Occurrence, abundance and distribution of benthic macroinvertebrates in the Nyando River catchment, Kenya

D. A. Abongo, S. O. Wandiga, I. O. Jumba, P. J. Van den Brink, B. B. Naziriwo, V. O. Madadi, G. A. Wafula, P. Nkedi-Kizza and Henrik Kylin

Published in ***African Journal of Aquatic Science*** 40(39): 373-392.
DOI: 10.2989/16085914.2015.1113397

OCCURRENCE, ABUNDANCE AND DISTRIBUTION OF BENTHIC MACROINVERTEBRATES ALONG RIVER NYANDO DRAINAGE BASIN, KENYA

Abong'o DA[1]*, Wandiga SO[1], Jumba IO[1], Van den Brink PJ[2], Naziriwo BB[3],Madadi VO[1], Wafula GA[1], Nkedi-Kizza P[4], Kylin H[5, 6]

1. University of Nairobi, Department of Chemistry, Nairobi, Kenya
2. Wageningen University, Aquatic Ecology and Water Quality Management Group, Wageningen, The Netherlands
3. Makerere University, Department of Chemistry, Kampala, Uganda
4. University of Florida, Soil and Water Science Department, Gainsville, Florida, USA
5. Linköping University, Departments of Thematic Studies - Environmental Change, Linköping, Sweden
6. North West University, Environmental Sciences and Development, Potchefstroom, South Africa

*Corresponding author: e-mail dabongo@uonbi.ac.ke

ABSTRACT

A baseline study was conducted of the occurrence of macroinvertebrates at 26 sites in the Nyando River catchment in 2005–2006. A total of 13 orders and 16 families of Arthropoda, Mollusca, Platyhelminthes and Annelida were collected, with the order Ephemeroptera being most abundant in the up- and mid-stream reaches, followed by Hemiptera and Plecoptera respectively. The downstream sections of the river were dominated by Hirudinea and tubificids, as the water quality deteriorated mainly due to local land use, raw sewage effluent discharge and annual floods. Insects and annelids were the main invertebrates found and the extent of pollution increased from mid-section (Site 15) downwards as the river flowed into the Winam Gulf. Stringent management measures are required to safeguard the environment and ecosystems of Lake Victoria.

Key words: Biodiversity index, environmental monitoring, Lake Victoria Basin, species distribution, water quality, Winam Gulf

INTRODUCTION

Benthic macroinvertebrates differ in their sensitivity to water pollution and, therefore, provide information about the quality of a water body over a period of time (Grant 2002). The presence of fish may not provide adequate information about long-term water quality problems because fish can move away to avoid polluted water and then return when conditions improve. Most benthic macroinvertebrates cannot move far enough to avoid pollution and the biodiversity of macroinvertebrates can, therefore, provide information about pollution that may not be present at the time of sample collection (Grant 2002).

Although water quality has a strong impact on biological components in aquatic systems (Grant 2002; Ndaruga et al. 2004), the literature on macroinvertebrate composition, distribution and diversity in East Africa is limited (Mwangi 2000; Kilonzo et al. 2014). Only a few studies have attempted to relate macroinvertebrate composition, density, diversity or assemblage to the aquatic environmental conditions (Ndaruga et al. 2004; Masese et al. 2009; Raburu et al. 2009; Mbaka et al. 2014). Typically, these studies focused on biodiversity in relation to different pollution levels, although this aspect was not investigated in depth. The use of macroinvertebrate sensitivity for environmental assessment and monitoring of the water quality of streams and rivers is, consequently, still uncommon in most of Africa. The exception is South Africa, where a scoring system for rapid bioassessment of river water quality has been used in the national biomonitoring programme (Dallas 1997; Dickens and Graham 2002).

The structure, taxonomic composition and temporal distribution of benthic macroinvertebrates in the Nyamweru River, Uganda, were surveyed by Tumiwesigye et al. (2000). Mathooko (2002) investigated colonisation of artificial substrates by aquatic insects in the Naro-Moru River, Kenya, and 10 orders of macroinvertebrates, dominated by Ephemeroptera, Trichoptera and Diptera, were found in streams of the Lake Naivasha catchment (Barnard and Biggs 1988). Only a few oligochaetes and chironomids were found in the anoxic section of the Nairobi River, while Trichoptera and Simuliidae were present at the Nairobi Falls and the upper reaches of the river (Kinyua and Pacini 1991). Ndaruga et al. (2004) studied the impacts of water quality parameters on macroinvertebrate assemblages in the Gatharaini River basin, Central Kenya. There have also been attempts to develop a biodiversity index for a river system emptying into the Kenyan sector of Lake Victoria (Masese et al. 2009; Raburu et al. 2009). Raburu et al. (2009) reported 13 orders in both the Nyando and Kipkarren rivers, and 15 in the Moiben River in the upper catchment of the Lake Victoria basin in Kenya.

In East Africa, the water quality of Lake Victoria is considered especially problematic (LVEMP 1999). It is important to study and understand the water quality and pollutants of the rivers of the Lake Victoria catchment to determine the types of action required to improve the water quality of the lake. The Nyando River is one of the most important rivers feeding into the Kenyan sector of Lake Victoria (LVEMP 2003). Therefore the aim of the present study was to assess the occurrence, abundance and distribution of benthic macroinvertebrates in the Nyando River basin, to correlate these to the impacts of measured physical and chemical parameters, and to establish baseline data for the river from which future changes in water quality could be evaluated. The long-term goal was to develop a scoring system to assess the water quality and pollution status of other river basins in the Lake Victoria catchment and elsewhere in East Africa.

MATERIALS AND METHODS

The Study Area

The Nyando River (Figure 1) has a total length of 170 km and a catchment area of 3 450 km2 which lies between 0°25' S and 0°10' N and between 34°50' W and 35°50' E. The climate is subhumid with a mean annual temperature of 23 °C. The mean annual rainfall of 1 360 mm varies from 1 000 mm near Lake Victoria to over 1 600 mm in the highlands (NES 2002). The annual rainfall is bimodal with peaks during the long rains (March–May) and short rains (October–December). The rainfall depends on the north–south movements of the Inter-Tropical Convergence Zone (ITCZ) during the dry seasons (January–February) (NES 2002).

The Nyando River has two main tributaries, the small Nyando River (Kericho-Upper Nyando) and the Ainamotua River (Nandi-Lower Nyando). The Awach-Kano River flows into the main Nyando River 15 km downstream of the small Nyando-Ainamotua confluence. The Nyando Basin drains major agricultural and industrial zones of eastern Kenya. The average annual and monthly runoff flows are 18.0 $m^3 s^{-1}$ and 18.3 $m^3 s^{-1}$, respectively (LVEMP 2003). The Nyando River has the highest average sediment transport capacity index (0.30) and average slope (5%) of all rivers draining into Lake Victoria (LVEMP 2003).

Environmental conditions at sampling sites

Small-scale subsistence maize, sorghum and rice farming characterise the lower part of the watershed and the lake plains. At higher altitudes, there are large- and small-scale maize farms, sugarcane and coffee plantations, tea estates and small-scale horticulture. There are severe widespread land degradation problems throughout the Nyando River basin that affect an estimated 1 444-1 932 km^2 of its area (Odada et al. 2009). These include accelerated runoff and sheet erosion over much of the basin leading to severe rill, gully and stream bank erosion in the lower parts of the river basin, as well as landslides in the upper parts. The principal causes of erosion in the basin include deforestation of the headwaters and slash-and-burn agricultural activities over extensive areas of fragile lands on both hill slopes and plains, coupled with loss of watershed-filtering functions through encroachment on the wetlands and loss of riverine vegetation (Abong'o 2009).

Two areas of the Nyando River basin were investigated: the Kericho-Upper Nyando and Nandi-Lower Nyando subbasins. Twenty-six sampling sites were identified by the Lake Victoria Environment Management Project (LVEMP) Pollution Loading Component in Kenya (Figure 1): Sites 1-14 in the Kericho-Upper Nyando sub-basin and Sites 15-33 in the Nandi-Lower Nyando basin (Table 1). The sampling sites were selected based on the levels of human interference (low vs high human impact) and water quality. Sites were considered as "reference" if the streams were in the forest and had no human settlements or activities within 1 km upstream, and if the riparian vegetation was intact. "Impaired" sites were identified as those with damaged or eroded riverbanks and no human activities within the 10-m riparian zone, such as manmade erosion, sand mining, recreation, and point or non-point sources of pollution like industries and municipal discharges into the river within 15 km upstream. Other sites were classified as “moderately impaired”.

Benthic macroinvertebrates and water samples were collected from the sampling sites representative of the Nyando River drainage basin. The sampling was done four times a year, in February, May, September and December 2005, and in similar periods in 2006, to capture the effects of different seasons and human activities on the benthic macroinvertebrates. Typically, May and February are the wettest and driest months, respectively.

Macroinvertebrate sampling and identification

Benthic macroinvertebrate samples were collected using a 500-μm mesh kick-net for 1 minute in an area measuring approximately 1 m^2 (Grant 2002). Sieves of 500-μm mesh size were used to separate organisms from sediments. Large debris was removed from the samples after carefully washing off the attached organisms into a bucket and the water filtered through 250-μm mesh size sieves after hand sorting to separate the organisms from debris. Samples were taken randomly over a river length of 50 m at each site, put in labelled 750-ml amber bottles and preserved in 10% formalin. Samples from all the sites were taken to the Zoology Department laboratory at the University of Nairobi for counting and identification. In the laboratory, samples were filtered through 250-μm mesh sieves, rinsed with distilled water into Petri dishes and sorted, identified and counted under a stereomicroscope to the lowest possible taxonomic level using identification keys by Quigley (1977) and Merritt and Cummins (1996), and preserved in 70% alcohol.

Measurements of water quality parameters and river flow

Temperature, pH, conductivity and dissolved oxygen (DO) were measured in the field at depths of about 5-10 cm below the water surface at the time of macroinvertebrate sample collection using a precalibrated Hydrolab YSI 610 instrument. River width and water depth were measured using a tape measure and a graduated rod, respectively. Current velocity was measured at 60% of the total water depth with a 2030R flow meter (General Oceanics, Florida). Whenever cross-sectional area measurements could not be made due to high flows, a rough estimate of velocity was made by measuring the time required for a weighted float to travel a fixed distance along the river (Grant 2002). Water discharge was calculated from velocity, width and depth data, as described by Gordon et al. (2004).

The water for physical and chemical analysis was collected from each sampling site using three 1-litre plastic containers, thoroughly cleaned by rinsing with nitric acid (8 M HNO_3), followed by repeated washing with de-ionised water and thrice rinsed with sample water before collection. Samples were placed in cooler boxes and taken to the LVEMP laboratory in Kisumu, stored in freezers at -18 °C prior to the determination of turbidity, total nitrogen (TN), phosphorus (TP) and suspended solids (TSS). For the determination of TN, TP and TSS, the method of Mackereth et al. (1989) was used.

Data Analysis

The collected macroinvertebrates were analysed to obtain average number of organisms per square metre (m^{-2}) and the percentage composition of each taxonomic group in the two subcatchments. The data were presented in terms of differences in faunal occurrence (order and families) and the required information on composition, diversity, densities and distribution of macroinvertebrates in the two subcatchments were obtained. Diversity indices were calculated using the Shannon–Wiener function (H') (Shannon 1948).

