucoridae	*Naucoris* sp			1	4	1						4	
Belostomatidae	*Appasus* sp					1							
Veliidae	*Rhagovelia* sp					3	3						
Nepidae	*Borborophilus sp*						2	3					
	Ranatra sp							1					
Corixidae	*Micronecta* sp						1		1				
Gerridae	*Eurymetra* sp						2	1					
	Hydrometra sp						2						
Pleidae	*Plea* sp	1	1		4						1	1	2
Saldidae	*Capitonisalda ripa*				1			1	2				
Notonectidae	*Notonecta* sp							6	1				
Ceratopogonidae	*Bezzia* sp					5	2			2		1	
Chironomidae	Orthocladinae	3		3	7	18	9		10	11	4	5	8
	Chironominae	18		3	2	7	4		2	1		5	4
	Tarnitarcinae	12		1	3	9	14		4	2		10	2
	Tarnipordinae	5		4	2	2	1		5		2		
Athericidae	*Suragina* sp	1		2	2	4				2	1	1	
Simulidae	*Paracnephia* sp	6			1	4			3	2	2		7
	Simulium sp	4		2	3	5	2		83	25	18	15	16
Dixidae	*Dixa* sp					2			7				
Tipulidae	*Limnophila* sp			1							2		
	Tipula sp				1				2	2			
Tabanidae	Unidentified						2		1				

Appendix 3: Macroinvertebrates collected from the Haruni (H) and Nyahode (N) Rivers in October 2004 (continued).

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N 2	N3	N4	N5	N 6
Hydropsychidae	*Macrostemum sp*					3	1						2
	Hydropsyche sp	5		10	7	17	2			2	30	17	56
	Cheumatopsyche spp	8		8	9	19	60		14	19	7		14
	Polymorphunisus sp						1						2
Philopotamidae	*Chimarra* sp	4		2	12	36			5				
Leptoceridae	*Leptocerina* sp			4		1	3						4
	(Pupae)					10	3						6
	Leptoceridae sp 1			3		2							4
Ecnomidae	*Ecnomus thomasetti*			1		2							
	Parecnomina sp			1									
Potamonautidae	Unidentified				1	2			1	1			1
	Platyhelminhes	6					3		4				
Pyralidae	Unidentified	1	1		1					1			
	Abundance	160	18	109	95	513	194	162	282	174	300	156	214
	Taxonomic richness	34	12	33	35	59	38	16	35	26	37	27	22

Appendix 4: Macroinvertebrates collected along the Haruni and Nyahode Rivers in December 2004

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N 2	N3	N4	N5	N 6
Baetidae	*Baetis sp1*	8	5	3	2	1	4	3	6	47	23	3	1
	Baetis sp 2	5	4			5			4	12	3		
	Baetis sp3		3			5				3	5		
	Pseudocloeon sp			1	3	8	3		33	6	21	6	
	Pseudopannota sp					2				3	4	4	1
	Demoulinia sp		8								1		
	Acanthiops sp						2		1				
Leptophlebiidae	*Euthraulus sp*	1		5	4		3	3	1				2
Heptagenidae	*Afronurus sp*	10	3	12	8	17	35				19	24	2
Trichorythidae	*Dicercomyzon sp*	6		5	6	5	11					3	
	Trichorythus sp	3					26						20
Caenidae	*Barnardara sp*				1	12		7					
	Afrocaenis sp	1			4	5	1	5	3	3	4	2	1
	Caenospella sp							4	3				
Ephemerythidae	*Ephemerythus sp*			1	3		1					5	
Perlidae	*Neoperla sp*	6	1	5	1	1	7					1	7
Ancylidae	*Burnupia* sp			1	1	46			14	38	28	3	31
Lymnaeidae	*Lymnea sp*					1							
Melaniidae	*Melanoides sp*										1		
Psephenidae	*Afrobrianax ferdyi*	8	19	27	18	11	5		1		5	7	
	Afropsephenus sp	3									8	3	
	Psephenidae sp 1							27					
Elmidae	Elmidae (adults)	1	1	6	21		1			3	1	1	
	Elmidae (larvae) sp 1	2	1	2		1			2		3	1	2
	Elmidae (larvae) sp3	1							4			4	1
	Elmidae (larvae) sp 2	1		1	3		6			3	5	6	3
	Elmidae (larvae) sp 4								1				

Appendix 4: Macroinvertebrates collected along the Haruni and Nyahode Rivers in December 2004 (continued).

