CLIMATE CHANGE AND RIVERS

Researchers develop environmental water temperature guidelines for SA rivers

Environmental water temperature guidelines have been developed for South Africa's perennial rivers. The Water Wheel reports about the research that underpins it, and the processes and tools available to help water practitioners use it to its fullest potential. Article by Jorisna Bonthuys.

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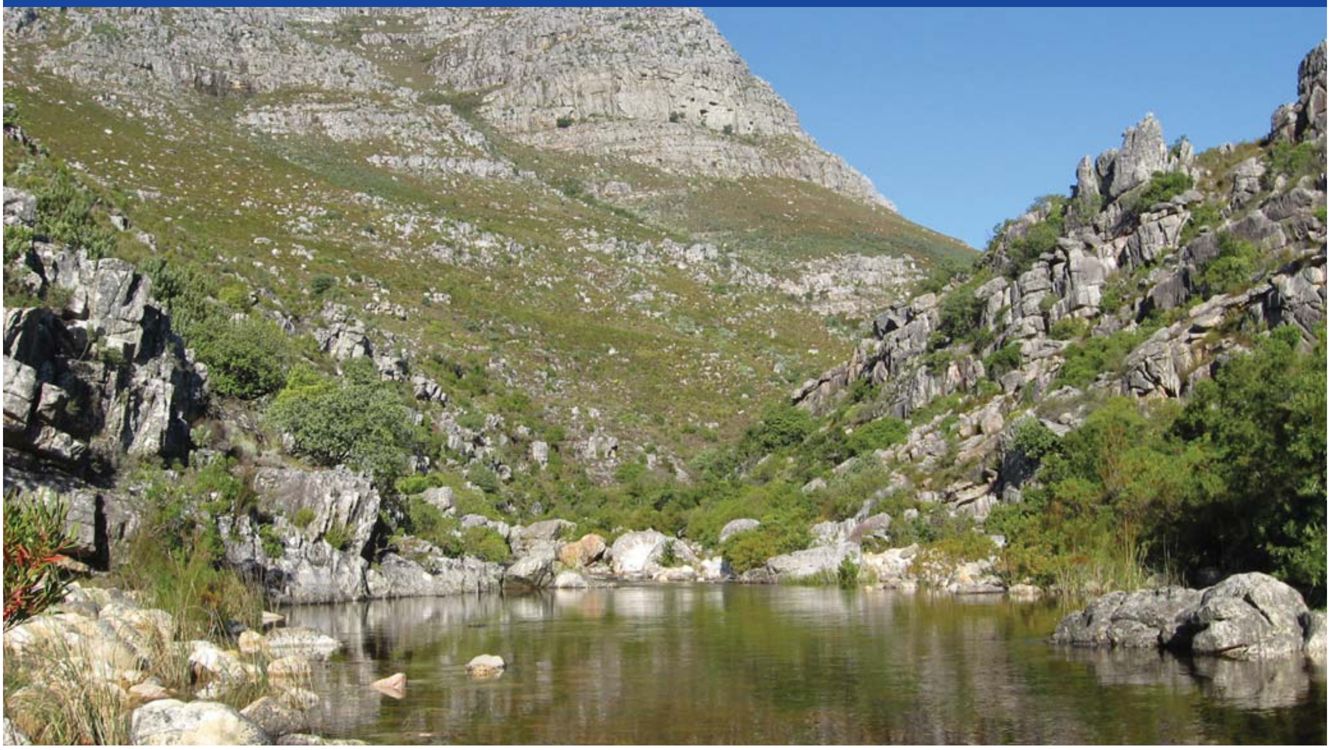


It is a well-known fact that effective water resource management needs reliable data, Dr Helen Dallas, Executive Director of the Freshwater Research Centre (FRC), highlighted. "Reliable data underpins good water governance, and effective water management helps with adaptation to climate change."

Dallas and Dr Nick Rivers-Moore recently published a comprehensive technical manual for setting water temperature targets for South Africa's perennial rivers. Dallas has over 30 years' experience working on and leading collaborative research projects on the ecology, conservation and management of aquatic ecosystems in southern Africa. She is a C2-rated researcher with the National Research Foundation, and a research associate of the University of Cape Town and the Nelson Mandela University. Rivers-Moore, a fellow researcher at the FRC in Cape Town, is an aquatic ecologist with 20 years of experience in this field.

The manual is part of their ongoing efforts to support evidence-based decision-making among water practitioners in the country. The researchers produced two volumes on the topic of environmental water temperature guidelines for rivers. The Water Research Commission (WRC) funded this research.

