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TECHNICAL BRIEF

# Water & Environment

## A recent WRC-funded project explored the best ways of conserving South Africa's rivers.

### Conservation planning and rivers

Freshwater ecosystems, the most threatened ecosystems globally, experience the fastest loss of biodiversity and the greatest number of species extinctions. The most recent national appraisal of South African freshwater ecosystems indicated that over 80% of South African river ecosystems are threatened, one reason being the intimacy between catchment condition and river health.

One tool available for arresting the current rate of loss of freshwater biodiversity is systematic conservation planning, which provides a structured approach to identifying biologically significant areas for conservation action. A necessary component of conservation planning for rivers is the setting of targets for the required protection of each biodiversity feature and for maintaining the connection between different biodiversity patches.

Target-setting may follow either participatory or empirical approaches. Participatory approaches are typically based on expert opinion, and done on a case-by-case basis. Empirical approaches use statistical relationships and can be automated, which makes them more appropriate for national conservation planning initiatives.

Because rivers are characterised by length and not by area, and because species persistence at one site is very often a function of upstream and downstream ecological processes, statistical methods for setting area-based targets for terrestrial ecosystems are currently not suitable for rivers. Furthermore, the current South African approach in freshwater planning which makes use of a 20% conservation target value is inadequate because it assumes that diversity patterns between river systems and down the lengths of rivers are similar, which is not the case.

### A proposed new approach for setting river conservation targets

A suitable approach for rivers would be to base targets on established measures of species diversity and river ecology theory. In terms of the river continuum concept, which makes predictions of species diversity patterns with downstream distance based on ecosystem processes, the location of highest alpha diversity (number of species in a sample of standard size) and beta diversity (species turnover along a river's longitudinal axis) determine where and how much of a river should be targeted to conserve maximum species diversity.

Between-river diversity (gamma diversity) determines how many river systems should be conserved within each biome, and this relies on a suitable river classification system. Such an approach encompasses spatio-temporal variability, and would incorporate ecological processes operating at different scales along environmental gradients.

This approach means that:

- Species targets are set based on good biological data along a species axis.
- For alpha diversity to be maintained, upstream and downstream processes that conserve the diversity (or pattern) within a segment need to be sustained.
- Low beta diversity (i.e. low disparity between sites) implies that a relatively short section of river needs to be conserved. However, if beta diversity is large, then more of the river needs conservation measures.
- The more variable the system, the higher the beta diversity, and the longer the length of river needed for protecting diversity. Conversely, the more stable, predictable and resilient the system, the lower is the beta diversity and the shorter the length of river requiring protection.

- River systems in similar ecoregions should have lower gamma diversity than rivers in different eco-regions.

## Developing and assessing the approach

In order to develop and test the new approach, aquatic macro-invertebrates and fish species data from nine rivers in South Africa (Western, Eastern Cape and KwaZulu-Natal provinces) were assessed, using longitudinally located sites from surveyed and historical data. Data from previous studies (Great Fish, Berg, Thukela, Sabie-Sand, Mzimkhulu, Mkuze and Mvoti Rivers) were used together with new data collected for the Mvoti, Mzimkhulu, Mkuze and Keurbooms Rivers. After establishing that no useful trends were discernable in fish species data, however, fish were excluded and further analyses confined to macro-invertebrate species.

Species diversity patterns and turnover rates were calculated and interpreted using river profiles and site characteristics (flows, water temperatures and geomorphology). Statistical analyses and a probability model were developed for predicting specific sites on which river conservation should focus, as well as river lengths upstream and downstream of these focal sites which need to be conserved. Initial estimates of gamma diversity between rivers were obtained based on total numbers of species per river, excluding common species.

## Significant findings

### Alpha diversities – selection of focal river reaches

Highest species diversity occurred in mid-order streams and at an intermediate distance down a river's longitudinal axis. Within this diversity gradient, community structure is complicated by the relative contributions of rare, abundant (common), and very abundant species. Site-specific alpha diversity is typically made up of a few very abundant or rare species, with many common ones. Common species provide a better approximation of overall species patterns than do rare ones. However, the selection of target river zones should be guided by the conservation planning goals, i.e., whether these target rarity or maximum species number (pattern), or the more common species which drive the system energy dynamics (process).