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N2	N3	N4	N5	N 6
Hydraenidae	Hydraenidae (adults)									1			1
Helodidae	*Helodes* sp	2		2	1			1	1			14	
	Cyphon sp			3	5	1		1					
Dystiscidae	*Yola* sp		7	6	2	17	2		2		2	4	
	Laccophilus sp		7	4	5	1					1	1	
	Hydaticus sp								6				
Gyrinidae	*Orectogyrus* sp	6	1	1	1		2		1		7	1	
	Dineutus sp	1	1	3	2	1	2			3	8	3	
Hydrophilidae	*Enochrus* sp	2	1				4			1	1	2	
	Adults (unid)	1			2		4		1		5		
Aeshnidae	*Aeshna* sp			1	3	3			1	5	8	3	1
	Anax		1										
Libelludidae	*Zygonyx* sp	26	5		2	14	1				1	13	11
	Tholymis sp								15				
	Atoconeura sp	4	11			20				16	5	16	
	Trithemis sp						1						
Corduliidae	*Hemicordulia* sp		1				2	1		3			
	Syncordulia sp	1		2	1								
	Phyllomacromia sp			2									
Coenagrionidae	*Ischnura* sp		1	1					4				
	Pseudagrion sp	2	9	1	9	15			44	2	10	7	
Chlorocyphidae	*Platycypha caligata*	1			3	2						2	
Gomphidae	*Microgomphidia* sp								2				
	Microgomphus sp					1			8	3	1		
	Unidentified				3								
	Onychogomphus sp			1		5							4
	Notogomphus sp								6		1		
Platycnemididae	*Mesocnemis sp*								3				
Naucoridae	*Naucoris* sp		1	1	2		1		2	2	1	2	
	Neomacrocoris sp											2	
Belostomatidae	*Appasus* sp					1						1	
	Limnogeton sp					4					3		
Veliidae	*Rhagovelia* sp			2						1		1	
Nepidae	*Borborophilus sp*					1			2				
	Laccotrephs sp								1				
Corixidae	*Micronecta* sp	1	5				2		18	1	1		
Pleidae	*Plea* sp	2		3	2		5		4			17	3
Notonectidae	*Notonecta* sp								6				
Chironomidae	Orthocladinae		3			11			7	6	12	10	5
	Chironominae				1	1					3	1	
	Tarnitarcinae							1	2		1	1	
	Tarnipordinae		1				3	1	7		1		

Appendix 4: Macroinvertebrates collected along the Haruni and Nyahode Rivers in December 2004 (continued)

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N 2	N3	N4	N5	N 6
Athericidae	*Suragina* sp	1										1	
Simulidae	*Paracnephia* sp	8		2	14	4	3	1		8	15	2	7
	Simulium sp	5	4	12	9		5	1	4	12	6	8	
Dixidae	*Dixa* sp								1				
Tipulidae	*Limnophila* sp	1		2	2		5						
	Tipula sp											1	
Tabanidae	Unidentified			1	2	2							
Hydropsychidae	*Macrostemum sp*	2		2	17	17							
	Hydropsyche sp	4		3	3	2				3	12		3
	Cheumatopsyche	17	21	7	23	24	97	9	10	6	11	17	1
	Polymorphunisus sp	1					8						2
	Protomacrocnema sp										8	3	
Philopotamidae	*Chimarra* sp	2	2	13	16	7	3		1			2	1
	Dolophiloidse sp								2				2
Leptoceridae	*Leptocerina* sp		4									24	
	(Pupae)	6										3	
	Leptoceridae sp1		8										
	Leptoceridae sp 2		2									3	
Ecnomidae	*Ecnomus sp*			1	3							1	
	Parecnomina sp			1	1								
Potamonautidae	*Potamonautes*					1			3	1	1		
Platyhelminhes		1	4	6	4	7			7			18	
Pyralidae	Unidentified		6							1			
	Abundance	153	151	152	213	282	255	65	245	193	256	257	112
	Total number of taxa	37	32	38	40	39	31	13	42	27	40	46	23