The first volume provides the technical background to the project, including an overview of water temperature, thermal impacts and the effect of thermal changes on river organisms. Included in this document is an outline of the engagement with water resource practitioners during the project, as part of a process to ensure alignment between the tool and practitioners needs. It also provides a summary of the protocol for establishing environmental temperature guidelines for perennial rivers in South Africa, demonstrated with three case studies.

For those wishing to gain more detailed information, it also includes, as a resource, a list of previous publications related to this research.

The second volume is a technical manual for setting water temperature targets. It provides guidance on when water temperatures in rivers should be considered and how to assess changes in water temperature, among other aspects.

The manual serves as a road map for water resource practitioners needing to incorporate water temperature into resource directed measures, including ecological reserves and resource quality objectives, and source directed controls. These allocations are a legal requirement to ensure adequate water flow and quality for the ecosystem health of rivers.

Dallas said: "This manual speaks directly to several tools, packaged into a toolbox, developed for establishing environmental water temperature guidelines for our rivers."

The current rate of climate change affects rivers through changes in water temperature and flow, and adds to stressors that are already impacting freshwater ecosystems.

Both these documents emanate from a project entitled 'Environmental water temperature guidelines: bridging the gap between research and implementation'.

The aim of this research was to translate knowledge generated over more than a decade of thermal research on South African rivers into a protocol for those practitioners and decision-makers responsible for the protection of our rivers.

"This project aimed to bridge the gap between research and management and implementation, by taking the body of research on water temperature and packaging it in ways that best serve the end-users," the researchers said.

The researchers developed new tools and resources for water resource practitioners, including a spatial framework and a national map of river system resilience that could help inform their decisions.

The heat is on

Southern Africa is considered a 'critical region' of water stress. Scientists have identified the region as a climate change hotspot, with southern Africa warming at about twice the global rate of temperature increase.

Climate patterns are already shifting in the region, thereby impacting on water resource planning. Freshwater resources are considered particularly vulnerable to global climate change and access to better data for decision-making is becoming increasingly urgent, given climate change.

The current rate of climate change affects rivers through

Drs Helen Dallas and Nick Rivers-Moore were the lead researchers on the project.

Thermal experiments to determine upper limits.

changes in water temperature and flow, and adds to stressors that are already impacting freshwater ecosystems. "Climate-related extremes in water temperature will affect many species," Dallas said. "Freshwater species are more restricted in their movement and the smaller water bodies they inhabit heat up more rapidly."

Climate change is making the waters too warm for many species. Dallas and some of her colleagues at the Freshwater Research Centre have been investigating the effect of climate change on freshwater fish species of the Cape Fold ecoregion (CFE). This is one of 93 ecoregions in Africa, with each ecoregion containing a distinct assemblage of natural communities and species. The CFE region is home to many range-restricted endemic freshwater fishes, of which the majority face the risk of extinction. Climate change models developed for this region predict a warmer and drier climate over the next 50 to 100 years, signs of which have already started to show.

From a climate change perspective, climate resilience can be strengthened through healthy ecosystem services that rely on well-functioning river catchments. These 'services' refer to the benefits that humans derive from nature, including natural flood control and water purification.

Focus on elevated water temperature

Water temperature has significant effects on aquatic life in rivers, Dallas highlighted. "Understanding the response of aquatic organisms to warmer water temperatures offers valuable insight into the ecological consequences of climate change on many freshwater species," she said.

The establishment of water temperature guidelines that protect aquatic ecosystems depends on an understanding of a river's 'thermal signature' and the vulnerability of its animal and plant life to changes in water temperature. Climate change impacts on aquatic life can be significant. Issues around water temperatures in rivers should be taken seriously, the researchers pointed out. This project highlighted some of these issues.

Pest insects like larval blackfly, for instance, thrive under certain flow and water temperature conditions. Blackfly populations attack livestock and, in particular, sheep. Under current flow and water temperature conditions, outbreaks of adult blackfly along the Orange River are already causing major losses for the stock farming industry calculated to exceed R500 million per annum. Previous research estimated that a 2°C increase in current water temperature could result in pest blackfly populations increasing by a twenty-fold factor annually, in addition to the number of generations increasing by 25% annually.

