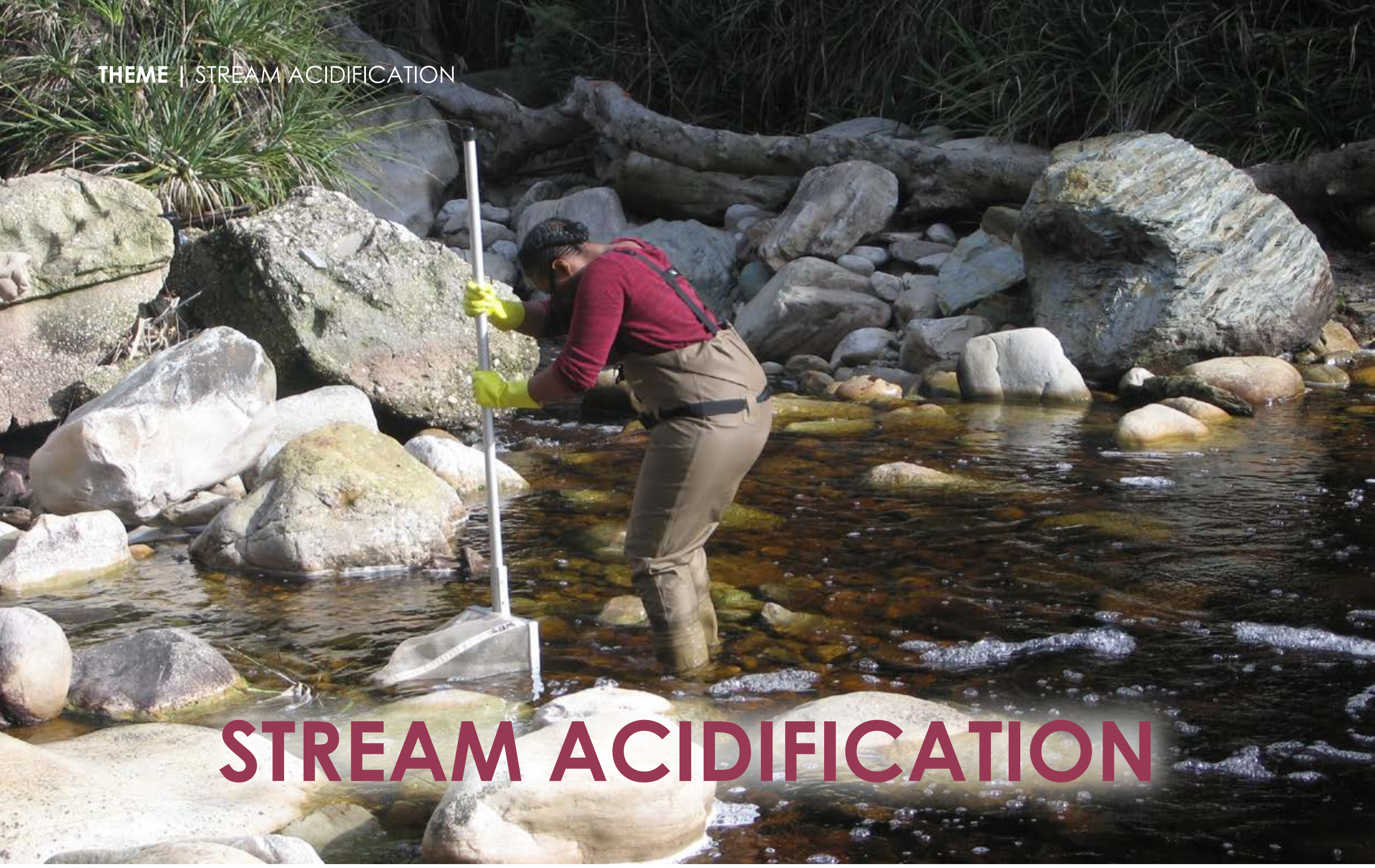

STREAM ACIDIFICATION

Londiwe Khuzwayo shares her research on acid deposition in South African streams

The Mpumalanga Highveld, where approximately 80% of South Africa's coal-fired power stations are located, has previously been shown to have acid deposition rates comparable with those linked to soil and water acidification in European countries. We also know that air from the Highveld – together with its pollutants – can be transported in different directions and over long distances.

This tells us little about which areas are vulnerable to acidification, though, because soil type has a major influence. For example, soils derived from granite and quartzite rock, which weather very slowly, are more sensitive to acidification because they have relatively low concentrations of certain minerals that can neutralise strong acids. By contrast, limestone-derived soils are rich in calcite, a mineral form of calcium carbonate ($CaCO_3$), which allows them to counteract acidification.

The thickness of the soil layer over the underlying rock also affects the buffering capacity – the capacity to resist pH change. But even resilient soils may lose their ability to neutralise acid if minerals are leached away through acid deposition faster than they are replaced by weathering processes. Furthermore, inorganic aluminium leached from soils is toxic to plants and aquatic animals.

