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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Socio-Ecological System Management

Managing the lower Phongola river system

A Water Research Commission (WRC) study investigated socio-ecological system management of the lower Phongola river and floodplain using the relative risk methodology.

Background and Rationale

The construction of the Pongolapoort Dam in the Phongolo River started in 1960 with the purpose to supply irrigation water for the proposed sugarcane and cotton plantations in the adjacent floodplain, the Makhathini flats.

The floodplain of approximately 10 000 ha increases in size to 13 000 ha at full inundation. The floodplain extends to the confluence of the Phongolo and Usutu Rivers in Ndumo Game Reserve (NGR) up to the border with Mozambique.

Ndumo was proclaimed a game reserve in 1924 with the primary objective being strict protection of its biodiversity. Today, NGR is a RAMSAR site because of its unique wetlands, which is particularly rich in bird species.

Surrounding the NGR is communal areas that are heavily dependent on resources from the floodplain. However, the environmental sustainability of the floodplain has been questioned over time.

Following an earlier ecological study of the floodplain system it was suggested that the ecosystem infrastructure of the Phongolo floodplain be maintained through controlled flood releases that were introduced to simulate the flood regime prior to the construction of the dam wall.

The controlled flood releases were required to mimic the annual inundation of the floodplain. Although there are proper protocols for water releases they seem to be ignored and therefore not in accord with ecological needs.

The environmental flow requirements to maintain the physical and chemical structure, biodiversity, ecosystem processes and functions in the Lower Phongolo River and floodplain are therefore not met in most cases.

Since the construction of the Pongolapoort Dam, there have been no major ecological studies that have monitored the floodplain wetlands of the Phongolo River. Very little is therefore known about the current ecological state as well as functioning and structure of the floodplain as a whole.

The health and diversity of the fish, amphibians, water-associated birds and invertebrate communities have not been assessed recently. Information of this nature is needed for setting Environmental Flow Requirements (EFRs) and targeted conservation measures.

Scientists and water resource managers need relevant information on the Lower Phongolo River and floodplain for the application and revision of protocols for water releases from the Pongolapoort Dam. It is important to note that the study was requested partly by Ezemvelo KZN Wildlife in order to address the concerns of the local and regional stakeholders.

Many of the environmental concerns emanated from the lack of information. This project was therefore conceptualised with one of the key aims being to conduct an integrated regional scale risk assessment of the Lower Phongolo River and floodplain using the Relative Risk Model (RRM) to establish and evaluate threats to the ecosystem.
The findings were then to be assimilated as an input into a conservation management plan drafted by Ezemvelo KZN Wildlife.

Methodology

Thirteen sampling sites situated in two Ecoregions were selected in the study area (see Figure 1). Three sites were in the Lebombo Uplands Ecoregion with a site immediately below the dam wall and two sites in the Ngwavuma River. Ten sites were selected in the Lowveld Ecoregion with six sites associated with floodplain pans in the Lowveld Ecoregion.

Of these six sites four were in the Ndumo game Reserve and in the communal areas. Two of the river sites were in the Phongolo River and one was selected in the Usutu River and used as a reference site. The sites were carefully selected to include habitats where relevant information could be gathered to meet all the aims set for the study.

Five surveys were undertaken from November 2012 to April 2014 to include two low-flow or dry-season and two high-flow or wet-season surveys. The Present Ecological State assessment using PAI, VEGRAI, GAI, MIRAI and FHAI was followed, while the socio-economic investigation used a mixed qualitative and quantitative set of interviews conducted in the broader area of Jozini municipality and Ndumo community.

The spatial scope of the RRM selected was the Phongolo River and its associated floodplain pans from below the Pongolapoort Dam, down to the Mozambique border. It extends for approximately 50 km in length with an adjacent floodplain pan system of 130 km^2. Risk regions were defined based on the degree of interaction of human communities with the river and associated floodplain pans.

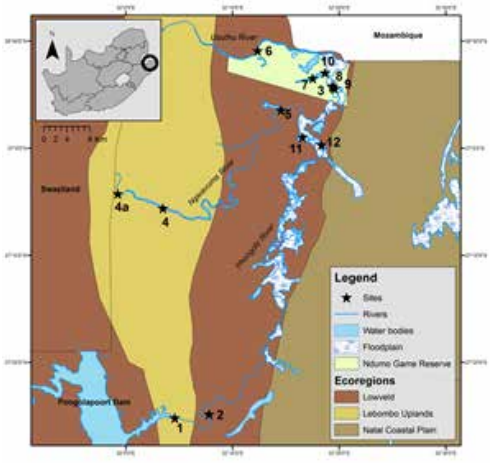

Figure.1 The map of the study area indicating the selected sites for this study, indicating the ecoregions associated with each site.

Two general management endpoints were identified, i.e. endpoints related to maintenance of biodiversity and utilisation of fish as a natural resource. Four different conceptual models were developed related to maintenance of fish, amphibian and bird biodiversity and utilisation of fish as a protein source.

These conceptual models were formatted into Bayesian network (BN) structures and the models were parameterised. The BN models and the preliminary analyses, the model's structure, parameterisation and findings were evaluated. The process was completed by conducting a sensitivity analysis of the model and revising the data with new evidence or knowledge

Key results and discussion

The Physicochemical driver Assessment Index (PAI) model indicated that the water quality is generally in category C due to impacts upstream of the study area. The analyses of historical data for the area upstream of the Pongolapoort Dam showed that the water quality is in a poor state. Upstream from the impoundment elevated levels of nutrients as well as salinity were recorded and these elevated nutrient levels can result in eutrophication of the water resources if not managed.