The data were analysed using CANOCO for Windows Version 5 (ter Braak and Šmilauer 2012). All analyses were performed for each catchment separately. The first analysis was performed to show the changes of the were introduced as species and sampling date as nominal explanatory variables. A permutation test was performed under the canonical correspondence analysis (CCA) option, since the lengths of gradients were rather large (>3.5 SD).

For the second analysis, the CCA option was also used to test significance of the fraction of variance in the community composition of the macroinvertebrates that is explained by all physico-chemical parameters separately. In these tests sampling date was introduced as covariables, the biological dataset as species, and the physico-chemical dataset as explanatory variables. From this analysis a graphical overview of the differences in species composition between the sites and their correlations with the measured explanatory variables was obtained.

RESULTS

Site categories and environmental conditions

Due to the scarcity of previous data from the region, the selected sites were classified as reference, impaired and moderately impaired sites. The Nyando River had one reference site at the upper reaches (Site 30), and 12 impaired and 13 moderately impaired sites in the mid and lower sections. Human and industrial activities were concentrated in the middle and lower reaches (Table 1). The highest densities, abundance and distribution of macroinvertebrates are presented in Table 2, i.e. for May 2005 and 2006 in the upper subcatchment, and for February 2005 and 2006 in the lower subcatchment. The physico-chemical parameters for the corresponding periods in the two subcatchments are presented in Table 3. Appendices 1 and 2 contain additional information on the taxa and physicochemical parameters found at the various sampling sites during all four sampling seasons, 2005 and 2006.

Macroinvertebrate assemblage characteristics

A total of 13 orders and 16 families were recorded from each of the two subcatchments. The benthic macroinvertebrates collected were dominated by the Arthropoda, which were mainly larvae, nymphs and pupae of Hemiptera (Belostomatidae), Ephemeroptera (Baetidae, Caenidae), Plecoptera (Perlidae), Trichoptera (Limnephilidae), Neuroptera (Sisyridae), Zygoptera, Anisoptera, Coleoptera (Elmidae, Psephenidae) and Diptera (Athericidae, Culicidae). Hydrachnidae, Naididae (Tubificidae) and Hirudinea were also present.

Density, abundance and distribution

The density (individuals per m2) and distribution of macroinvertebrate families per sampling sites in the two subcatchment areas were recorded. Detailed data are presented in Table 2 and Appendix 1. In the Kericho subcatchment, Site 1 had the highest densities of 478 ind. m^{-2} and 484 ind. m^{-2} in the two sampling years, respectively (Table 2). This was followed by Site 6 with 447 ind. m^{-2} and 425 ind. m^{-2}, respectively. At Site 1 the order Ephemeroptera had the highest density followed by the Plecoptera. These were mainly nymphs of Baetidae (188 ind. m^{-2}, 195 ind. m^{-2}), Caenidae (49 ind. m^{-2}, 30 ind. m^{-2}) and Hydrachnoidea (36 ind. m^{-2}, 47 ind. m^{-2}) in 2005 and 2006, respectively. The order Ephemeroptera dominated the taxonomic composition, contributing 74% and 68% of total macroinvertebrates found at Site 10 in 2005 and 2006 respectively. This was followed by Trichoptera (20% and 25%) at Site 8 and Plecoptera (16% and 18%) at Site 9, respectively. The subclass Hirudinea were the only macroinvertebrate organisms not found in the Kericho-Upper Nyando area. The order Neuroptera was only found at Site 5 and contributed 3% and 2% of the total macroinvertebrate numbers at that site during the sampling periods, respectively. Site 4 did not have Ephemeroptera or Plecoptera in the sampling periods.

In the Nandi-Lower Nyando subcatchment area, Site 25 had the highest densities of 494 ind. m^{-2} and 316 ind. m^{-2} in the two years respectively followed by Site 33 which had densities of 331 ind. m^{-2} and 309 ind. m^{-2} respectively (Table 2). At these two sites, the dominant orders were Ephemeroptera (Baetidae, 99 ind. m^{-2} and 90 ind. m^{-2}) and Hirudinea (159 ind. m^{-2} and 158 ind. m^{-2}) respectively. Mollusca (Corbiculidae, 1 ind. m^{-2}) and Tubificidae (7 ind. m^{-2}) were the only macroinvertebrates found at Site 16 in 2005 but were absent in 2006. There were no macroinvertebrates collected from Site 17 during the same periods. Tubificidae and Hirudinea were the main invertebrates found at Sites 18 and 33. The order Ephemeroptera also dominated the taxonomic diversity (71% and 68%) at Site 15 in the Nandi-Lower Nyando in the sampling periods. Site 18 had the highest number of Hirudinea, contributing to 83% and 73% in 2005 and 2006, respectively, while the numbers of Tubificidae were highest at Site 16 (88% and 76%). The order Neuroptera was only found at Site 21 contributing 0.3% and 0.7% of the total organisms at that site in the two sampling periods.

In the Nyando River, no single family of the benthic macroinvertebrates organisms was represented at all sampled sites during the sampling periods. The Kericho- Upper Nyando had the highest density of macroinvertebrate families and the orders Hemiptera, Coleoptera and superfamily Hydrachnoidea were present at all the sampling sites but were absent in some sites in Nandi-Lower Nyando subcatchment.

There were no pollution-sensitive macroinvertebrates collected beyond Site 15 (Nyando at Ogilo). The orders Ephemeroptera, Hemiptera, Plecoptera and Trichoptera were mostly found in the upper and middle sections of the river. Tubificidae were found both at Site 4 in the upper section and in the lower sections of the river while Hirudinea were mainly restricted to the lower reaches at Sites 18 and 33.

Biodiversity

Sites 1 and 14 had the highest family diversity, 14 and 13 respectively, followed by Site 6 which had a diversity of 12 families while Site 4 had the lowest family diversity (Figure 2a). The Shannon–Wiener diversity index (*H′*) for the Kericho-Upper was 2.2244 and 1.9636 in 2005 and 2006 respectively.

In the Nandi-Lower Nyando subcatchment Site 27 showed the highest taxa diversity (13) followed by Sites 23 and 25 with diversities of 13 and 12 families each (Figure 2b). These three sites were in the upper reaches of the river. Sites 16, 17, 18 and 33 in the lower reaches had the lowest diversity ranging from 0 to 5 in 2005 and from 0 to 7 in 2006 (Figure 2b). The Shannon–Wiener index (*H′*) was 2.0015 and 2.0171 in 2005 and 2006 respectively. This shows higher diversity for the Kericho-Upper Nyando subcatchment than for the Nandi-Lower Nyando.

Using CCA options to test the significance of community composition between the two subcatchments, the ordination test resulted in a $p \leq 0.001$. Sampling date explained a significant 18% of the total variation in macroinvertebrate community composition, and subcatchment explained 5%. The datasets were therefore analysed separately for the changes in macroinvertebrate community composition in time (Table 2, Appendix 1), and for the correlation of these changes with the measured physico-chemical parameters (Table 3, Appendix 2). The analysis showed interannual variation in community composition, with the highest biodiversity in the February samples in the two subcatchments, respectively, and small intra-annual variation between the two periods. In Figure 3a, sampling date explained 19% of the total variation, of which 56% is displayed on the horizontal axis and 23% on the vertical axis. In Figure 3b, sampling date explained 15% of the total variation, of which 59% is displayed on the horizontal axis, while another 31% is displayed on the vertical one.

For the canonical correspondence analysis indicating the variation in macroinvertebrate community composition in relation to the physico-chemical parameters in the Kericho-Upper Nyando (Figure 4a), sampling date explained 19% of the total variation, which is excluded from the analysis. The physico-chemical parameters explained 19% of the total variation of which 30% is displayed on the horizontal axis, while another 24% is displayed on the vertical axis. The underlined physico-chemical parameters explained a significant ($p < 0.05$) part of the variance in the community composition of the macroinvertebrates in the permutation tests, only altitude explained a significant fraction of the variance in the community composition of the macroinvertebrates of the Kericho-Upper Nyando subcatchment. Altitude was negatively associated with a higher biodiversity (Figure 4a). In contrast to the Kericho-Upper Nyando subcatchment (Figure 4a), the physico-chemical parameters explained a significant part of the variance in the community composition of the macroinvertebrates in the Nandi-Lower Nyando subcatchment (Figure 4b). The physico-chemical parameters explained 15% of the total variation, of which 59% was displayed on the horizontal axis, while another 31% is displayed on the vertical axis. The underlined physico-chemical parameters explained a significant part ($p < 0.05$) of the variance in the community composition of the macroinvertebrates in the Nandi-Lower Nyando catchment (Figure 4b). Altitude and dissolved oxygen (DO) were correlated positively, while temperatures, discharge, river width, area, TP, TSS and turbidity correlate negatively with biodiversity (Figure 4b).

DISCUSSION

The number of macroinvertebrate orders found in this study is higher than in other studies from Kenya, except that of Mbaka et al. (2014). A total of 13 orders were identified in this study as compared to 10 found in the Lake Naivasha catchment streams (Barnard and Biggs 1988) and eight in the Sagana River (Mwangi 2000). In the anoxic section of the Nairobi River only a few individual Oligochaeta and Chironomidae were found (Kinyua and Pacini 1991). Only two dipteran families were found in the present study as compared to three reported in Lake Naivasha catchment streams (Barnard and Biggs 1988) and six in the Gatharaini River (Ndaruga et al. 2004). Specifically for the Nyando River catchment 13 orders and 65 families were found at five sites (Raburu et al. 2009) as compared to 13 orders and 16 families in this study. However, the higher number of families found by Raburu et al. (2009) is attributed to a single sampling site, inhabited by hippopotamus, located within the wetland at the river mouth in Winam Gulf. This site was excluded from the present study.

In the Kericho-Upper Nyando catchment, Sites 1 and 14 (moderately impaired) had the highest taxon diversity, while Sites 4, 7 and 8 (impaired) had the lowest (Figure 2a). This may be attributed to pollution at those sites. Site 4 receives raw domestic sewage directly from Londiani township while Sites 7 and 8 receive runoff laden with agrochemicals from maize, cabbage, kale, and potato farms in Kipkelion Division (Abong'o 2009).

In the Nandi-Lower Nyando subcatchment, Sites 23, 25 and 27 (moderately impaired) showed the highest diversity of taxa (Figure 2b). Sites 16, 17, 18 and 33 (impaired) in the lower reaches of the Nyando River are prone to severe annual floods, and hence had the lowest taxon diversity (Abong'o 2009). Site 17 receives raw domestic sewage effluent from Ahero township while Sites 18 and 33 are served with water from channels in the irrigated rice growing areas in Ahero where agrochemicals are intensively used (Abong'o et al. 2014). The Kericho-Upper Nyando subcatchment had higher taxon diversity than the Nandi-Lower Nyando section. The taxon diversity decreased downstream with no benthic macroinvertebrates caught at Site 17, the most downstream site in either 2005 or 2006. The abundance of most macroinvertebrates declined downstream of Site 15. Tubificidae and Hirudinea were the main invertebrates found beyond this sampling site. The Oligochaeta are tolerant to pollution (Ndaruga et al. 2004). This implies that the stress imposed by pollution is highest beyond sampling Site 15 on the Nyando River, and that it increases in the downstream sections as the river drains into the Winam Gulf (Abong'o 2009). Altitude was the major determinant for the macroinvertebrate community composition in the Kericho-Upper Nyando subcatchment (Figure 4a). Most macroinvertebrates were found in the middle section of the river, which comprised the moderately impaired Sites 5, 6, 9, 10, 11, 12 and 14.

