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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

Ecological reserve

Water temperatures and the Ecological Reserve

A three-year WRC-funded study investigated the management of aquatic ecosystems according to their temperature regimes.

Improving sustainable management of freshwater systems

Freshwater systems, both globally and in South Africa, are under pressure, and are among the most deteriorated and worst-off systems, due in part to water abstraction, flow regulation and pollution. Successful implementation of environmental flow management requires taking cognisance of the full spectrum of flows together with thermal regimes, including their temporal and spatial variability.

Water temperature is recognised as an important abiotic driver of aquatic ecosystems, and understanding the role that temperature plays in driving ecosystem change is important if effective management of thermal stress on aquatic ecosystems is to be achieved. Only through a foundation of fundamental research linking water temperatures and biotic response will the water temperature requirements for the ecological Reserve be met.

This WRC-funded project set out with the following aims:

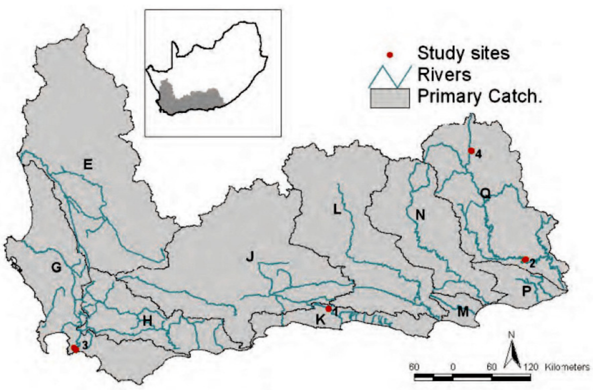
- To collect baseline water temperature data in a range of rivers in the Western and Eastern Cape;
- To develop a generic water temperature model for South Africa;
- To develop an understanding of the response of aquatic organisms to water temperature regimes in South African rivers;
- Identify a suite of suitable aquatic macroinvertebrates for use as bio-indicators of thermal change;
- Develop preliminary guidelines for the water temperature component of the ecological Reserve; and
- Develop scenarios of the potential biotic responses to changes in water temperature regimes as a result of climate and hydrological changes.

Baseline water temperature data collection

A total of 92 sites in rivers in the Eastern and Western Cape provinces were selected for installation of water temperature loggers. Sites were selected to cover a range of ecoregions and river longitudinal zones. An additional 50 sites from collaborative projects were also used.

Hourly water temperature data were collected over a period of two years. Air temperature and relative humidity data were collected at 47 sites to facilitate linking water temperatures to air temperatures for water temperature modelling purposes.

The final report has been divided into three main themes, namely modelling and mapping of water temperatures, biotic responses to thermal change and stress, and applications for management and inclusion into South Africa's



Study sites selected for model assessment based on their heuristic value.

ecological Reserve planning. Through this process, the collection of hourly water temperatures at a spread of seemingly unrelated sites have been integrated into a broader context to illustrate how water temperature time series can be linked to biotic responses, and integrated into a spatial framework.

Modelling and mapping

Measured water temperatures are the end result of complex interactions between solar radiation (heat inputs), flow rates, groundwater inputs and mixing with surface flows, shading, and land use (affecting turbidity levels). Increased turbidity can affect maximum daily water temperatures by up to 1°C, while groundwater inputs reduce daily ranges of temperatures and seasonal variability.

Because water temperature time series across South Africa are limited in distribution and length of data (i.e. >two years), it is more typically necessary to simulate water temperature time series from data which are readily available, *viz.* daily air temperature data. The statistical relationship between air and water temperatures is well established, and is usually linear over the range of water temperatures currently measured from South African rivers.

Water temperature time series can be simulated using linear models, either as stand-alone exercises, or to generate inputs for established process-based water temperature models. The process-based models are more complex to populate, but have the capability of running more sophisticated water temperature scenario analyses.

For ecological Reserve assessments, modelling outputs should include daily mean, minimum and maximum temperatures. Good quality input data (air and water temperatures) are key to good temperature simulations and ideally each site should be modelled individually after a site visit.

A water temperature time series can be broken into metrics that describe it in terms of thermal magnitudes, and frequency, timing and duration of extreme events. Using this approach, variation in water temperatures could be quantified, and was shown to vary between hydraulic biotopes, and regionally.