Appendix 5: Macroinvertebrates collected from the Haruni (H) and Nyahode Rivers in January 2005.

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N2	N3	N4	N5	N6
Baetidae	*Baetis sp1*	6	7	2	3	5			9	28	10	6	1
	Baetis sp 2	3			2	6	1		3	14	4		
	Pseudocloeon sp		11	6	3	4	1		29	7	9	4	
	Pseudopannota						2	18		1		1	
	Demoulinia sp		1									1	
	Acanthiops sp	6											
Leptophlebiidae	*Euthraulus sp*	4		3	1	2	6	1			1		
	Adenophlebia sp			1									
Heptagenidae	*Afronurus sp*	10	5	8	21	34	32				12	1	
	Compsonuria		1			3					2		
Trichorythidae	*Dicercomyzon sp*	3	3	8	11	10						3	
	Trichorythus sp				1		9						21
Caenidae	*Afrocaenis sp*		12				1	7	3	3	2		1
Ephemerythidae	*Ephemerythus sp*										4	12	
Perlidae	*Neoperla spio*	13		3	5	7	8						2

Appendix 5: Macroinvertebrates collected from the Haruni (H) and Nyahode Rivers in January 2005 (continued)..

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N2	N3	N4	N5	N6
Ancylidae	*Burnupia* sp				1	15	1		12	31	3	4	19
Lymnaeidae	*Lymnea sp*												2
Psephenidae	*Afrobrianax sp*	24	13	7	13	34	6		7	3	5	3	
	Afropsephenus sp									6	3		
	Psephenidae sp 1							6					
Elmidae	Elmidae (adults)	6	7	8	2	15	4		3	12			2
	Elmidae (larvae) sp 1	1			1		8		4	1	3	4	1
	Elmidae (larvae) sp3						1		2		8	3	
Hydraenidae	Hydraenidae (adults)	2					11						
Helodidae	*Helodes* sp	1	6	1			3	2	5			13	
	Cyphon sp	3		2	2	2	1	3	2				
Dystiscidae	*Yola* sp	2	9	7	2	8		3	10			3	
	Laccophilus sp 1		3	4			1	3	7			2	
	Hydaticus sp							6					
	Laccophilus sp 2							4					
	Laccophilus sp 3							4					
Gyrinidae	*Orectogyrus* sp	1	8	2	1	3	1		3	3	2	7	
	Dineutus sp		4		2		3			2	4	1	
Hydrophilidae	*Enochrus* sp				2					2			
	Adults (unid)										1		
Aeshnidae	*Aeshna* sp		4		1	7				14	8	5	
	Anax		2	5	2	1							
Libelludidae	*Zygonyx* sp	27		2	3	8	1				3	3	1
	Tholymis sp			5	12								
	Atoconeura sp	6	5	2	14	14				9	6	26	
	Trithemis sp		1			9						2	
	Bradinogypa sp				4								
Corduliidae	*Hemicordulia* sp		1										
	Syncordulia sp			2				3					
Coenagrionidae	*Ischnura* sp		3										
	Pseudagrion sp	3	25	31	19	18	5	4	26		4	14	
Lestidae	*Lestes sp*		1										
Synlestidae	*Chlorolestes sp*		2										
Chlorocyphidae	*Platycypha caligata*				1	1				1		2	1
Gomphidae	*Microgomphus* sp		4		2	2			2	2			1
	Onychogomphus sp			2								1	
	Nepogomphoides sp			1	2	4							
Naucoridae	*Naucoris* sp				2	4	3	1	1		1	7	1
	Laccocoris sp					2					2		2
	Neomacrocoris sp	2			1							3	
Belostomatidae	*Appasus* sp					2						3	
Veliidae	*Rhagovelia* sp		1	1	1	1	2	1		1		3	

