Small reservoirs water quality monitoring using plankton abundance and diversity

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Scope: questions/ challenges the tool addresses

Rural populations often are heavily dependent on small reservoirs for their water supply, and it is widely accepted that land use has a large impact on water quality in these reservoirs. Water quality can be defined in terms of its physical, chemical and biological (including bacteriological) characteristics (Straskraba and Tundisi, 1999). Which characteristics are considered important depends on the intended use of the water.

Approaches that look at ecosystem integrity can be used to assess water quality. Some of these approaches are based on the response of specific biological species to water quality. Among aquatic biota, microorganisms are generally highly sensitive and their dynamics can be seriously affected by environmental perturbation. Bacteria, phytoplankton and zooplankton have fast growth rates and therefore can provide meaningful and quantifiable indicators of ecological change in short timescales (Paerl et al. 2003). Moreover, these organisms can respond to low levels of pollutants such as pesticides, often a major anthropogenic stress on natural communities (Relyea 2005). This tool uses plankton (zooplankton and phytoplankton) abundance and diversity to measure water quality. Changes in abundance and diversity of these organisms represent direct and profound responses to pollution entering reservoirs.

Target group of the tool

Water resource managers, environmental specialists, health personnel, and water users

Requirements for tool application

The tool requires an understanding of aquatic biology and the processes and procedures used in assessing aquatic ecology. For zooplankton collection, a net of 40 cm diameter and 62µm mesh size is needed. For phytoplankton collection a similar net is needed of 40 cm diameter and 20µm mesh size. A 4% formalin solution (for zooplankton) and Lugol solution (for phytoplankton) are required for sample preservation after collection. An inverted microscope is required for phyto taxa identification and counting. A binocular microscope is used for zooplankton. Dichotomic keys are required for identification of taxa. Tool users must have the capacity to interpret results correctly and express them clearly.

Tool: description and application

Methodology

The small reservoirs to be assessed for plankton abundance and diversity are selected based on their main uses. The kinds of analysis described below are especially relevant for reservoirs where water is used for direct household consumption and for livestock watering. An important part of this analysis is to document land use activities and settlements around reservoirs and in the watershed upstream of the dam, as well as erosion, and pollution types and sources.

Zooplankton samples are collected with a zooplankton net of 40 cm diameter and 62µm mesh size while phytoplankton samples are collected using similar nets of 20µm mesh size. The samples are collected using the standardized method presented in Edmondson and Winberg (1971). The concentrated samples are collected in small 130 ml bottles that are labelled. Samples are collected from each reservoir at a horizontal line situated at 10 to 20 m facing the dam wall. Four samples are collected for zooplankton and four for phytoplankton.

A preservation solution of 4% formalin is added to the sample bottles of zooplankton and Lugol solution is added to the bottles containing phytoplankton for fixing purposes. The samples are then taken to an appropriate laboratory. Taxa are identified and counted under an inverted microscope OLYMPUS CK40 (or equivalent) and pictures of the various species are taken using a digital camera (e.g., NIKON model E995) mounted on the inverted microscope. Taxa are identified according to dichotomic identification keys (Durand and Lévêque 1980; Cander-Lund and Lund 1995; Fernando 2002).

If possible, clusters of small reservoirs should be used for solid statistical analysis of the data. Reservoirs can then be grouped in terms of species composition and abundance. Zooplankton and phytoplankton taxa can also be grouped to ascertain the extent to which they co-occur in reservoirs. Correlations between all means are computed, including for the abiotic data. Graphs are drawn and analyses, such as Spearman's rank correlations, are calculated using appropriate statistical software (e.g., SigmaPlot, SPSS and Statistica software packages). A Simpson's index of diversity D (a measure of diversity which takes account of species richness and evenness[1], which is 1-D) is calculated as follows:

$$D = \sum (n/N)^2$$

with n = the total number of organisms of a particular species;

N = the total number of organisms of all species.

The value of this index ranges from 0 to 1. The greater the value, the greater the sample diversity.

[1] http://www.countrysideinfo.co.uk/simpsons.htm

Results in the Limpopo Basin

Phytoplankton

The tool was applied in the Limpopo basin during February and April 2005 in reservoirs located in communal areas (supposedly in denuded surroundings and degraded condition) and in Matopos National Park (supposedly in pristine condition). Results are summarized below.

The most abundant taxon was *Hydrodictyon spp.,* which accounted for an average of 30% of the overall phytoplankton sampled in April. *Hydrodictyon* was followed by *Anabaena* (19.9%), *Peridinium* (15.7%), and *Melosira* (11.7%), all sampled in April. *Hydrodictyon* was very rare during in the February sampling, accounting for only around 0.1% of the level found in the April sampling. The February phytoplankton sampling showed an abundance of *Melosira* (18.7%) followed by *Ceratium hirundinella* (17.3%) and *Pinnularia* (11.9%). It was noted that the taxa collected in April were much more abundant than in February (84% in April vs. 15.8% in February).