In the former case, flow differences translated more markedly in affecting daily maximum temperatures during the hotter time of year, with shallower biotopes (riffles) being more vulnerable to thermal extremes.

In spite of an average prediction success of around 40% for thermal groups, this research has provided a foundation for including water temperatures in a regional approach to managing river systems. Further research is required to refine regional water temperature mapping.

Biotic responses

The importance of water temperatures to aquatic biota has been well documented from Northern Hemisphere research. Southern Hemisphere studies are relatively scarce, with this project contributing substantially to the growing body of knowledge on biotic responses to water temperature.

Studies from this research showed that water temperature regimes have a measurable impact on aquatic macroinvertebrate life histories, and lifecycle cues. Through a combination of field surveys and laboratory experiments, it was shown that life histories of three target macroinvertebrate species showed differing degrees of flexibility in life history responses – from subtle changes in the timing of emergence and egg hatching to more extreme differences involving the production of additional generations within a year, given differing environmental conditions. Life history data are useful in that they can be linked to *in situ* thermal data and be used in the development of thermal guidelines and scenario analysis.

Thermal stress is likely to increase in the south-western Cape as a result of predicted climate change. Sampling macroinvertebrate assemblages, with the aim of assessing if biota differed in rivers with different thermal signatures, did not, however, reveal any distinct faunal trends that could be related to thermal conditions, even though water temperature data showed distinct differences in thermal conditions across the range of sites. Likely reasons for this are the relatively course level at which the sampling took place, mesh size and the likelihood of catchment signatures playing a role.

Management

Understanding the predictability of cyclical constancy of water temperatures, and how this changes with downstream distance, is an important predictive tool in relating biotic responses to abiotic change. Temperature regimes can be summarised and quantified using statistics that describe distribution.

A total of 37 metrics to describe water temperature time series were developed. The temperature metrics define statistics of a river's thermal regime with respect to magnitude of water temperatures, frequency, timing and duration of thermal events. The metrics were shown to be sensitive enough to distinguish adjacent sites based on their thermal signatures, but also robust enough to remain relatively consistent (assuming no trends) inter-annually.

Determination of environmental flows and the ecological Reserve are incomplete without incorporating water temperatures into their assessments. Water temperatures have been shown to be as important as flows in determining aquatic biotic patterns. Impacts on river systems which particularly affect water temperatures include impoundments and flow abstractions. These impacts are felt a thermal stress by aquatic macroinvertebrates.

In this research, response of aquatic macroinvertebrates to thermal conditions was successfully achieved using thermal stress thresholds and cumulative measures of heating. Cold-adapted specialist aquatic macroinvertebrates which breed only once a year are most vulnerable to small increases in water temperatures. Pest species of aquatic macroinvertebrates, which typically breed throughout the year and which are widespread, are likely to benefit from increased water temperatures.

Outbreaks of pest species are likely to become more severe. Under conditions of increased water temperatures, aquatic macroinvertebrate communities could become increasingly dominated by warm water, widespread generalist species.

Main outputs

The body of research in this project represents a considerable advancement in understanding thermal patterns in South African rivers, and how biota respond to thermal variability and stress. Understanding spatio-temporal thermal patterns in the Eastern and Western Cape provinces requires a multi-scale approach.

Among others, the project has:

- Provided the tools for simulating water temperatures in the absence of water temperature data
- Automated the calculation of temperature metrics that facilitate the conversion of sub-daily temperature data into statistics that define a river's thermal regime with respect to magnitude of water temperatures, frequency, timing and duration of thermal events;
- Identified thermally sensitive macroinvertebrate taxa that may be used as bio-indicators of thermal alteration;
- Identified key life history cues for selected macroinvertebrates in the context of water temperatures;
- Demonstrated the importance of maintaining thermal variability in river systems for aquatic macroinvertebrate community structure;
- Generated a preliminary map of thermal regions that can provide an initial framework within which the thermal ecological Reserve is applied; and
- Developed a thermograph that incorporates the natural range of variability and the concept of reference sites (and condition) with which an assessed (impacted) site can be compared, and the effect (if any) quantified; and
- Provided a decision tree for determining thermal ecological Reserve exceedance.

Further reading:
To order the report, ***Water temperatures and the ecological Reserve,*** (**Report No. 1799/1/12**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za, or Visit: www.wrc.org.za to download a free copy.