Site 13 (impaired) had very few macroinvertebrates, as it receives discharges from a calcium carbonate factory as well as runoff from nearby sugarcane farms.

In the Nandi-Lower Nyando subcatchment, altitude and DO showed a strong positive correlation with the macroinvertebrate community composition (Figure 4b). Most macroinvertebrate families were found in the upper reaches of the river at higher altitude with very close proximity to Nandi Hills, which receives rainfall almost throughout the year (Abong'o 2009). This study indicates that the temperatures in the Nandi-Lower Nyando section are lower (Table 3). Oxygen dissolves more easily in cold than in warm water (Grant 2002). Low water temperatures, therefore, favour increased DO and, hence, indirectly the survival of macroinvertebrate (Grant 2002).

Higher discharge (flow rate), large surface area and river width had negative correlations to the macroinvertebrate assemblage. River discharge, area and width have a profound effect on the composition of a riverbed (sand or silt) and prevent the benthic invertebrates from maintaining a foothold, respiring and feeding (Grant 2002). As the amount of water in a river increases, the river must adjust its velocity and cross sectional area in order to form a balance. Discharge increases as more water is added through rainfall, from tributaries, or from groundwater seeping into the river. As discharge increases, generally width, depth and velocity of the river also increase. Increasing the depth and width of the stream may cause the stream to overflow its channel resulting in a flood. Floods occur when the discharge of the stream becomes too high to be accommodated within the normal river channel. Flooded rivers are often responsible for heavy sand and silt transportation and deposition downstream (LVEMP 2003). Variable flow rate can have a far greater impact on benthic populations than low levels of pesticide contamination (Grant 2002). High turbidity is linked to high amounts of total suspended solids (TSS) that affect the macroinvertebrate composition in water. Macroinvertebrates attach strongly to suspended particulate matter and will be transported downstream fairly quickly. Increases in TP, turbidity, TSS, area, width and discharge showed strong negative correlations with macroinvertebrate population distribution (Figure 4b); however, TP has little direct impact on fauna (Grant 2002). Therefore turbidity, TSS, area, width and discharge determine much of the population distribution in the Nandi-Lower Nyando subcatchment.

In the Nyando River drainage catchment, the order Ephemeroptera was the most abundant taxon, followed by Hemiptera, Plecoptera and Trichoptera respectively and was mainly found in the upper and middle reaches of the river. Hirudinea and Tubificidae were mainly found in the lower sections of the river where phosphates and nitrate fertilisers are intensively used in the irrigated rice farms (Abong'o et al. 2014). Human activities at the downstream sites may have a negative effect on the diversity of in-stream habitats through trampling and sedimentation, as well as on macroinvertebrate assemblages. An increase in the intensity of cattle grazing (Braccia and Voshell 2007) has been reported to affect sensitive macroinvertebrate taxa and in-stream habitats negatively (McInnis and McIver 2009).

Conclusion

This study has established baseline data regarding the occurrence, abundance and distribution of benthic macroinvertebrates in the Nyando River catchment, which can be used to evaluate the current and future biodiversity and river water quality. Both point and non-point sources of pollution have been identified. Pollution problems are severe from Site 15 downstream as the river flows into Winam Gulf. Better management of the Nyando River catchment is required before it reaches the point of no return in terms of environmental conservation. The results of this study can form the basis for the study of the other waterways of Lake Victoria and that of the lake itself.

The benthic macroinvertebrate communities responded to changes in water quality (Abong'o 2009) and this was seen in changes in the composition of family assemblages, and in diversity and densities along the river. Improper land-use practices, such as overuse of extensive areas of fragile lands, both on the hill slopes and in the plains, for subsistence and plantation agriculture, industrial pollution from a calcium carbonate factory, and raw sewage effluent from municipalities, negatively influence the environmental conditions in the Nyando River.

Currently, there are no mitigation measures in place to reverse or contain disturbances. There is need for the National Environmental Management Authority (NEMA) in Kenya to prohibit the disposal of raw industrial and sewage effluents into lakes and rivers by enforcing existing and new environmental legislations. Cultivation of river channels and riparian lands, as well as the reclamation of wetlands and the clearing of forest cover for human settlements, should be prohibited to minimise negative effects on water resources and biodiversity. Cleared marshy and swampy areas along the rivers should be restored and protected in future during the implementation of development projects.

In the meantime, urban councils, together with other relevant government ministries, should control unacceptable land-use and development plans on riparian land. Future development plans for residential and industrial areas should cater for proper sanitation and solid waste disposal systems. There is also a need to carry out similar studies for the other waterways feeding Lake Victoria.

Acknowledgements – We are grateful to the International Foundation for Science (IFS), which provided the research grant (No.W3982-1) for this project. The Higher Education Loans Board (HELB) in Kenya for the partial sponsorship during this study. Mr. John Okungu, Project Manager, Lake Victoria Environment Management Project, Kisumu, Kenya, who provided a vehicle and field officers for sample collection.

References

Abong'o DA. 2009. Occurrence, distribution and environmental impact of organochlorine pesticide residues in the Lake Victoria catchment: a case study of River Nyando drainage basin of Winam Gulf in Kenya. PhD thesis, University of Nairobi, Kenya.

Abong'o DA, Wandiga SO, Jumba IO, Madadi VO, Kylin H. 2014. Impacts of pesticides on human health and environment in the River Nyando catchment, Kenya. *International Journal of Humanities, Arts, Medicine and Sciences* 2: 1-14.

Barnard PC, Biggs J. 1988. Aquatic macroinvertebrates in Lake Naivasha catchment streams. *Revue d'Hydrobiologie Tropicale* 21: 127-134.

Braccia A, Voshell JR Jr. 2007. Benthic macroinvertebrate responses to increasing levels of cattle grazing in Blue Ridge Mountain streams, Virginia, USA. *Environmental Monitoring and Assessment* 131: 185-200.

Dallas HP. 1997. A preliminary evaluation of aspects of SASS (South Africa Scoring System) for the rapid bioassessment of water quality in rivers, with particular reference to the incorporation of SASS in a national biomonitoring programs. *Southern African Journal of Aquatic Sciences* 23: 79-94.

Dickens CWS, Graham PM. 2002. The South African Scoring System (SASS) Version 5 rapid bioassessment method for rivers. *African Journal of Aquatic Science* 27: 1-10.

Gordon ND, McMahon TA, Finlayson BL, Gippel CJ, Nathan RJ. 2004. *Stream hydrology: an introduction for ecologists*. Chichester: John Wiley & Sons.

Grant FI. 2002. Environmental parameters. In: Grant IF, Tingle CCD (eds), *Ecological monitoring methods for the assessment of pesticide impact in the tropics*. Chatham: Natural Resources Institute. pp 115-157.

Kilonzo F, Masese FO, Van Griensven A, Bauwens W, Obando J. 2014. Spatial-temporal variability in water quality and macro-invertebrate assemblage in the Upper Mara River basin, Kenya. *Physics and Chemistry of the Earth* 67–69: 93-104.

Kinyua AM, Pacini N. 1991. The impact of pollution on the ecology of the Nairobi-Athi River system in Kenya. *International Journal of BioChemiPhysics* 1: 5-7.

LVEMP (Lake Victoria Environmental Management Project). 1999. Environmental, technical socio-economic, gender and socio-cultural issues in catchment conservation: main findings and conclusions. Interim Report. Diversified Management Dynamics Ltd, Nairobi.

LVEMP (Lake Victoria Environmental Management Project). 2003. Phase 1, Revised draft: scientific stocking report—progress during LVEMP 1 and challenges for the future. World Bank, Washington, DC.

Mackerth FJH, Heron J, Talling JF. 1989. *Water analysis; some revised methods for limnologists* (2nd edn). FBA Scientific Publication No. 36. Ambleside, Cumbria: Freshwater Biological Association.

Masese FO, Raburu PO, Muchiri M. 2009. A preliminary benthic macroinvertebrate index of biotic integrity (B-IBI) for monitoring the Moiben River, Lake Victoria Basin, Kenya. *African Journal of Aquatic Science* 34: 1-14.

Mathooko JM. 2002. The sizes, maturity stages and biomass of mayfly assemblages colonising disturbed streambed patches in central Kenya. *African Journal of Ecology* 40: 84-93.

Mbaka JG, M'Erimba CM, Thiongo HK, Mathooko JM. 2014. Water and habitat quality assessment in the Honi and Naro Moru rivers, Kenya, using benthic macroinvertebrate assemblages and qualitative habitat scores. *African Journal of Aquatic Science* 39: 361-368.

McInnis M, McIver J. 2009. Timing of cattle grazing alters impacts on stream banks in an Oregon mountain watershed. *Journal of Soil and Water Conservation* 64: 394-399.

Merrit RW, Cummins KW. 1996. *An introduction to the aquatic insects of North America* (3rd edn). Dubuque, Iowa: Kendell/Hunt.

Mwangi BM. 2000. Bed sediments, organic matter and macroinvertebrate response to changes in catchment land use along a low order tropical stream; Sagana River, Kenya. MSc thesis, Vienna University, Austria.

Ndaruga MA, Ndiritu GG, Gichuki NN, Wamicha WN. 2004. Impact of water quality on macro-invertebrate assemblages along a tropical stream in Kenya. *African Journal of Ecology* 42: 208-216.

NES (National Environment Secretariat). 2002. First national communication of Kenya to the conference of the parties to the United Nation Framework convention on climate change (UNFCCC). NES, Nairobi.

Odada EO, Ochola WO, Olago DO. 2009. Drivers of ecosystem change and their impact on human well-being in Lake Victoria basin. *African Journal of Ecology* 47: 46-54.

Quigley ED. 1977. *Invertebrates of streams and rivers*. London: Edward Arnold.

Raburu PO, Masese FO, Mulunda CA. 2009. Macro-invertebrate Index of Biotic Integrity (M-IBI) for monitoring rivers in the upper catchment of Lake Victoria Basin, Kenya. *Aquatic Ecosystem Health & Management* 12: 197-205.

Shannon EP. 1948. A mathematical theory of communication. *Bell System Technical Journal* 27: 379-423.

ter Braak CJF, Šmilauer P. 2012. Canoco reference manual and user's guide: software for ordination, version 5.0. Ithaca: Microcomputer Power.

Tumiwesigye C, Yusuf SK, Makanga B. 2000. Structure and composition of benthic macroinvertebrates of a tropical forest stream, River Nyamweru, western Uganda. *African Journal of Ecology* 38: 72-77.