Appendix 5: Macroinvertebrates collected from the Haruni (H) and Nyahode Rivers in January 2005 (continued).

Family	Genus	H1	H2	H3	H4	H5	H6	N1	N2	N3	N4	N5	N 6
Nepidae	*Borborophilus sp*		1					1	1				
	Laccotrephs sp							4					
Corixidae	*Micronecta* sp		2	1				18	2				
Gerridae	*Eurymetra* sp		1	1									
Pleidae	*Plea* sp	8	1		1		2					37	1
Saldidae	*Capitonisalda sp*								4	4	1		
Notonectidae	*Notonecta* sp		3			2		16					
	Anisops sp		1	1									
Ceratopogonidae	*Bezzia* sp									1			
Chironomidae	Orthocladinae	2	6		3				2	5		1	1
	Tarnitarcinae		2				2	5					
	Tarnipordinae		5						2				
Simulidae	*Paracnephia* sp	1	3	1	4	3				2	3		
	Simulium sp	12	4		1		1		13	5	1	2	1
Dixidae	*Dixa* sp							2					
Tipulidae	*Limnophila* sp		1	2	1		3						
	Tipula sp				1							1	
Tabanidae	Unidentified		2			1				2			
Hydropsychidae	*Macrostemum sp*	2		1	27	45							
	Hydropsyche sp	4		4	3	3				4	18	5	1
	Cheumatopsyche spp	6	11	1	5	6	38		8	29	4	5	
	Polymorphunisus sp					1	1						
	Protomacrocnema sp										2	3	
	Diplectonelle sp							2					
Philopotamidae	*Chimarra* sp	8	1	4			3		2				
Leptoceridae	*Leptocerina* sp								4				
	Leptoceridae sp1												
	Leptoceridae sp 2												
Ecnomidae	*Ecnomus sp*	7				1	1						
	Parecnomina sp	2			1		1						1
Potamonautidae	*Potamonautes*		2		1	3	2	4		8	3	1	2
	Platyhelminhes	3			2								
Pyralidae	Unidentified	1	1	1									
	Abundance	179	186	130	187	286	165	118	166	200	129	192	62
	Total number of taxa	31	42	33	42	38	33	23	27	28	31	36	19

Appendix 6: Biotopes sampled. SIC = stones in current, SOOC = stones out of current, MV = marginal vegetation, AQV = aquatic vegetation.

Haruni River	October	December	January
H1	Bedrock, SIC	Bedrock, SIC	MV, bed rock
H2	SIC, AQV	MV, SIC, AQV	MV, SIC, AQV
H3	SIC, sand,	SIC, sand	SIC, sand, MV
H4	SIC, MV	SIC, MV	SIC, MV
H5	SIC, AQV, MV, silt, gravel	SIC, AQV, MV, silt, gravel	SIC, AQV, MV, silt, gravel
H6	SIC, MV	SIC, MV	SIC, MV
Nyahode River			
N1	MV, silt	MV, silt	MV, Silt
N2	SIC, MV, mud	SIC, MV, mud	SIC, MV, mud
N3	SIC	SIC, silt	SIC, silt
N4	SIC, MV, sand	SIC, MV, sand	SIC, MV, sand
N5	SIC, MV, SOOC, silt	SIC, MV, SOOC, silt	SIC, MV, SOOC, silt
N6	SIC, sand, silt, gravel	SIC, sand, silt, gravel	SIC, sand, silt, gravel