Lindane, chlordane and DDT were the organic compounds that bioaccumulated at high levels in the fish tissue. The combined effect of environmental conditions and the impacts related to pesticide presence are currently affecting the health of the fish species used for the assessment of biomarker responses. DDT had the highest accumulation levels in all species at all the sampling sites.

The continuous monitoring of the situation is important to assess and ensure the sustainability of human-fish interactions in the region. The macroinvertebrate community showed a clear separation between high- and low-flow (wet and dry respectively) sampling seasons at most sites in the system, most notably in the lower Ngwavuma, Phongolo and in the Usutu Rivers.

The diversity in reference samples showed relatively similar species compositions under high- and low-flow conditions, indicating that there was little change in the reference community between high- and low-flow seasons. The MIRAI EC for all sites ranged between C-D, which is cause for concern.

The removal of natural vegetation by land clearing for cultivation and housing, increased grazing pressure, trampling, removal of wood for fuel and building material and exposure

of soil result in erosion. The FRAI scores calculated for the sites with a C as the highest Ecological Category at the reference site showed that the instream habitats were more severely impacted than the riparian vegetation. The VEGRAI scores confirmed this observation.

The findings of socio-ecological section of the study further revealed that, despite significant challenges such as poverty, poor infrastructure, concerns about education, and an inadequately perceived provision of basic municipal services, members of the Ndumo community exceeded above average levels of psycho-social wellbeing generally. The study also raised the issue of the impact of communities being primarily governed by traditional, rather than local government authority.

The Bayesian Belief Network – Relative Risk Model (BN-RRM) used to determine the ecological risk of anthropogenic and flow-related impacts showed that the ecosystem services provided by the Phongolo floodplain have undergone significant changes.

Risk Regions 1 and 2 indicated a small likelihood for a moderate risk state for maintenance of frog biodiversity and it may necessitate further monitoring. However, the greater than 50% likelihood of moderate risk found to the endpoints will require management interventions and monitoring.

The observed moderate risk posed to the biodiversity and subsistence fisheries in Risk Regions 1 and 2, and the more than 50% likelihood that there would be low risk to these endpoints in Risk Region 3, suggests that the Ndumo Game Reserve is important in providing adequate protection to the upstream regions of the Phongolo floodplain.

Although the probability of endpoints being in a high risk (unacceptable state) state is low, ongoing monitoring and regulation should be considered.

Conclusions and Recommendations

This study demonstrated that the RRM approach can effectively be used as a tool for resource and conservation managers. The study further demonstrate that the resource protection afforded to the NGR provides a biodiversity refuge in the Phongolo catchment.

Through different scenarios, i.e. increased human disturbances in riparian zones as well as increased fisheries, it was established that the socio-ecological risk distribution in NGR would reach similar high risk conditions to those outside of the Reserve.

Risks posed by changes in both water quantity (in this example a singular parameter change in flood releases) and quality (in this example the DDT bioaccumulation in aquatic biota) were addressed using the RRM. The application of RRM can contribute to greater application of adaptive management practices in resource and conservation management in the Phongolo River catchment.

RRM tested can easily be updated and refined by trained resource managers, thereby increasing ownership in the adaptive management processes.

The Relative Risk Methodology that was developed during this project provides an innovative way to contribute to the determination of water resource protection measures and associated objectives as required by the National Water Act and should be considered besides Ezemvelo KZN Wildlife, by DEA and DWS as an option.

These measures include the Reserve Determination procedures, Water Resource Classification procedures and the Resource Quality Objectives. Other measures such as role of floods in maintaining ecosystem processes in the floodplain pans will increase the certainty associated with the risk predictions.

It therefore remains essential that fundamental research be conducted in order to provide the necessary data that address these processes. One of the outcomes of this project was the first report of the invasive freshwater red-clawed crayfish, Cherax. quadricarinatus, from this region as well as the first report in Africa of its associated non-indigenous parasites.

The impacts of this alien and its parasites on indigenous aquatic fauna must be investigated and its current Alien and Invasive Species listing of 1b should be re-assessed.

High levels of DDT were detected in all the fish species tested and thus pose a potential serious health risk to the local community and neighboring Mozambicans.
Africa. Flow paths were therefore calculated from the hydrologically improved DEM for cross-border areas of the Molopo catchment. A thresholds of 100 was used to indicate the start of flow paths from a flow accumulation grid.

River networks were selected from flow paths, taking into consideration homogenous areas with respect to drainage density (DD) and environmental variables such as precipitation, land cover, soils and terrain. This task was based on the

conjunctive use of digital elevation data and environmental parameters in a grid-based GIS. The landscape was manually stratified into drainage density classes.

Two parameters that showed a high correlation with DD were the Arenosols soils group and mountainous areas. Particular characteristics of Arenosols are low reserves of weaterable minerals and low silt: clay ratios.

The mountainous areas were derived from the SRTM DEM. They had a high DD while Arenosols had a low DD. All areas were ranked according to rainfall and vegetation with sparser vegetation and higher rainfall areas resulting in higher DD.

Further reading:
To order the report, *Socio-ecological system management of the lower Phongola river and floodplain using the relative risk methodology (***WRC Report No. 2185/1/15***)*, contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.