ESTUARIES

From macro to micro: Tools for monitoring estuarine health and recovery

South Africa's estuaries are in crisis. A massive chemical spill near the uMhlanga Estuary on the KwaZulu-Natal coast a few years ago exposed their fragility, but also revealed powerful tools scientists are using to track damage, recovery, and the fight against pollution. Article by the Institute of Natural Resources and partners.

South African rivers and estuaries are under serious threat. As national water demand soars and water quality plummets in many parts of the country, the challenge of monitoring and protecting aquatic ecosystems becomes increasingly urgent. The manner in which the impacts of acute and chronic pollution on aquatic systems are managed and mitigated is critically important in maintaining and restoring impacted aquatic ecosystems. Field-based monitoring of pollution impacts and recovery, while important, is often difficult to implement due to high costs and limitations in capacity (in terms of the number of people with the required expertise) and capability (the degree of skills individual experts possess). So, when disaster strikes, how do we measure the damage and the recovery?

In 2021, a massive chemical spill near the uMhlanga Estuary on South Africa's East Coast presented both a tragedy and an opportunity. The spill devastated the estuarine ecosystem, killing fish, aquatic life, and riverside vegetation. In the wake of the event, researchers from the Institute of Natural Resources and the University of the Western Cape, along with their partners, sought answers: Which indicators are most effective in tracking pollution impacts and ecosystem recovery? The team received project funding from the UK Department for Environment, Food and Rural Affairs (DEFRA) through the Joint Nature Conservation Committee Environmental Pollution Programme.

What was measured and why it matters?

To establish what needed to be monitored and the value that this would offer to decision-making, the team compared the uMhlanga Estuary, heavily impacted by the spill, with two other estuaries of similar makeup: the uMdloti, affected by ongoing pollution but no acute event, and the iMpenjati, considered relatively pristine (Figure 1). The comparison allowed for a valuable, side-by-side look at how ecosystems respond to different types of stress, both sudden (episodic) and chronic.

For each river-estuary system assessed, water quality samples were collected to test for concentrations of agrochemicals, nutrients and related water quality parameters to detect the impacts of the spill and those of associated land uses for in the other two systems. For the biological monitoring, our study used the South African Scoring System 5 (SASS5) for macro-invertebrates and recognised diatom indices (which were also used by the professional teams to assess the response of the system to the mitigation measures by the polluter). SASS5 is a method of collecting and identifying aquatic macroinvertebrates from different biotopes.

The goal of SASS5 is to assign a score, such as the SASS score, number of taxa, and average score per taxa (ASPT), which gives an indication of the water quality (Figure 2). Diatom indices also assess water quality through microscopic algae known as diatoms, which are sensitive to pollution. We also included the use of the Fish Rapid Assessment Index (FRAI), which is South Africa's standard tool for a quick assessment of the ecological conditions of a river from its fish community (Figure 2), and remote sensing (satellite imagery) to understand the spatial impact of the spill on riparian vegetation over time.

Using this mix of water sampling, species surveys, and cutting-edge earth observation techniques, the team tracked a wide range of environmental indicators. The most useful of these indicators were those measured using remote sensing, satellite-based vegetation monitoring, as they proved most powerful for visualising large-scale impacts over time (Figure 3). Using indices such as NDVI (Normalized Difference Vegetation Index) and SAVI (Soil Adjusted Vegetation Index), researchers tracked changes in riparian vegetation from 2018 to 2024. The data told a clear story: Following the spill, vegetation health around uMhlanga plummeted and has yet to return to pre-spill levels, even three years on. Similar analyses in the iMpenjati and uMdloti estuaries helped confirm the devastating impacts of the spill on the system, but also pointed to the fact that the system was impacted by extreme weather events (floods, specifically) after the spill, and like most other estuaries in the region, is impacted by a variety of chronic pollution streams.