Figure 1

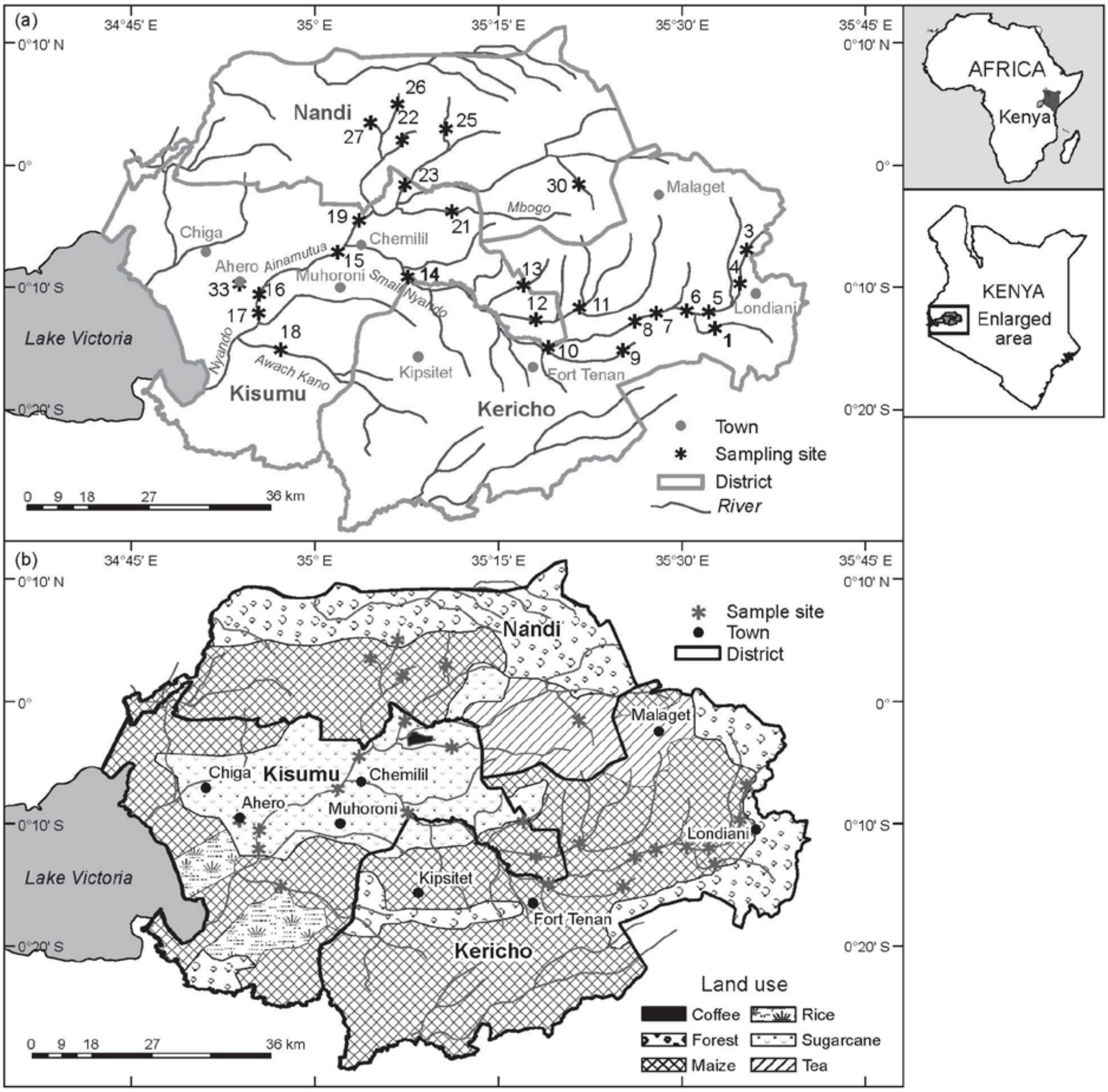

Figure 1: Map of the Nyando River drainage basin showing (a) rivers and locations of sampling sites, and (b) land use.

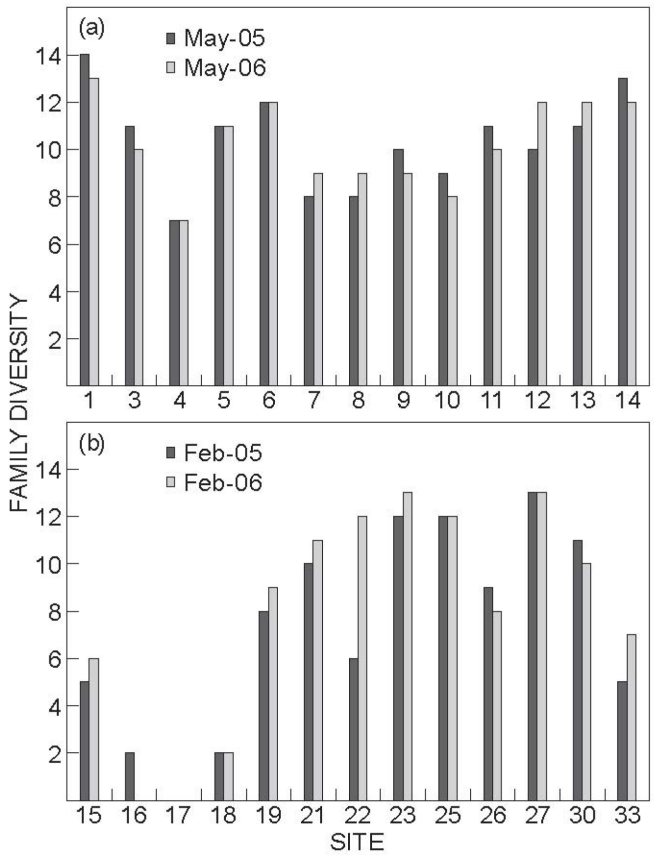

Figure 2: Macroinvertebrate diversity in (a) the Kericho-Upper Nyando subcatchment in 2005 and 2006; and (b) the Nandi-Lower Nyando subcatchment in 2005 and 2006.

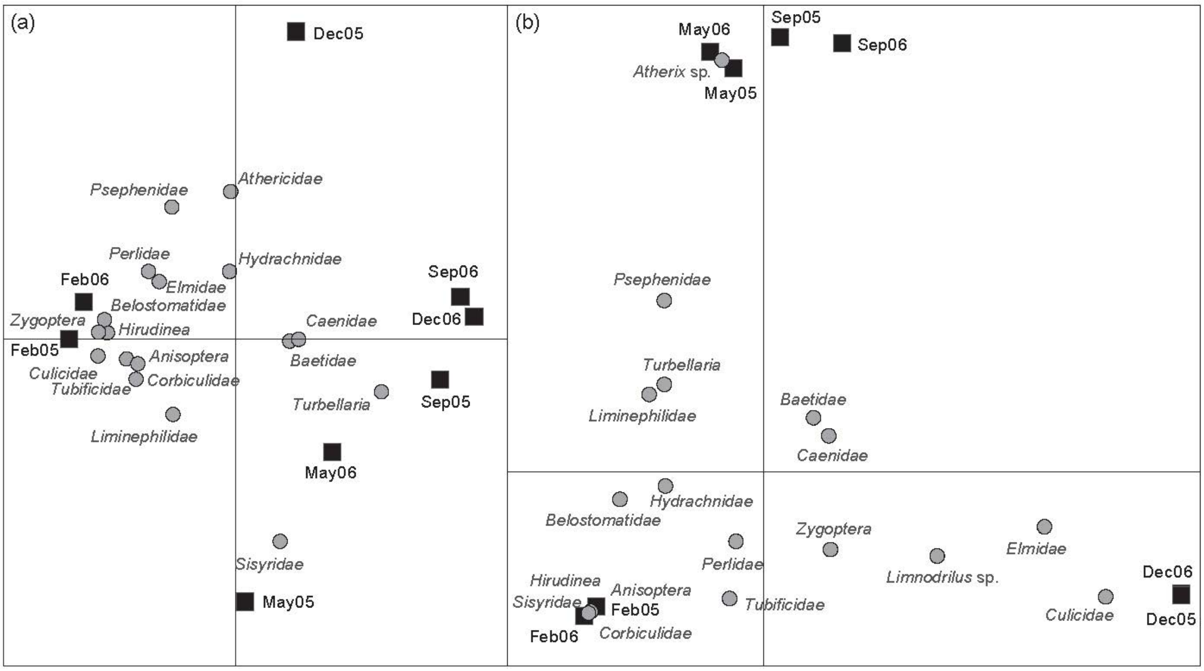

Figure 3: CCA diagram of variations in macroinvertebrate community composition in February, May, September and December 2005 and 2006 in (a) the Kericho-Upper Nyando subcatchment, and (b) the Nandi-Lower Nyando subcatchment.

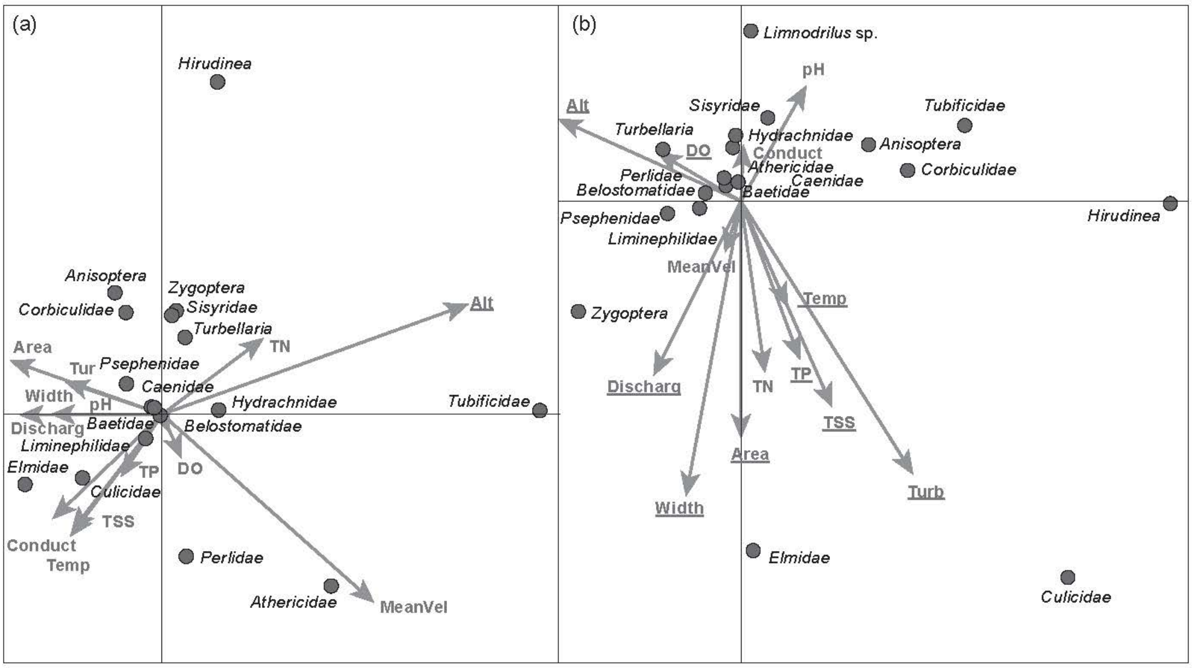

Figure 4: CCA diagram of variations in macroinvertebrate community composition in relation to the physico-chemical parameters in (a) the Kericho-Upper Nyando catchment and (b) the Nandi-Lower Nyando subcatchment. Underlined physico-chemical parameters explained a significant part of the variance ($p < 0.05$)

Table 1: Description of sampling sites in the Nyando River catchment.