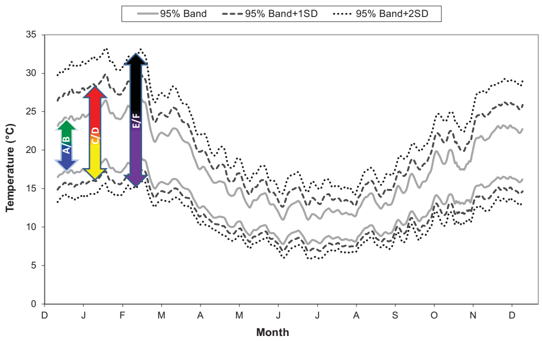
"Understanding the response of aquatic organisms to warmer water temperatures offers valuable insight into the ecological consequences of climate change on many freshwater species."

This example, highlighted in the technical report, underlines how important it is to track water temperature in rivers and use this information to inform analysis and decision-making. Dallas added: "This information (water temperature data) is also needed to improve water-air temperature models and to develop reference thermographs for different regions. [A reference thermograph is the expected natural pattern of water temperature over a one-year period against which water temperature at an impacted river can be compared] Modelling water temperature data is difficult — there is a clear need for logged water temperature data."

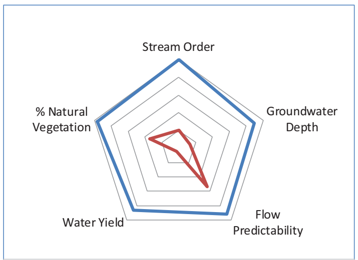
Several human activities change water temperature in rivers. These activities tend to increase temperature rather than decrease it. Water abstraction in summer, during natural low-flow periods in winter rainfall regions, will have a more significant thermal impact compared to abstraction in winter.

Changes in water temperatures (and flow) in rivers have many effects on aquatic life, including biological effects on river organisms. Such changes may include the spread of invasive and pest species (such as blackfly), an increase in waterborne and vector-borne diseases (including cholera and malaria), the extinction of vulnerable species, shifts in species distribution and range, and changes in biodiversity.

"These and other thermal impacts need to be mitigated, but to do so effectively, researchers and water managers need to understand the effects of thermal changes on rivers," Dallas said.

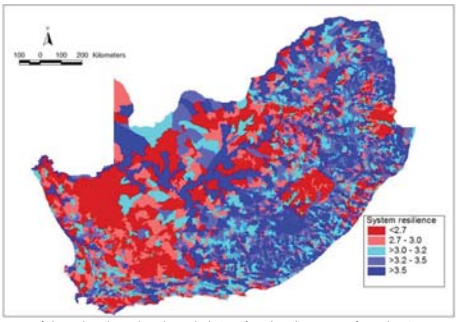


Reference thermograph showing ecological categories



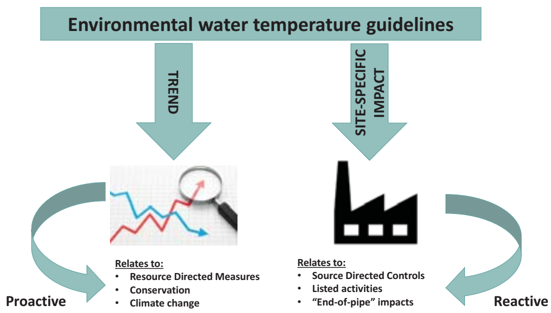
Radar plot showing the relative importance of five site variables potentially affecting system resilience. The blue line represents a site with high resilience, while the red line represents a site with low resilience.

Resilience radar



Map of Thermal Resilience based on calculation of Total Resilience Score for each quinary catchment (low resilience = red; high resilience = blue)

Map of thermal resilience



Environmental water temperature guidelines

"Realistically, very little can be done directly to mitigate impacts on water temperature. The most practical approach is to mitigate those insulators and buffers that indirectly affect water temperature," the researchers said.

The use of environmental water temperature guidelines may, therefore, be both proactive and reactive, the researchers highlighted. It can serve as a benchmark for tracking thermal change in rivers. It may also be a response to an existing thermal impact or a proposed impact for which a user has, for instance, submitted a water use licence application. This could include plans related to the water use of industries or mines, land-use changes, and groundwater abstraction.

Currently, there are very little time-series water temperature data available for South Africa's rivers, particularly data sets for longer than one full thermal year. The researchers estimate that such data sets are available for only 1% of the quinary sub-catchments, which represent nested hydrological catchments, covering the country.