### Beta diversity – how much river should be conserved?

Aquatic macroinvertebrate species patterns exhibited predictable patterns of turnover with downstream distance, and are valuable in setting conservation targets. Average species turnover happened at predictable rates, and these rates could be decomposed into turnover of common ("core") species, which are further accelerated by rare species (single occurrences) and narrow range species (single site occurrences). Moreover what drives this turnover with downstream distance are break-points and river geomorphology. Sharp environmental change occurs as a result of geomorphology and topography, while gradual environmental change is driven by geography and climate through a combination of physical habitat, water temperature (magnitude and timing) and flows (predictability, magnitude of high flow events and perenniality). Understanding turnover patterns thus requires a spatially hierarchical understanding of river systems before targets should be set.

Disruptions to the river continuum would impact on the rate of turnover. The amount of natural vegetation at the catchment scale is a good predictor of river habitat integrity. The turnover pattern may be clouded by both catchment and river disturbance, causing taxa sensitive to pollution and disturbance to decline and generalist, opportunistic species to increase.

Consistent with other research on South African rivers, aquatic macroinvertebrate communities could be grouped into upland versus lowland assemblages, and also defined by geomorphological zones. The rate of species turnover in the rivers assessed was related to environmental gradients and breakpoints, where the more variable upper sites have more rapid turnover than reaches further downstream, i.e. upper reaches require more representative conservation zones than the reaches further downstream.

### Gamma diversity – how many basins should be targeted?

As only four rivers were assessed, it was difficult to draw definite conclusions on gamma diversity. The basic gamma diversity estimates showed that to achieve riverscape-level conservation of aquatic biodiversity, it is necessary to explicitly target as many different primary catchments as possible. Under resource-limited conditions, it is more pragmatic to choose primary catchments further apart than closer together within the conservation planning region.

## Key conclusions

- A blanket 20% conservation target for river types is not adequate;

- Upper river zones are the key sections of river length that drive species patterns; consequently, upper river zones should be given greater weight in conservation planning than lowland zones;
- With river types being characterised by boundaries and ecotones, the obvious ecotonal boundary that provides justification for more than one generalised conservation target value per river type is the clear distinction in species turnover between the steeper upper river zone and the less steep lowland zone;
- An initial refinement of conservation targets would be the adjustment of the existing 20% target to cater for the needs of upland and lowland targets, with targets of at least 20% being applicable to lowland zones and 40% applicable to the upper zones;
- Upper catchments in identified river systems should be secured in order to maintain natural rates of species turnover in river sections where species richness is highest and also to secure ecosystem services for downstream users;
- Ecosystem services should be linked to river health, with catchment stakeholders deciding on the level of service they would require. This level of service or desired state could then be related back to ecosystem integrity by freshwater ecologists.

## Directions for future research

Future research should focus on:

- Refining differential targets for different geomorphological zones, using as a basis the hydraulic biotope heterogeneity per zone, one of the key drivers of species turnover.
- Quantifying the effects of seasonality on alpha diversity, the contributions of alpha and beta diversity to gamma diversity and the functional relationships between the pattern of both common and rare species and the downstream distance and biotope type.
- Refining river type classifications for upper river zones (upstream of profile inflections), focusing on selected whole systems rather than a percentage target of types.
- Refining a classification of river types for South Africa according to a hierarchical approach, beginning at the level of a river system (defined here as the mainstem in a secondary catchment), focussing on biotope heterogeneity, geomorphology, and intra-annual flow patterns.
- Automating the process of setting river conservation targets in a spatial conservation planning system.

**Further reading:**
To obtain the report, ***Deriving Conservation Targets for Rivers*** (**Report No: 1796/1/10**) contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za; or Visit: www.wrc.org.za