Site no.	Name	Coordinates		Altitude (m)	Human activities around sites
		Latitude	Longitude		
		Kericho-Upper Nyando subcatchment			
1	Kedowa at bridge	0.234° S	35.545° E	2 290	Subsistence agriculture and depleted forest cover
3	Masaita at dam	0.135° S	35.602° E	2 310	Subsistence agriculture and depleted forest cover
4	Masaita at Londiani township	0.163° S	35.584° E	2 290	Human settlement, subsistence agriculture on river banks, cattle and sheep watering, raw sewage effluent discharge into the river
5	Masaita at Lambel farm	0.197° S	35.536° E	2 050	Cattle watering, subsistence agriculture
6	Kipchorian at Tuiyobei	0.190° S	35.512° E	2 000	Subsistence agriculture
7	Kimoson	0.207° S	35.464° E	1 920	Subsistence agriculture on river banks, cattle and sheep watering
8	Nyando at Kipkelion	0.207° S	35.462° E	1 920	Subsistence agriculture on river banks, cattle watering, recreation
9	Tugunon at bridge	0.250° S	35.415° E	2 000	Subsistence agriculture
10	Namting at Fort Ternna	0.204° S	35.347° E	1 560	Sugarcane farming, subsistence agriculture
11	Murgut at Koru	0.214° S	35.319° E	1 500	Sugarcane farming, subsistence agriculture
12	Pararget at bridge	0.212° S	35.301° E	1 500	Sugarcane farming, subsistence agriculture
13	Homa Lime	0.184° S	35.299° E	1 320	Sugarcane farming, subsistence agriculture on river banks, discharge of effluent from calcium carbonate factory
14	Nyando at Muhoroni bridge	0.166° S	35.184° E	1 280	Sugarcane farming, subsistence agriculture on river banks
		Nandi-Lower Nyando subcatchment			
15	Nyando at Ogilo	0.166° S	35.162° E	1 190	Sugarcane farming, subsistence agriculture, recreation
16	Nyando at Ahero bridge	0.172° S	34.921° E	1 170	Human settlement, livestock rearing, subsistence agriculture, solid wastes on river banks coupled with recreational activities
17	Nyando at dykes	0.201° S	34.929° E	1 150	Constructed dykes, discharge raw domestic sewage from Ahero town, cattle watering and recreational activities
18	Awach Kano	0.234° S	34.957° E	1 150	Irrigated rice farming cattle watering coupled with subsistence agriculture and recreational activities
19	Ainamutua-Kibigori	0.076° S	35.056° E	1 210	Sugarcane farming, cattle watering and subsistence agriculture and sand mining
21	Mbogo	0.061° S	35.148° E	1 270	Sugarcane farming, subsistence agriculture on river banks, recreational activities
22	Anopsiwa	0.030° N	35.118° E	1 320	Large-scale sugarcane farming, sand mining and recreat-ional activities
23	Anopngetuny	0.028° S	35.118° E	1 330	Large-scale coffee and sugarcane farming
25	Chemwanabei	0.065° N	35.188° E	1 820	Large-scale tea farming
26	Kapngorium at bridge	0.054° N	35.100° E	1 850	Human settlement, large-scale tea farming, subsistence agriculture, raw sewage effluent from tea factory
27	Kundos at bridge	0.051° N	35.062° E	1 850	Large-scale tea farming, subsistence agriculture
30	Chebirirkut at dam	0.037° S	35.348° E	1 820	Forest, no human settlement or activities
33	Ahero irrigation channel	0.172° S	34.908° E	1 150	Irrigated rice farming, cattle watering and recreational activities

Table 2: The density (individuals m^{-2}) and distribution of benthic macroinvertebrates in the Nyando River catchment in 2005-2006.

Taxon	Site no.												
	1	3	4	5	6	7	8	9	10	11	12	13	14
	Kericho-Upper Nyando, May 2005												
Turbellaria	2	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta													
Tubificidae	20	19	25	22	16	12	12	4	4	2	21	4	22
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea	36	10	15	26	33	28	33	28	10	25	9	1	14
Insecta													
Belostomatidae	34	16	20	21	17	15	18	8	12	23	10	14	22
Sisyridae				10									
Baetidae	188	24		211	182	14	12	88	169	126	125	59	150
Caenidae	49	10		39	66	3	8	65	55	20	18	38	61
Limnephilidae	17	11	24	22	19	28	48	9	15	52	65	5	24
Perlidae	63	3		21	79	25	16	45	46	36	26	1	11
Zygoptera	26				3				3	6		9	2
Anisoptera	12			10	6					1		4	2
Psephenidae	10	3	28		6						1		5
Elmidae	11	9	13	18	15	14	8	13	8	4	3	10	23
Culicidae	6												11
Athericidae	1	23						15					
Mollusca													
Corbiculidae	5	6	17	30	5			3		6	1	3	12
Total	**478**	**134**	**142**	**430**	**447**	**139**	**155**	**278**	**322**	**301**	**279**	**148**	**359**
	Kericho-Upper Nyando, May 2006												
Turbellaria	7	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta													
Tubificidae	35		39	1	1	1	5			6	6	1	17
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea	47	72	61	34	62	29	27	36	6	16	11	3	13
Insecta													
Belostomatidae	54	2	22	11	8	1	6	9	7	15	17	10	8
Sisyridae				4									
Baetidae	195	164		131	125	107	46	94	139	78	61	81	173
Caenidae	30	130		93	88	67	23	72	99	60	44	60	111
Limnephilidae													
Perlidae													
Zygoptera	34	29		64	35	35	28	21	27	20	71	12	11
Anisoptera	59	3		9	70	3	10	38	19	12	13	4	18
Psephenidae	4		10		8						3	3	
Elmidae	1			56	11					1	3	6	1
Culicidae	3	29	27		3	28			1		8	2	1
Athericidae	19	6	7	9	14	1	2	11	8	11	5	8	14
Mollusca													3
Corbiculidae	3	9						9					
Total	**484**	**444**	**166**	**412**	**425**	**272**	**147**	**290**	**306**	**219**	**242**	**190**	**370**
Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
	Nandi-Lower Nyando, February 2005												
Turbellaria	0	0	0	0	0	13	0	0	9	0	3	0	0
Oligochaeta													
Tubificidae	3	7		15	83			9	38	25	17	38	148
Hirudinea													
Arhynchobdellida				158				30					159
Acariformes													
Hydrachnoidea					7	41	8	34	45	14	18	21	
Insecta													
Belostomatidae	1				15	42	21	14	47	17	35	9	2
Sisyridae						2							
Baetidae	13				122	60	30	46	99	37	48	21	

Table 2: (cont.)

Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
Caenidae	8				51	26	18	34	45	32	37	12	
Limnephilidae	6				18	35		24	58	38	22	31	
Perlidae					4	48		22	67	31	23	14	
Zygoptera								3	3		19	2	
Anisoptera								14	3		7	7	
Psephenidae						3	4		9	3	28	3	
Elmidae						10	13	32	56	23	16		6
Culicidae												7	
Athericidae						8		15			15		
Mollusca													3
Corbiculidae		1			21				24		1		16
Total	**31**	**8**	**0**	**173**	**321**	**275**	**94**	**277**	**494**	**220**	**286**	**165**	**331**
	Nandi-Lower Nyando, February 2006												
Turbellaria	0	0	0	0	0	11	0	0	23	0	14	0	0
Oligochaeta													
Tubificidae				7	39		6	1	10	12	4	10	122
Hirudinea													
Arhynchobdellida				138				3					158
Acariformes													
Hydrachnoidea					4	18	13	13	15	12	11	28	
Insecta													
Belostomatidae	1				15	42	21	14	47	17	35	9	2
Sisyridae						2							
Baetidae	15				98	75	65	95	90	86	74	55	
Caenidae					10	50	50	65	80	68	65	32	
Limnephilidae	2				11	27	24	15	25	14	10	6	
Perlidae	3				4	7	10	42	35	61	6	5	3
Zygoptera						17	6	1			3	5	
Anisoptera	3					6	6	1	9		21	1	
Psephenidae									4		13		
Elmidae						6	14	5	21	11	6		2
Culicidae					3	3	1					2	15
Athericidae	4						6	1			11		
Mollusca													
Corbiculidae	6				10			1	19				10
Total	**27**	**0**	**0**	**145**	**187**	**219**	**210**	**268**	**316**	**300**	**229**	**154**	**309**

Table 3: Physical and chemical parameter values at sample sites in the Nyando River catchment in 2005-2006.

Site no.	Temp. (°C)	Conductivity (μS cm^{-1})	TSS (mg l^{-1})	DO (mg l^{-1})	pH	Turbidity (NTU)	TP (mg l^{-1})	TN (mg l^{-1})	Area (m^2)	Mean velocity (m s^{-1})	Discharge (m^3 s^{-1})	River width (m)
Kericho-Upper Nyando subcatchment, May 2005												
1	27.1	140	76	7.7	7.8	130	0.21	3.6	0.44	0.64	0.28	3.7
3	28.1	78	39	7.0	7.9	62	0.08	3.4	0.34	0.38	0.13	2.6
4	28.1	96	76	7.2	8.5	63	0.11	2.7	1.8	0.46	0.81	6.0
5	27.7	110	63	8.2	8.7	80	0.16	3.8	4.9	0.43	2.1	6.2
6	28.1	100	62	7.4	8.0	100	0.13	2.9	5.4	0.39	2.2	7.3
7	27.7	76	130	7.2	7.9	130	0.15	2.2	0.88	0.53	0.45	2.0
8	27.3	94	190	7.6	7.9	150	0.18	3.2	6.8	0.60	0.60	9.5
9	27.3	81	170	7.2	7.8	130	0.23	2.7	1.2	0.56	0.64	4.5
10	27.1	170	220	8.2	7.7	140	0.17	2.6	2.3	0.39	0.91	6.7
11	27.3	170	190	7.5	8.3	150	0.23	1.2	0.42	0.61	0.26	2.3
12	27.2	160	150	8.0	8.2	140	0.18	2.5	1.8	0.56	1.0	6.6
13	27.2	170	65	8.4	7.9	56	0.30	1.9	2.1	0.34	0.71	7.5
14	27.7	120	240	7.1	8.2	160	0.21	2.6	33.0	0.38	13.0	27.0
Kericho-Upper Nyando subcatchment, May 2006												
1	27.2	140	76	7.7	7.8	130	0.22	3.6	0.12	0.10	0.01	2.5
3	28.4	74	32	7.0	7.9	68	0.08	3.4	0.29	0.22	0.06	0.18
4	28.2	98	57	6.7	8.1	61	0.15	2.7	0.75	0.24	0.18	2.8
5	27.1	119	69	8.2	8.0	79	0.16	3.8	1.6	0.21	0.35	4.2
6	28.2	106	68	7.5	8.2	103	0.11	2.9	1.4	0.66	0.94	6.8
7	27.0	82	128	7.2	8.3	134	0.15	2.2	0.39	0.95	0.37	2.1
8	27.7	90	193	7.5	7.9	156	0.10	3.1	2.3	0.43	0.99	6.3
9	27.5	86	173	7.3	7.8	137	0.29	2.7	1.6	0.68	1.10	4.0
10	27.0	176	224	8.2	7.7	143	0.14	2.6	1.8	0.63	1.30	8.4
11	27.8	174	194	7.5	8.3	150	0.22	1.2	0.6	0.28	0.18	3.7
12	27.6	168	152	8.0	8.2	140	0.16	2.5	4.1	0.37	1.50	13.0
13	27.8	170	68	8.0	7.9	59	0.36	1.9	1.4	0.38	0.54	5.4
14	27.0	129	244	7.7	8.3	169	0.24	2.6	2.1	0.35	0.67	0.68
Nandi-Lower Nyando subcatchment, February 2005												
15	27.0	130	210	7.0	7.9	160	0.48	5.0	34	0.40	28.0	29.0
16	27.4	130	330	7.4	7.6	260	0.50	5.0	28	1.0	28.0	29.0
17	27.2	130	330	7.2	7.5	270	0.50	5.0	28	1.3	28.0	29.0
18	26.1	47	140	7.7	7.4	120	0.23	5.0	2.8	0.54	1.6	6.2
19	26.8	110	43	6.8	7.2	190	0.29	3.1	7.3	0.56	4.1	7.0
21	26.9	110	210	6.2	7.4	190	0.33	1.4	2.7	0.64	1.8	5.0
22	27.3	160	70	7.8	7.7	77	0.20	1.9	5.1	0.65	3.3	9.3
23	27.1	160	59	7.8	7.7	49	0.15	2.3	3.7	0.20	0.76	5.5
25	26.6	92	110	7.1	7.5	86	0.14	2.3	0.37	0.26	0.10	2.4
26	26.6	45	48	7.2	7.5	42	0.16	3.5	2.2	0.30	0.67	4.6
27	27.1	32	47	7.3	6.9	38	0.19	1.6	1.2	0.81	0.99	2.5
30	27.2	38	3.3	7.5	7.0	5.5	0.01	0.24	0.03	0.12	0.04	1.9
33	26.4	96	150	7.5	7.7	120	0.34	0.94	0.25	0.18	0.54	3.2
Nandi-Lower Nyando subcatchment, February 2006												
15	16.3	110	810	61	7.5	380	0.49	5.8	39	1.5	57	23
16	19.5	110	870	59	7.6	300	0.41	5.7	52	1.3	67	35
17	19.1	120	880	60	7.4	310	0.32	5.4	56	1.4	64	13
18	20.1	100	830	36	7.4	260	0.15	3.2	38	1.1	9.8	8.5
19	14.9	200	380	61	7.9	130	0.16	5.4	14	0.80	11	7.6
21	13.0	190	180	72	7.7	100	0.14	0.50	0.96	1.0	0.97	0.49
22	15.7	250	130	74	7.8	61	0.17	0.92	6.3	0.3	1.9	9.9
23	15.4	250	120	60	7.9	44	0.10	1.1	6.2	0.70	4.0	6.1
25	19.9	160	120	64	7.5	46	0.19	2.7	0.69	0.30	24	0.22
26	15.6	73	110	65	6.9	37	0.09	1.7	0.85	0.90	0.80	3.1
27	20.6	50	86	36	6.3	23	0.09	1.5	1.5	0.50	0.79	3.2
30	16.9	42	3.2	62	5.8	3.0	0.02	0.41	0.04	0.30	0.01	0.60
33	25.5	130	280	5.3	7.1	230	0.32	4.2	0.88	0.70	0.64	0.20