Dallas and Rivers-Moore developed a spatial framework to help fill this data gap. This framework provides information on the system resilience of rivers, among others. The researchers also provide a protocol that comprises two processes needed for establishing environmental water temperature guidelines, namely the screening process, and the evaluation process.

Screening and evaluating processes

Screening information includes details of system resilience, water quality and habitat, the sensitivity of river organisms, thermal impacts and a thermal risk assessment.

The screening process allows people using these guidelines to determine if the water temperature should be examined at a particular site. A workflow diagram has been generated to guide the water practitioner during this process.

"Not all sites, reaches and rivers need to be managed for water temperature," Dallas explained. "Asking the right questions allows one to evaluate the importance of maintaining an appropriate thermal regime at a particular site."

For site-specific impacts, aspects such as the likely thermal impact of an activity (important especially in source-directed controls and water licensing) and the sensitivity of the site and its river organisms (for instance, endangered cold-water fish species) to thermal change, are considered.

Three key questions must be asked when assessing whether water temperature needs to be considered before quantifying thermal stress and assessing risk. These questions are:
How resilient is the site, reach or river to changes in water temperature?

Are there other hydrological, physicochemical (water quality) and habitat considerations that could increase or reduce thermal impacts?

How sensitive are the river organisms?

"The spatial scale of screening may vary from a site to a reach to a river, depending on the size of the river," Dallas added. "So, for example, a site on a large fifth-order river would be screened at site-scale, while a small first-order tributary may be screened at the river-scale."

The first question enables practitioners to determine just how resilient a particular river system is. The resilience of a river – an indication of its ability to withstand external impacts – is likely to be affected by variables, such as stream order, groundwater depth, flow predictability, water yield and catchment transformation.

Dallas and Rivers-Moore have integrated these and other factors into a map of thermal resilience. This map allows users to evaluate if the site, reach or river is likely to be resilient or vulnerable to thermal stress based on five catchment variables.

The second question is answered by considering water quality issues, the potential for algal blooms or invasive aquatic weeds to dominate and whether or not the river's flow is natural or transformed, among others. The third question can be answered by considering the ecological state of a river or reach and if endemic or species of conservation importance, are for instance present at the site.

These questions have been integrated into a thermal risk assessment matrix which is the final stage of the screening process. The risk rating is then generated based on predetermined risk classes: low, moderate, high, and very high risk. This guides users as to whether water temperature needs to be further examined at a particular site, in which case the user continues with the evaluation process.

A thermal sensitivity index based on aquatic macroinvertebrates has also been developed, whereby each taxon is assigned a thermal sensitivity weighting. These weightings have been applied to most taxa used in the South African Scoring System (SASS). This assessment tool of biota (animal life) in rivers is widely used to determine the condition or 'health' of rivers.

The evaluation process also allows practitioners to set thermal targets for specific reference sites, reaches or rivers, using either logged water temperature data or modelled water temperature data, and to evaluate changes in water temperature at comparable sites.

The protocol includes details of collecting water temperature data, the spatial framework within which the reference thermographs are created, and calculations of model accuracy. This information can be used to generate a thermal report card for a particular river.

The thermal assessment provides specific guidelines for the timing and the duration of mitigation measures if needed. Dallas says: "Mitigation plans can then be developed, including for instance to limit water extraction from a particular river or during the hot summer months."

Next steps on monitoring

The processes and tools developed in this project provide water resource practitioners with the necessary knowledge and tools for incorporating water temperature guidelines into resource directed measures, including ecological reserves and resource quality objectives, and source directed controls.

There are now two key follow-on actions to be taken, according to the researchers. The first is to roll out a national water temperature monitoring programme. The second action is to automate the processes developed in this project.

Dallas said: "There is a clear need to roll out a national water temperature monitoring programme. This will need to be driven by the government with support from organisations that have a vested interest in tracking long-term change in water temperature.

"If we can establish a network of thermal monitoring programmes, this could offer many benefits to society," Dallas said.

Automation of the processes can be achieved by securing funding to develop a thermal module linked to the Freshwater Biodiversity Information System (www.freshwaterbiodiversity.org), currently being developed by the FRC. This system is a platform for hosting, visualising and sharing freshwater biodiversity information for South African rivers.

"The systems and climate-related changes we are dealing with are complex, and we need to ensure water practitioners have the best possible data to help manage these," she concluded.

To download the manual, ***Environmental water temperature guidelines for perennial rivers in South Africa*** (**WRC Report no. TT 799/2/19**), click here: https://bit.ly/3fUSwd2

Visit www.frcsa.org.za for more information.