Although phytoplankton were more abundant in April, there was a greater diversity of taxa in February. Chlorophytes constituted the major group in both periods with 29 genera in February and 20 in April. Chlorophytes were followed by bacillariophytes (diatoms) with 17 genera observed in February compared to 12 in April. Cyanophytes (5 genera), euglenophytes (4 genera), Fungi (3 genera), dinophytes (2 genera), xanthophytes (1 genus) and canophytes (2 genera) were also observed in February. In the April sampling, the comparable incidence was: Cyanophytes (4 genera) and euglenophytes (2 genera).

There was no significant difference in phytoplankton species composition between February and April (Spearman's rank correlation coefficient $r_s = 0.203$, N=71). The Student's t-test did not show any significant difference between February and April's phytoplankton species either ($t = -1.71$; $P = 0.087$; $N = 71$).

Reservoirs in the National Park were significantly (Student's $t = 21.0$; $df = 1$; $P = 0.03$) more diversified in taxa compared to those in the communal lands, with 49 taxa against 38 sampled in February and 32 against 22 taxa identified in the samples of April (Figures 1 and 2). Also it was found that phytoplankton communities were more diverse in February on both communal lands and within the National Park (Student's $t = 33.0$; df=1; $P = 0.019$).

A significant correlation was found between the phytoplankton diversity recorded in communal lands and in the National Park, and between February and April, using the Spearman's rank correlation coefficient ($r_s = 1.000$, n=2, $p < 0.01$ level (2-tailed)). The Simpson's index of diversity confirmed that the highest as well as the lowest indices were recorded in the National Park respectively in February and in April. The diversity in communal lands was consistently high.

Zooplankton

The zooplankton community investigated was represented by common freshwater groups, the crustacean cladocerans and copepods (Cyclops and Calanoids) and rotifers. A few individuals belonging to the Ostracods group were also recorded. The zooplankton community was dominated in February by copepods; Cyclopes having 28.6 % followed by their youngsters (Nauplii) with 15.2%, the rotifer *Keratella* (14.2%) and copepod *Calanoids nauplii* (13%).

Communal lands had the highest zooplankton abundance in both February and April samples with respectively 63% and 57%. The Cyclopes were again dominant in April with 27 % of the total abundance followed by their nauplii, a cladoceran species, the rotifers *Keratella* and *Brachionus* all constituting some 10% each. There was no significant difference in species composition for the student's t-test between communal lands and National Park in February (t=1.41; P=0.17; df=14) and in April samples (t = 1.13; P = 0.27; df = 14). Seasonal differences in zooplankton distribution and abundance were seen in both the communal lands and National Park (Figures 1 and 2). Copepods (composed of Cyclopoids and Calanoids) dominated the samples, comprising 60% of total zooplankton abundance in February and 49 % in April. Ostracods were not found in February samples. Few Ostracods were recorded in April in Chitampa reservoir and Maleme reservoir, both located in the Matopos National Park.

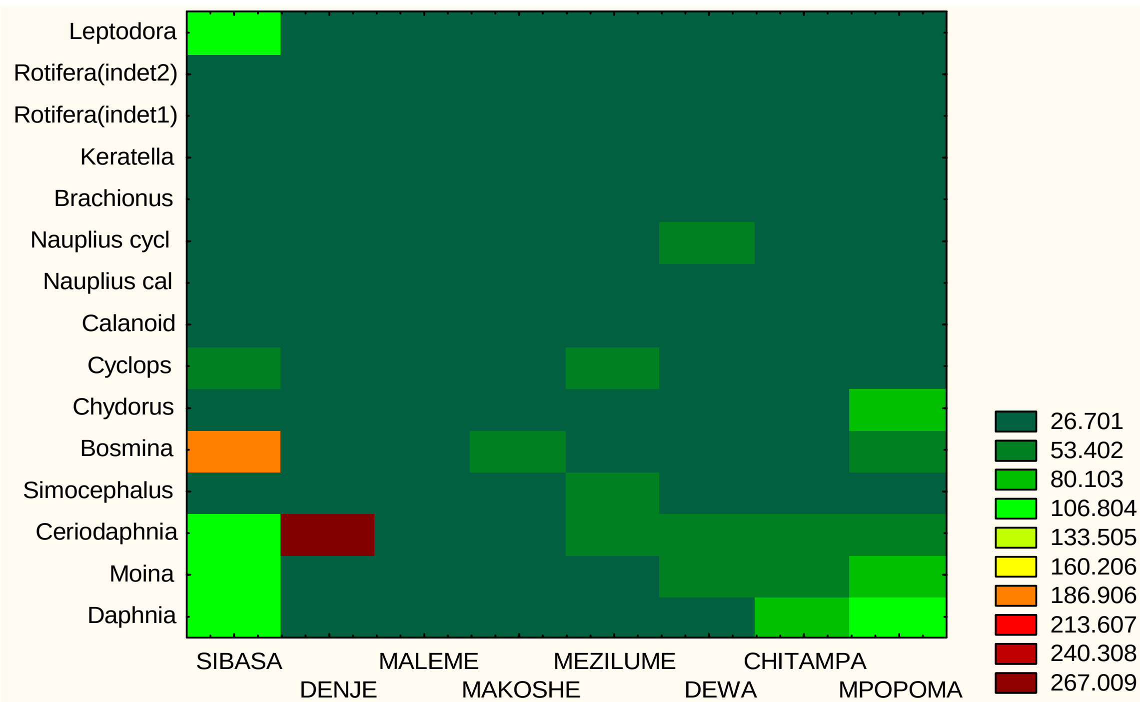

Figure 1. Zooplankton species distribution and abundance (numbers of zooplankton per liter on the right) among the 8 reservoirs (x-axis) in February