Appendix 1: Additional density (ind. m⁻²) and distribution data on benthic macroinvertebrates in the Nyando River catchment in February, May, September and December 2005–2006

Taxon	Site no.												
	1	3	4	5	6	7	8	9	10	11	12	13	14
	Kericho-Upper Nyando, February 2005												
Turbellaria													
Oligochaeta													
Tubificidae		3	5	8	3					13	2		5
Hirudinea													
Arhynchobdellida	2												
Acariformes				3									
Hydrachnoidea					8			9	1	8	10		
Insecta													
Belostomatidae													
Sisyridae													
Baetidae	6			51	62			19	17	21	13	33	30
Caenidae	3			27	32			13	10	11	9	23	19
Limnephilidae	5			9	6	2	3	19	40	32	21	2	56
Perlidae					4				10	14	4		
Zygoptera	2		4		3				4	2	11	2	14
Anisoptera				4	6		4	6	12	6	13		14
Psephenidae					8	1					4	3	
Elmidae					4				40		10	4	17
Culicidae					14						3	8	
Athericidae	7						4	2			9		
Mollusca													
Corbiculidae		2	5										
Total	**25**	**5**	**14**	**102**	**150**	**3**	**11**	**68**	**134**	**107**	**134**	**75**	**155**
	Kericho-Upper Nyando, February 2006												
Turbellaria													
Oligochaeta													
Tubificidae												1	
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea			12		12			7	3	12	18		
Insecta													
Belostomatidae	25							23	26	20	36	24	11
Sisyridae													
Baetidae	10												
Caenidae	5												
Limnephilidae	1			23	10	6	16	26	62	45	19	4	54
Perlidae			11						28	40	30		
Zygoptera			15	3	2						12		
Anisoptera					21						12		
Psephenidae					12						1	6	
Elmidae													
Culicidae											10		
Athericidae													
Mollusca													
Corbiculidae		9			20						1	11	
Total	**41**	**9**	**38**	**26**	**75**	**6**	**16**	**56**	**119**	**117**	**139**	**46**	**65**
Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
	Nandi-Lower Nyando, May 2005												
Turbellaria										5			
Oligochaeta													
Tubificidae		2		9	25				21	12			11
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea				80									112
Insecta													
Belostomatidae	3				10	30	2		37	24	15	5	7
Sisyridae													
Baetidae	15				19	11	32	6	14	7	19		

Appendix 1: (cont.)

Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
Caenidae	10				10	2	25	3	10	4	18		
Limnephilidae	8				11	11	11	9	7	6	6		
Perlidae					5	30		18	48	15	38	14	
Zygoptera	4				7	8		13	10	3	16	3	
Anisoptera								1	1		7	2	
Psephenidae					2	4	5	1	12	1	18	2	
Elmidae					15	8	12	21	30	10	9		10
Culicidae						3		8			15		
Athericidae		1											
Mollusca													
Corbiculidae		1			17				18				8
Total	**40**	**4**	**0**	**89**	**104**	**107**	**87**	**81**	**208**	**82**	**161**	**26**	**148**
	Nandi-Lower Nyando, May 2006												
Turbellaria	3			2				1					
Oligochaeta													
Tubificidae	2				24	3	2	1	7	1	5	3	80
Hirudinea													
Arhynchobdellida				120									142
Acariformes													
Hydrachnoidea					2	10	14	9	13	8	10	24	
Insecta													
Belostomatidae					10	10	20	15	16	12	26	7	2
Sisyridae						3							
Baetidae	17				82	64	30	70	65	23	75	40	
Caenidae	14				8	33	23	66	48	20	69	15	
Limnephilidae					2	19	15	13	23	10	12	2	
Perlidae					3	4	10	33	32	21	7	4	2
Zygoptera					10	3		1	6		19	2	
Anisoptera					3	3					3		
Psephenidae	4				1				6		10		
Elmidae						8	10	3	18	9	9		3
Culicidae					1	1	3	2	4		2	1	19
Athericidae								1	1		9		
Mollusca													
Corbiculidae					8			3	20		8		2
Total	**30**	**0**		**122**	**104**	**161**	**167**	**218**	**227**	**114**	**245**	**98**	**250**
Taxon	Site no.												
	1	3	4	5	6	7	8	9	10	11	12	13	14
	Kericho-Upper Nyando, September 2005												
Turbellaria	1												
Oligochaeta													
Tubificidae	2	2	11	3	7			4				4	
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea	6	1		20	14	10	22	8	10	5	9	1	14
Insecta													
Belostomatidae						1		1					
Sisyridae				10									
Baetidae	140	34		11	102			263	19	26	65		94
Caenidae	107	20		9	56			201	10	4	34		34
Limnephilidae								1					6
Perlidae	23	4		27	9	10	37	5	36	26	16		8
Zygoptera	3	1			5					2		2	4
Anisoptera	2			1	3					1		1	2
Psephenidae	3			6	2			5	9	12	2		7
Elmidae	6			8	10		20	4	5	6	5	1	20
Culicidae	6												11
Athericidae	1	4						7					
Mollusca													
Corbiculidae	4	3	2	10	4			5		7	3		
Total	**302**	**69**	**13**	**105**	**214**	**21**	**79**	**504**	**89**	**89**	**134**	**9**	**300**

Appendix 1: (cont.)

Taxon	Site no.												
	1	3	4	5	6	7	8	9	10	11	12	13	14
	Kericho-Upper Nyando, September 2006												
Turbellaria				4					2	3	1	2	
Oligochaeta													
Tubificidae		10	39	19	7	17	6	2	1	6	8		12
Hirudinea													
Arhynchobdellida			7										
Acariformes													
Hydrachnoidea	4	2		11	19	4	18	11	13	9	11		11
Insecta													
Belostomatidae	99	14	15	13	8	13	11	19	16	9	9	11	13
Sisyridae	8			4									
Baetidae	84	80		12	11		12	10	95	6	12		104
Caenidae	71	56		14	9		4	71	11	4	12		61
Limnephilidae	98	3	30	16	9	11	21	2	16	19	21		12
Perlidae	6			9	83	8	9	7	2	18	1	1	
Zygoptera					2					1	8		4
Anisoptera				8	7					1	2		7
Psephenidae				9	7				2		3	1	4
Elmidae				9	3	4	4	2	14		1		2
Culicidae											2		
Athericidae								1					
Mollusca													
Corbiculidae			11	21	14	1	17	4	4	9	8		1
Total	**370**	**165**	**102**	**145**	**179**	**58**	**102**	**129**	**158**	**85**	**99**	**15**	**231**

Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
	Nandi-Lower Nyando, September 2005												
Turbellaria										5			
Oligochaeta													
Tubificidae		2		9	25				21	12			11
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea				10						1			2
Insecta													
Belostomatidae	3				2	10	2		19	22	85	2	2
Sisyridae													
Baetidae	15				19	2	19	2	4	8	9		
Caenidae	10				10	1	11		2	4	14		
Limnephilidae	8						11		3				
Perlidae					2	11		10	21	14	11	6	
Zygoptera	6				3	6		4	8	2	9	4	
Anisoptera								1	1		7	2	
Psephenidae					6	1	7	3	1	1	6	2	
Elmidae					7	9	8	11	13	8	4		6
Culicidae						1		3			8		
Athericidae		2											
Mollusca													
Corbiculidae		1			9				20				11
Total	**42**	**5**	**0**	**19**	**83**	**41**	**87**	**34**	**112**	**77**	**153**	**14**	**33**
	Nandi-Lower Nyando, September 2006												
Turbellaria						7			9		14		
Oligochaeta													
Tubificidae				2	10		3	4	1	9	2	4	72
Hirudinea													
Arhynchobdellida				108									86
Acariformes													
Hydrachnoidea					1	10	13	17	3	2	11	28	
Insecta													
Belostomatidae	1				3	5	10	5	6	9	10	8	1
Sisyridae						1							
Baetidae	9				41	11	15	61	8		14	5	

Appendix 1: (cont.)

Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
Caenidae	2				6	9	10	40	3		8	2	
Limnephilidae	3				2	9	14	6	9	2	12	11	
Perlidae	1					5	7	2	8	6	6	5	3
Zygoptera						3	2				3	6	
Anisoptera	2					6	4	3	7		12	1	
Psephenidae									2		13		
Elmidae						3	8		3	3	4		2
Culicidae					2	2						2	10
Athericidae	3							2			9		
Mollusca													
Corbiculidae	3				2				8				4
Total	**24**	**0**	**0**	**110**	**67**	**71**	**86**	**140**	**67**	**31**	**109**	**72**	**178**
Taxon	Site no.												
	1	3	4	5	6	7	8	9	10	11	12	13	14
	Kericho-Upper Nyando, December 2005												
Turbellaria	2												
Oligochaeta													
Tubificidae	12	10	15	22	4	1	9	1	4	1	9	1	17
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea	20	2	10	13	12	4	12	11	12	13	6		12
Insecta													
Belostomatidae	18	1	11	9	11	1	15	5	9	10	7	2	15
Sisyridae				7									
Baetidae	108	3		100	99	3	20	65	104	92	94		112
Caenidae	31	11		34	72		4	24	38	31	10		38
Limnephilidae	6	9	2	17	10	3	16	5	7	41	41	1	18
Perlidae	13	8		18	11	2	8	12	21	20	11	1	17
Zygoptera	21				7				1	2		2	
Anisoptera	9			7	6							2	1
Psephenidae	8	1	4		3								2
Elmidae	10	3	2	4	4	1	5	11	6	1	1	4	11
Culicidae	5												6
Athericidae		4						12					
Mollusca													
Corbiculidae	2	1	2	3	1			1		2	2	2	7
Total	**265**	**62**	**46**	**234**	**240**	**14**	**89**	**147**	**202**	**213**	**181**	**15**	**256**
	Kericho-Upper Nyando, December 2006												
Turbellaria	3												
Oligochaeta													
Tubificidae	17		21	2	1	1	5			4	9		20
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea	19	31	12	29	32	2	20	26	4	12	9	2	17
Insecta													
Belostomatidae	20	2	10	24	6	1	2	7	4	13	12	4	2
Sisyridae				2									
Baetidae	105	86		101	110		21	3	107	61	54		123
Caenidae	21	72		86	96		17	61	84	54	41		98
Limnephilidae									1		2		6
Perlidae													
Zygoptera	10	7		55	25	12	12	18	9	17	69	9	15
Anisoptera	15	2		6	42	9	8	27	12	9	11	5	10
Psephenidae	3		2		5						2	1	
Elmidae				36	8						1	2	
Culicidae	1	9	13		1	17					2	1	
Athericidae	11	4	2	7	9	1	1	8	6	7	2	3	10
Mollusca													1
Corbiculidae	1	6						6					
Total	**227**	**219**	**60**	**348**	**335**	**43**	**86**	**156**	**227**	**164**	**214**	**27**	**302**

Appendix 1: (cont.)

Taxon	Site no.												
	15	16	17	18	19	21	22	23	25	26	27	30	33
	Nandi-Lower Nyando, December 2005												
Turbellaria										2			
Oligochaeta													
Tubificidae		1		9	16				10	9			7
Hirudinea													
Arhynchobdellida													
Acariformes													
Hydrachnoidea				7									98
Insecta													
Belostomatidae	1				9	17	2		19	9	9	2	5
Sisyridae													
Baetidae	9				9	9	11	7	9	3	11		
Caenidae	7				7		13	1	10	2	7		
Limnephilidae	5				10	4	9	4	9	3	4		
Perlidae					8			11	12	11	2	9	
Zygoptera	3				3	6		11	13	1	9	2	
Anisoptera									11		10	1	
Psephenidae					6	2	3		12		12		
Elmidae					14	9	7	19	12	13	6		6
Culicidae						2		5			4		
Athericidae		1											
Mollusca													
Corbiculidae		1			11				11				3
Total	**25**	**3**	**0**	**16**	**93**	**49**	**45**	**58**	**128**	**53**	**74**	**14**	**119**
	Nandi-Lower Nyando, December 2006												
Turbellaria	1			3				2					
Oligochaeta													
Tubificidae	1				19	1		1	4		7	1	74
Hirudinea													
Arhynchobdellida				109									139
Acariformes													
Hydrachnoidea					1	8	11	7	9	2	8	15	
Insecta													
Belostomatidae					9	11	12	9	9	3	12	5	1
Sisyridae						4							
Baetidae	10				67	59	11	65	52	7	69	31	
Caenidae	9				9	21	17	59	41	3	54	9	
Limnephilidae					1	13	13	9	17	5	10	1	
Perlidae					1	1	9	21	19	9	5	1	1
Zygoptera					18	1		2	4		12	1	
Anisoptera					2	2					1		
Psephenidae	3								2		7		
Elmidae						5	7	1	11	7	7		1
Culicidae							1	3	1		1		11
Athericidae								2			4		
Mollusca													
Corbiculidae					5			1	9		3		1
Total	**24**	**0**	**0**	**112**	**132**	**126**	**81**	**182**	**178**	**36**	**200**	**64**	**228**

Appendix 2: Additional physical and chemical parameter values at sampling sites in the Nyando River catchment in February, May, September and December 2005–2006

Site no.	Temp. (°C)	Conductivity (µS cm^{-1})	TSS (mg l^{-1})	DO (mg l^{-1})	pH	Turbidity (NTU)	TP (mg l^{-1})	TN (mg l^{-1})	Area (m^2)	Mean velocity (m s^{-1})	Discharge (m^3 s^{-1})	River width (m)
Kericho-Upper Nyando, February 2005												
1	27.1	120	76	7.7	7.8	126	0.21	3.65	0.44	0.64	0.28	3.7
3	28.1	78	32	7.0	7.9	62	0.08	3.44	0.34	0.38	0.13	2.6
4	28.1	96	77	7.2	8.1	62	0.11	2.71	1.75	0.46	0.81	7.0
5	27.7	111	63	8.2	8.0	80	0.16	3.81	4.87	0.43	2.09	6.2
6	28.1	103	62	7.4	8.0	103	0.13	2.92	5.41	0.39	2.15	7.3
7	27.7	76	126	7.2	7.9	133	0.15	2.15	0.88	0.53	0.45	2.0
8	27.3	94	193	7.6	7.9	149	0.18	3.12	6.76	0.60	0.62	9.5
9	27.3	81	167	7.2	9.8	133	0.23	2.71	1.17	0.56	0.64	4.5
10	27.0	167	217	8.3	7.7	142	0.17	2.57	2.32	0.39	0.91	6.7
11	27.3	170	194	7.5	8.3	148	0.22	1.21	0.42	0.61	0.26	2.3
12	27.2	163	149	8.0	8.2	141	0.18	2.49	1.80	0.56	1.04	6.6
13	27.2	169	65	8.4	7.9	56	0.30	1.89	2.06	0.34	0.71	7.5
14	27.7	125	240	7.1	8.2	160	0.21	2.61	33.30	0.38	12.91	27.0
Kericho-Upper Nyando, February 2006												
1	15.4	124	67	5.6	7.3	73	0.15	1.41	0.57	2.40	3.80	1.49
3	18.4	65	22	6.4	6.9	76	0.08	2.18	0.9	0.50	2.70	0.46
4	18.4	80	53	6.4	7.1	89	0.08	2.30	1.19	0.63	6.0	0.76
5	17.5	119	58	7.4	7.5	93	0.07	1.60	2.00	0.60	4.50	1.20
6	12.1	115	53	4.8	7.5	84	0.11	1.72	4.4	0.30	7.40	1.20
7	15.4	68	118	4.5	7.8	30	0.21	1.39	0.22	0.20	1.70	0.10
8	15.9	84	182	7.4	7.4	81	0.14	1.58	3.97	0.30	8.1	1.00
9	19.8	79	141	4.5	7.5	35	0.18	1.55	0.73	0.20	3.50	0.10
10	25.8	159	89	5.7	8.1	37	0.21	1.16	2.60	0.60	8.00	1.56
11	25.6	148	38	5.2	7.1	27	0.23	1.44	0.85	0.30	2.70	0.23
12	25.7	158	64	5.9	8.2	32	0.22	1.38	4.61	0.33	11.30	1.54
13	25.4	158	97	5.2	8.0	39	0.21	0.43	2.67	0.27	8.40	0.73
14	25.8	118	215	5.4	7.8	94	0.18	1.29	11.08	0.80	24.80	0.94
Nandi-Lower Nyando, May 2005												
15	27.0	130	206	7.0	7.9	156	0.48	5.03	34.50	0.40	28.00	29.0
16	27.4	126	331	7.4	7.6	263	0.49	5.00	27.52	1.02	27.96	28.6
17	27.2	127	334	7.2	7.5	268.	0.50	4.97	28.40	1.34	28.40	29.0
18	26.1	47	137	7.7	7.4	122	0.23	5.00	2.85	0.54	1.65	6.2
19	26.8	110	43	6.8	7.3	189	0.29	3.09	7.32	0.56	4.09	7.0
21	26.8	108	214	6.2	7.4	188	0.33	1.38	2.73	0.64	1.75	5.0
22	27.3	157	70	7.9	7.7	77	0.20	1.92	5.13	0.65	3.34	9.3
23	27.1	160	59	7.8	7.7	49	0.15	2.34	3.67	0.20	0.76	5.5
25	26.6	92	109	7.1	7.4	87	0.14	2.31	0.37	0.26	0.10	2.4
26	26.6	45	48	7.3	7.5	42	0.16	3.48	2.23	0.30	0.67	4.6
27	27.1	32	47	7.3	6.9	38	0.19	1.59	1.21	0.81	0.99	2.5
30	27.2	37	3.33	7.5	7.0	5.5	0.01	0.24	0.03	0.12	0.04	1.9
33	26.4	96	146	7.5	7.7	124	0.34	0.94	0.25	0.18	0.54	3.2
Nandi-Lower Nyando, May 2006												
15	27.0	130	207	7.0	7.9	156	0.48	5.03	10.50	0.45	11.00	16.00
16	27.5	126	331	7.4	7.6	263	0.23	4.04	24.50	0.46	12.50	32.00
17	27.1	128	337	7.4	7.8	98	0.21	4.29	1.01	0.36	1.10	3.94
18	26.1	47	26	7.7	7.4	122	0.29	3.12	2.15	0.76	1.65	5.80
19	25.0	107	217	7.9	7.5	138	0.23	1.9	1.34	0.38	1.98	4.15
21	26.9	108	214	6.2	7.4	188	0.33	1.38	1.98	0.31	0.61	4.40
22	27.3	157	70	7.9	7.7	77	0.20	1.92	3.39	0.33	1.14	8.10
23	27.1	160	59	7.8	7.7	49	0.15	2.34	0.78	0.62	0.48	4.60
25	26.6	92	109	7.1	7.4	87	0.14	2.31	0.32	0.27	0.09	0.32
26	26.7	45	48	7.3	7.5	42	0.16	3.48	0.73	0.60	0.04	2.70
27	26.0	32.	47	7.4	6.9	38	0.18	1.59	0.54	0.26	0.23	2.60
30	27.2	37	0.09	7.5	7.0	5.5	0.01	0.07	0.04	0.25	0.10	0.40
33	26.4	96.	146.	7.1	7.7	124	0.37	3.97	0.5	0.86	0.04	1.80

Appendix 2: (cont.)