The maximum amount of acid deposition that ecosystems can tolerate without being damaged is called the critical load. In South Africa, the damaging effects of acid deposition are largely unknown, so I aimed to help address this in my PhD research by assessing the sensitivity of aquatic macroinvertebrates to acid deposition in headwater streams.

Why study macroinvertebrates?

Macroinvertebrates are commonly used to assess degradation of aquatic ecosystems caused by human activity such as urbanisation, industrialisation and agricultural practices. What's more, although acid deposition was shown to have a dramatic effect on fish life in Europe and North America in the past, it was subsequently discovered that particular types of aquatic insects disappeared before fish populations started declining.

A consensus was therefore reached among freshwater ecologists to use aquatic insects as early indicators of acidification. Aquatic insects are highly diverse and include species with a wide range of habitat and ecological preferences. The lifespan of most aquatic insects consists of two phases, the aquatic juvenile phase and the adult terrestrial phase. The adult insects, including dragonflies, mayflies, caddisflies, stoneflies and non-biting midges, live for only a short time, from less than a day to a few weeks, but the aquatic phase can last for a few weeks to several years, depending on the type of species and the physico-chemical properties of the water.

Previous studies have shown that different species display different tolerance levels to a variety of pollutants. For

A handheld vacuum pump was used to filter water samples for laboratory analyses.

instance, most mayflies are known for their low tolerance to pollution and are often the first organisms to disappear when a water body is polluted. A water body that lacks these sensitive taxa, but supports more tolerant taxa, is likely polluted. Even so, it's possible for an organism that's been shown to be sensitive to, for example, organic pollution to have a completely different response to changes related to other types of pollutants. Nevertheless, species that are able to survive harsh environmental conditions such as acidification tend to be resilient to a number of other adverse changes in the aquatic ecosystem.

Overall, acidified waters are generally characterised by a decline in productivity, species number and diversity, with increased dominance of acid-tolerant taxa, such as stoneflies, and a decline or absence of sensitive taxa, such as mayflies.

What was the research approach?

At the outset of my PhD research, I applied Geographic Information System (GIS) tools to identify three regions in South Africa that are potentially vulnerable to acidification. These regions – the Mpumalanga Highveld, Waterberg and the southern Cape – represent high, medium and low acid deposition loads respectively, based on the distribution of coal-fired power stations and the presence of acid-sensitive soils and waters.

Within these regions, 84 sampling sites on 80 mountain streams were then identified, with 21 sites in the Mpumalanga Highveld, 33 in the Waterberg and 30 in the southern Cape. These sites were selected on the assumption that they had no direct human influences on water quality, having no mining or intensive agriculture within their catchments, in order to focus the research on impacts related entirely to atmospheric deposition. Macroinvertebrate samples were collected from only 56 of these sites, due to habitat suitability, but water chemistry was investigated at all 84 sites. This involved measuring water temperature, dissolved oxygen, conductivity and pH with a multiprobe instrument, and collecting water samples for laboratory analyses of dissolved organic carbon (DOC) and major anion and cation concentrations.

The pH, temperature, dissolved oxygen and conductivity of streams was measured with a multiprobe instrument.

The ion concentrations are important because they are used to determine acid neutralising capacity (ANC), which has been shown to be the best correlate with biological response to stream acidification by aquatic insects. It is calculated by subtracting the sum of strong acid anions (SO_4^{2-} + NO_3^- + Cl^-) from the sum of base cations (Ca^{2+} + Mg^{2+} + Na^+ + K^+). Low base cations will lead to a low ANC, meaning that the stream has little ability to neutralise acid deposition and is therefore more susceptible to acidification and ecological impacts.

Unfortunately, determining the extent to which the three study regions are affected by acid deposition proved to be very difficult, because each differed greatly in terms of the type of aquatic insects occurring there, as well as the rainfall patterns, rock and soil formation processes, and overall response to environmental change in the short term (e.g. drought) and long term (climate change). The Mpumalanga Highveld sites had very high pH, probably because of pollution, while southern Cape streams are naturally acidic, so their macroinvertebrates are adapted to low pH. In addition, research effort on aquatic biodiversity has to date been more intensive in the southern Cape than in the Mpumalanga Highveld and Waterberg, where much of the aquatic insects remain undescribed. This created gaps in knowledge that could not be addressed within the time limits of a doctoral study.

In order to fully understand the impact of acid deposition in South Africa, more long-term research is needed as well as a collaborative approach across disciplines to avoid repetition and instances where data goes uninterpreted due to time constraints and lack of funding. The best approach would be to carry out research on the effect of acid deposition at a provincial level before attempting to address it on a national scale.

Dr Londiwe Khuzwayo completed her PhD at the University of the Witwatersrand towards the end of 2019. In April 2020 she joined the Pietermaritzburg-based Grasslands-Wetlands-Forests Node of the South African Environmental Observation Network (SAEON) as a postdoctoral researcher, focusing on the Thukela system.

Blackfly larvae on the underside of a rock.