May 2015
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

Climate change

Riverine biota and climate change

A completed Water Research Commission (WRC) study developed tools for assessing the biological effects of climate change on riverine biota.

Background

Freshwater ecosystems are among the most vulnerable in the world with respect to global climate change. Southern Africa has been identified as a 'critical region' of water stress.

Existing anthropogenic stresses on freshwater ecosystems are substantial and global climate change exacerbates this stress. Water temperature is a key component of aquatic ecosystems and understanding the role of temperature in these systems and the ecological consequences of changes in water temperature, is thus of critical importance.

The establishment of thermal guidelines that adequately protect aquatic ecosystems and their biota is dependent on an understanding of a river's thermal signature and the vulnerability of its biota to changes in water temperature.

This study focused on the development of biological temperature thresholds for one ecological component of freshwater ecosystems: the aquatic macroinvertebrates. Ultimately, these thresholds will be incorporated into the water temperature component of the ecological Reserve. This information will facilitate the evaluation of current thermal stress, together with scenarios of likely future stress given global climate change.

The research undertaken during the preceding WRC projects has seen the development of a protocol for establishing water temperature guidelines for incorporation into the ecological Reserve. This proposed method is based on sound science and encompass both a statistical and biological threshold. The transfer of this knowledge to appropriate implementing bodies such as the Resource Directed Methods Directorate of the Department of Water and Sanitation is seen as key.

Methodology

Hourly water temperature data collected from 18 rivers across five regions in South Africa (Western Cape, Southern Cape, Eastern Cape, KwaZulu-Natal and Mpumalanga) facilitated the generation of thermographs for each river and enabled comparisons to be made among rivers.

Thermal load (as mean annual temperature and summer temperatures) and variability (including predictability) best explained the grouping of rivers, which ranged from cool headwater streams to warmer lowland rivers.

Laboratory experiments were undertaken to determine the upper thermal limits of a number of aquatic macroinvertebrate taxa. These were undertaken for all five regions and, for the Western Cape, for all seasons. Sublethal effects were also examined.

Lastly, to establish catchment resilience, a connectivity index that incorporates longitudinal (instream barriers), lateral (catchment transformation) and temporal (function of changes in flow and water temperature regimes) thermal aspects was developed. This is critical in resource conservation and development planning.

Key findings

Upper thermal limits, expressed CT_{max} values (Critical Thermal maximum) and 96h ILUT (Incipient Lethal Upper Temperature) varied spatially among regions, with differences most evident among winter versus rainfall regions. Within-region variation was also apparent in the Western Cape, where both CT_{max} values and 96h ILUT varied by approximately 2°C among sites.

CT_{max} values and 96 ILUT varied temporally with distinct differences between summer (highest) and winter (lowest), and less distinct and more variable differences in spring and autumn. The influence of acclimation temperature on thermal limits was unclear with amphipods exhibiting a trend of increasing CT_{max} as acclimation temperature increased, although this was not evident for mayflies.

Similarly, the effect of the rate of temperature change varied among taxa, with amphipods showing no response, while CT_{max} values for mayflies decreased as rate of temperature change increased. CT_{max} values varied significantly among genera within families for five of the seven comparison undertaken.

Maximum Weekly Allowable Temperature (MWAT) thresholds, which serve as an integrator of physiological effects on aquatic organisms, varied among taxa and rivers, ranging from 15.8°C to 20.9°C.

From these thermal experiments it is clear that both spatial and temporal variation in upper thermal limits is evident across a range of taxa. Some broad observations regarding MWAT thresholds were noted as follows.

For all regions, the period of maximum thermal stress is similar and occurred during the warmer months (September to April) although the extent and duration varied among regions, river zones and in some instances sites within a region. Taxa from sites in upper catchments generally have lower MWAT thresholds than taxa from sites lower down in the catchment.

Taxa from a site below a dam that released warmer surface water had higher MWAT thresholds than a site on the same river above the dam. The MWAT threshold has correlated with Mean Annual Temperature (MAT), which means that in the absence of thermal experimental data, it is feasible to use MAT as a surrogate to derive a biological temperature threshold at a medium level of confidence.

Undertaking thermal experiments on a site-specific basis would increase the confidence of this MWAT threshold, but logistical constraints may now always allow for this. Generalisations in terms of thermal guidelines made at a broad national scale for the ecological Reserve are inappropriate and should at the very least need to be conceived at a regional or even local scale.

Sublethal effects of water temperature on aquatic macroinvertebrates

Life-history traits were determined for selected indicator species from the EPT taxa. Overall, life-history responses appeared to be finely tuned to the thermal regimes, while the hydrological regime was noted as a driver determining population size and mortality. This confirms the importance of water temperature as a driver of biotic responses.

The development of a connectivity index to reflect resilience of rivers to climate change

A connectivity index that incorporates longitudinal (in-stream barriers), lateral (catchment transformation) and temporal (function of changes in flow and water temperature regimes) connectivity was developed using rivers in KwaZulu-Natal.

The resultant disconnectivity layer was overlayed with the areas of conservation importance as developed for the provincial freshwater conservation plan. The combination of these data show areas of high conservation value relative to degree of connectivity, and when plotted together allow conservation planners to make choices between areas of high conservation value when resources are limited.

Ultimately, the utility of the connectivity index will be a function of the combination of vulnerability and connectivity as a measure of resilience. This connectivity index may be used for ranking catchments in terms of vulnerability and resilience.

Conclusions

This study has generated experimental data on thermal limits of aquatic macroinvertebrates, including both lethal limits and sublethal limits. This research has encompassed five geographic regions, 18 rivers and nine thermally sensitive taxa.

These thermal limits have been used to generate biological temperature thresholds. A protocol for incorporating water temperature into the ecological Reserve has been developed.

The project has developed a connectivity index for the rivers of KwaZulu-Natal, which may be used in subsequent validation of National Freshwater Ecosystem Priority Areas in South Africa. In addition, the protocol for which may be applied in other provinces.

Further reading:
To order the report, *Adaptability and vulnerability of riverine biota to climate change – Developing tools for assessing biological effects* (**Report No. 2182/1/15**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.