Site no.	Temp. (°C)	Conductivity (μS cm^{-1})	TSS (mg l^{-1})	DO (mg l^{-1})	pH	Turbidity (NTU)	TP (mg l^{-1})	TN (mg l^{-1})	Area (m^2)	Mean velocity (m s^{-1})	Discharge (m^3 s^{-1})	River width (m)
Kericho-Upper Nyando, September 2005												
1	26.3	60	500	9.0	7.0	370	0.25	4.2	1.9	1.1	2.1	3.7
3	25.9	66	270	7.5	6.8	150	0.19	4.8	0.47	0.34	0.16	2.2
4	22.9	58	130	8.2	6.8	190	0.29	3.8	4.6	0.77	3.6	2.6
5	26.4	58	410	7.7	7.1	340	0.34	3.3	8.5	0.92	7.9	6.1
6	26.8	67	430	6.6	7.1	270	0.31	3.5	5.2	0.42	2.2	7.7
7	26.2	200	12	8.4	7.9	33	0.17	3.3	0.26	0.23	0.06	1.6
8	26.1	68	420	8.4	7.1	280	0.37	3.5	0.38	0.17	0.06	2.0
9	26.5	90	46	7.9	7.6	84	0.22	3.3	0.61	0.23	0.14	3.5
10	26.0	100	200	8.6	7.5	150	0.28	3.4	3.8	0.69	2.6	9.6
11	25.1	370	34	5.6	8.1	39	1.7	4.3	0.56	0.39	0.22	1.8
12	27.2	200	130	7.5	8.2	29	0.25	2.9	0.88	0.84	0.74	3.0
13	26.9	120	130	7.6	7.8	28	0.41	3.2	0.81	0.22	0.18	7.6
14	26.7	120	98	7.6	7.5	90	0.27	2.6	2.0	0.23	0.47	7.1
Kericho-Upper Nyando, September 2006												
1	26.3	60	500	8.0	7.1	370	0.25	4.2	3.7	0.19	0.72	8.2
3	26.5	66	270	7.5	6.7	150	0.19	4.8	0.47	0.34	0.16	2.2
4	26.2	58	140	8.2	6.8	190	0.29	3.8	2.5	0.51	1.3	6.8
5	26.4	58	400	7.6	7.1	340	0.34	3.3	3.5	0.45	1.5	5.7
6	26.8	67	430	6.6	7.1	270	0.32	3.5	5.2	0.42	2.2	7.7
7	26.2	200	27	8.4	7.9	33	0.17	3.3	0.26	0.23	0.06	1.6
8	26.1	68	430	8.3	7.1	280	0.37	3.5	5.0	0.41	2.1	9.3
9	26.5	90	47	7.9	7.6	84	0.22	3.3	0.61	0.23	0.14	3.5
10	26.0	100	200	7.9	7.6	87	0.28	3.4	3.8	0.69	2.6	9.6
11	25.1	370	34	5.6	8.1	39	1.72	4.3	0.56	0.39	0.22	1.8
12	27.4	200	130	7.5	8.2	29	0.25	2.9	5.6	0.64	3.4	14.0
13	25.9	60	130	8.3	7.1	370	0.41	3.2	0.81	0.22	0.18	7.6
14	26.7	120	190	7.6	7.5	90	0.27	2.6	10	0.33	3.4	24.0
Nandi-Lower Nyando, September 2005												
15	26.5	120	230	7.8	7.4	90	0.34	4.0	40.0	0.52	20.0	33.0
16	27.3	100	340	6.5	7.2	160	0.46	3.8	35.0	0.53	18.0	49.0
17	26.7	130	340	7.8	7.5	190	0.49	3.3	20.0	0.93	18.0	17.0
18	26.2	48	100	8.4	7.0	92	0.27	2.6	3.7	0.19	0.72	8.2
19	27.3	120	240	7.7	7.7	100	0.46	3.2	3.5	0.57	2.0	11.0
21	26.2	180	78	7.1	7.9	67	0.13	2.2	8.5	0.92	7.8	7.1
22	25.7	120	290	7.2	8.0	100	0.19	3.6	1.9	0.25	0.49	4.3
23	25.4	250	44	8.6	8.1	33	0.15	2.4	2.1	0.49	0.49	4.8
25	25.0	200	92	25.0	7.8	60	0.19	3.4	0.43	0.37	0.16	2.4
26	26.0	71	52	7.7	7.49	38	0.07	3.6	0.60	0.46	0.27	1.7
27	24.5	68	34	6.0	7.19	27	0.06	2.0	0.95	0.30	0.29	2.6
30	25.5	68	36.0	6.0	7.19	27	0.01	0.02	1.5	0.51	0.77	2.6
33	25.3	130	8.00	7.2	6.21	6.5	0.96	2.9	0.99	0.10	0.12	0.4
Nandi-Lower Nyando, September 2006												
15	26.5	120	230	7.8	7.4	90	0.34	4.0	40.0	0.52	20.0	33.0
16	27.3	100	340	6.5	7.2	160	0.46	3.8	35.0	0.53	18.0	49.0
17	26.7	130	340	7.8	7.5	190	0.49	3.3	20.0	0.93	18.0	17.0
18	26.2	48	100	8.4	7.0	92	0.27	2.6	3.7	0.19	0.72	8.2
19	27.3	120	240	7.7	7.8	100	0.46	3.2	3.5	0.57	2.0	11.0
21	26.2	180	78	7.1	7.9	67	0.13	2.2	8.5	0.92	7.8	7.1
22	25.7	120	290	7.2	8.0	100	0.19	3.6	1.9	0.25	0.49	4.3
23	25.4	250	44	8.6	8.1	33	0.15	2.4	2.1	0.49	0.49	4.8
25	25.0	200	92	25.0	7.8	60	0.19	3.4	0.43	0.37	0.16	2.4
26	26.0	71	52	7.7	7.5	38	0.07	3.6	0.60	0.46	0.27	1.7
27	24.5	68	34	6.0	7.2	27	0.06	2.0	0.95	0.30	0.29	2.6
30	25.5	68	36	6.0	7.2	27	0.01	0.02	1.5	0.51	0.77	2.6
33	25.3	130	8.0	7.2	6.2	6.5	0.96	2.9	0.99	0.10	0.12	0.4

Appendix 2: (cont.)

Site no.	Temp. (°C)	Conductivity (µS cm⁻¹)	TSS (mg l⁻¹)	DO (mg l⁻¹)	pH	Turbidity (NTU)	TP (mg l⁻¹)	TN (mg l⁻¹)	Area (m²)	Mean velocity (m s⁻¹)	Discharge (m³ s⁻¹)	River width (m)
Kericho-Upper Nyando, December 2005												
1	15.4	150	28	56	7.3	73	0.15	1.4	0.57	2.4	1.4	1.3
3	18.4	130	79	64	6.9	75	0.08	2.2	0.90	0.50	0.46	1.2
4	18.4	130	53	64	7.1	89	0.08	2.3	1.2	0.63	0.76	2.6
5	17.5	140	31	74	7.5	93	0.07	1.6	2.0	0.60	1.2	7.8
6	12.1	140	29	48.0	7.5	84	0.11	1.7	4.4	0.27	1.20	4.1
7	15.4	310	53	44.0	7.8	30	0.21	1.4	0.22	0.15	0.11	2.6
8	15.9	160	62	74.0	7.4	81	0.14	1.6	4.0	0.25	1.0	2.4
9	19.8	170	31	45.0	7.5	35	0.19	1.6	0.73	0.15	0.11	4.3
10	25.8	310	88	5.7	8.1	36	0.21	1.2	2.6	0.62	1.6	6.1
11	25.6	130	38	5.2	7.1	230	0.23	1.4	0.85	0.26	0.25	2.1
12	25.7	320	64	5.9	8.2	31	0.22	1.4	4.6	0.33	1.5	4.7
13	25.4	300	97	5.2	8.0	38	0.21	0.43	2.7	0.27	0.73	4.0
14	25.8	240	160	5.4	7.8	93	0.18	1.3	11.0	0.83	0.93	13.0
Kericho-Upper Nyando, December 2006												
1	14.9	160	24	6.9	7.7	69	0.06	1.4	0.12	0.05	0.01	3.3
3	19.4	130	41	6.0	7.8	79	0.05	2.7	0.43	0.26	0.11	2.4
4	17.8	130	3.3	6.0	7.7	91	0.03	2.0	0.54	0.31	0.17	7.0
5	16.9	140	14	7.6	7.5	98	0.03	2.4	0.92	0.37	0.35	3.9
6	13.0	140	0.03	5.2	7.7	79	0.03	0.20	1.1	0.32	0.36	6.9
7	14.8	310	30	5.8	8.2	34	0.10	0.79	0.10	0.03	0.004	1.2
8	15.0	170	28	8.2	8.2	89	0.05	1.4	0.95	0.28	0.27	7.8
9	21.3	160	20	5.0	8.0	29	0.05	0.44	0.53	0.18	0.12	2.5
10	26.1	320	40	6.3	7.8	41	0.14	0.73	1.7	0.41	0.42	7.9
11	24.6	130	25	6.0	8.6	220	0.25	0.83	0.32	0.10	0.03	12.0
12	25.3	320	78	6.2	8.8	36	0.26	0.69	1.6	0.19	0.31	7.9
13	26.0	130	36	4.8	8.8	40	0.25	0.53	0.77	0.09	0.08	24.0
14	23.9	320	22	6.0	8.4	89	0.14	0.95	3.9	0.34	1.4	21.0
Nandi-Lower Nyando, December 2005												
15	15.4	150	28	56.0	7.3	73	0.15	1.4	0.57	2.4	1.4	1.3
16	18.4	130	79	64.0	6.9	75	0.08	2.2	0.90	0.50	0.46	1.2
17	18.4	130	53	64.0	7.1	89	0.08	2.3	1.2	0.63	0.76	2.6
18	17.5	140	31	74.0	7.5	93	0.07	1.6	2.0	0.60	1.2	7.8
19	12.1	140	29	48.0	7.5	84	0.11	1.7	4.4	0.27	1.20	4.1
21	15.4	310	53	44.0	7.8	30	0.21	1.4	0.22	0.15	0.11	2.6
22	15.9	160	62	74.0	7.4	81	0.14	1.6	4.0	0.25	1.0	2.4
23	19.8	170	31	45.0	7.5	35	0.19	1.6	0.73	0.15	0.11	4.3
25	25.8	310	88	5.7	8.1	36	0.21	1.2	2.6	0.62	1.6	6.1
26	25.6	130	38	5.2	7.1	230	0.23	1.4	0.85	0.26	0.25	2.1
27	25.7	320	64	5.9	8.2	31	0.22	1.4	4.6	0.33	1.5	4.7
30	25.4	300	97	5.2	8.0	38	0.21	0.43	2.7	0.27	0.73	4.0
33	25.8	240	160	5.4	7.8	93	0.18	1.3	11.0	0.83	0.93	13.0
Nandi-Lower Nyando, December 2006												
15	17.6	310	250	6.7	7.7	380	0.71	2.7	7.2	0.35	2.5	43.0
16	20.0	250	19	6.3	7.6	310	0.53	2.3	12	0.16	2.0	51.0
17	18.6	220	20	6.8	7.8	310	0.32	1.6	5.0	0.40	2.0	48.0
18	21.0	110	13	4.6	7.6	270	0.12	1.2	1.3	0.05	0.07	23.0
19	15.9	200	17	6.2	8.0	130	0.11	0.53	5.0	0.44	2.2	3.9
21	14.0	190	34	7.7	8.1	100	0.15	0.25	1.5	0.12	0.19	7.8
22	14.8	260	16	6.9	8.3	68	0.09	0.60	5.1	0.08	0.41	4.9
23	16.1	250	44	6.2	8.4	48	0.09	0.90	0.52	0.36	0.19	1.9
25	21.0	150	48	6.9	8.1	49	0.11	1.6	0.40	0.22	0.09	3.0
26	14.8	70	28	7.1	7.7	42	0.09	1.6	0.76	0.59	0.45	2.3
27	22.0	49	48	4.6	7.9	21	0.11	0.99	0.63	0.23	0.15	2.1
30	17.3	17	0.01	7.0	7.2	2.0	0.01	0.04	0.06	0.08	0.01	0.60
33	24.8	130	14	4.0	7.8	230	0.21	0.54	0.48	0.06	0.03	1.9