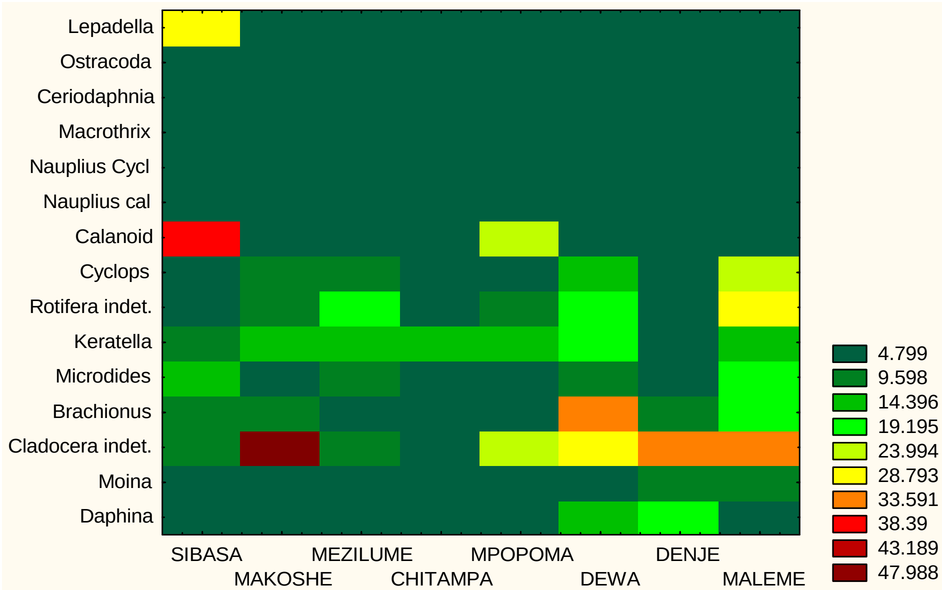

Figure 2. Zooplankton species distribution and abundance (numbers of zooplankton per liter on the right) among the reservoirs (x-axis) in April

Lessons learned

Plankton forms the basis of ecosystem survival-pyramid food chains. A healthy plankton base is needed to support the ecosystem. Although interesting results were obtained, it is important to note that monitoring should ideally be done once or twice a month. This would allow the capture of seasonal results. Plankton diversity and abundance is quite dynamic, so results have to be interpreted with care.

Bio-monitoring of water quality is important because it can indicate the health of the environment. Residents in communal lands are expected to complement scientific measurements with basic qualitative information such as algal blooms and changes in water colour and smell (these have implications concerning water quality and the ability of rural people to use the water). With water being central to Millennium Development Goals (MDGs), water health is an important area that needs constant monitoring.

Recommendations

There is a need for complementary research to explain biological results: pH, conductivity, depth of reservoir, transparency (secchi disk and light attenuation), nutrients, vertical profiling of the thermal (and oxygen) structure of the water column, and so on. (See Ka et al., 2006 for zooplankton and Arfi et al., 2003 for phytoplankton).

Reservoirs from areas with different land use patterns should be monitored. In this way, the consequences of changes in land use on ecosystem integrity can be indicated by plankton abundance and diversity. This information can help in the development of plans to mitigate negative effects. It is crucial to monitor reservoirs over a long period of time to account for the water quality variations. Water in reservoirs may not be made suitable for all water uses: each use has its own water quality standard. It is more practical to use the water for those purposes for which it is suitable for, and to put some effort into maintaining those particular standards.

Maintenance of vegetation cover is highly recommended as it acts as a buffer to influxes of elements. In order to have integrated watershed and water quality management, there is a need for modelling studies on ground water quality (complementing the surface water studies - water is a continuum!), sediment quality and non point source pollution.

Limitations of the tool

Many zooplankton species migrate daily from the bottom to the open water of reservoirs (scattering in the water column during the night while they stand near the bottom during the day). Ideal zooplankton samplings are thus performed at night. Alternatively, daily sampling can be performed vertically (from a boat), from the sediment up to the surface.

Phytoplankton and zooplankton constitute only a fraction of the planktonic pelagic food web: bacteria can also have a dramatic influence on primary productivity in many small reservoirs (see Bouvy et al., 1998). These influences extend to diversity. Both top-down (predation) and bottom-up (resources) controls act simultaneously to structure the pelagic planktonic communities (see Pagano et al., 2003). This means that surrounding information is required.

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