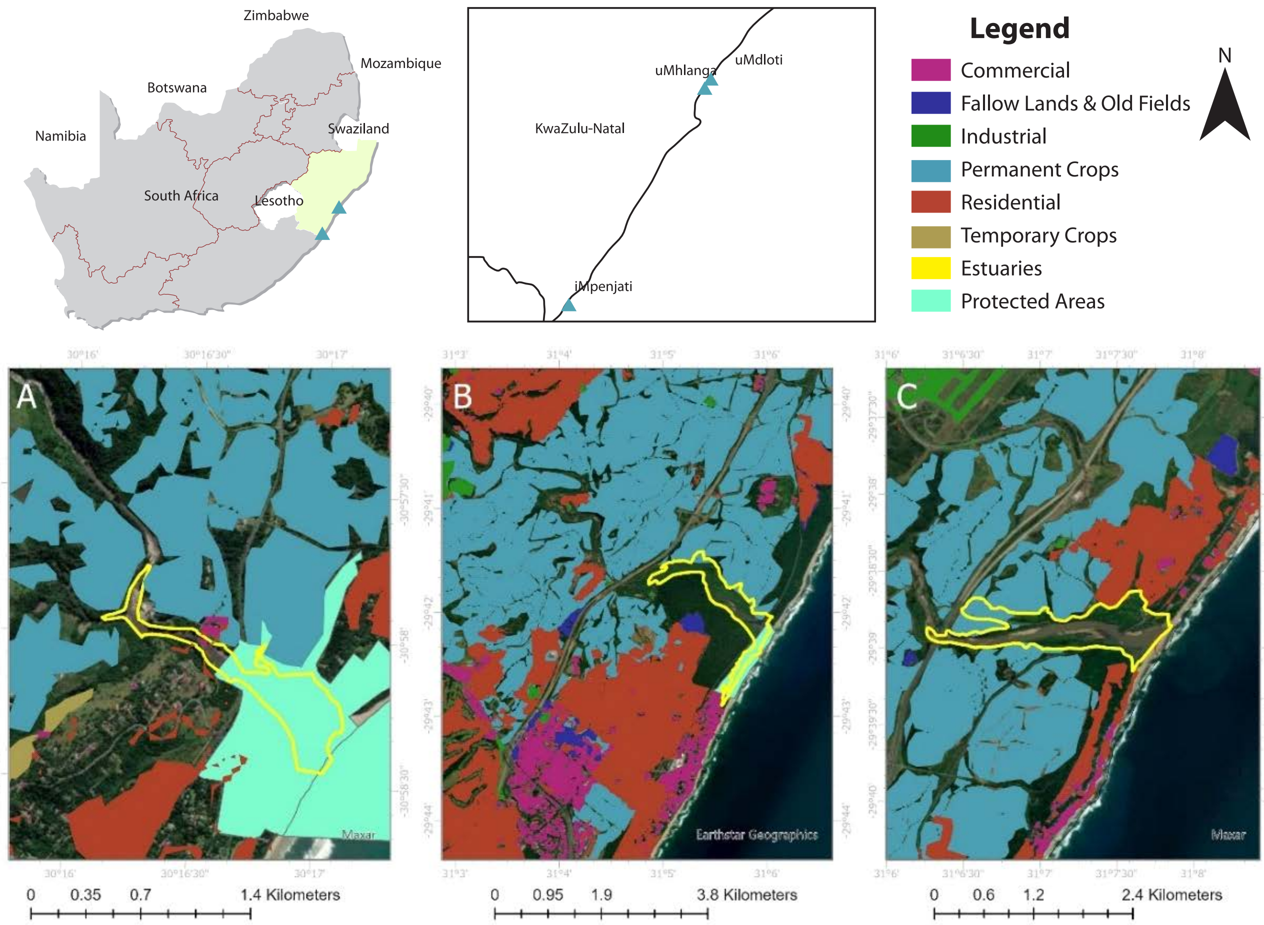

Figure 1: The locality of the three selected estuaries, iMpenjati (A), uMhlanga (B), and uMdloti (C), Estuaries and their associated land use for the present project, using land cover data from 2023.

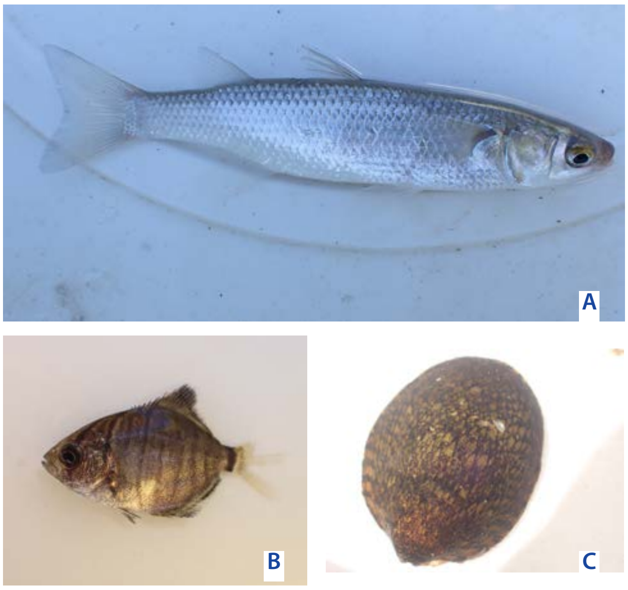

Figure 2: The freshwater mullet (A), a southern African endemic, and the oval moonfish (B) need healthy rivers and estuaries to complete their lifecycle and were found in the iMpenjati system with low abundances in the uMhlanga and uMdloti estuaries. A Septaria mollusc (C) that contributes to the macroinvertebrate health score for the freshwater systems.

One plant's story: The common reed as a pollution indicator
Using 'old-school' vegetation surveys (Figure 4), the team was also successful in showing that the common reed (***Phragmites australis***) could represent an unlikely hero in polluted estuaries. Its response to the spill, in the form of higher plant density but shorter stems, mirrored the satellite imagery and ground surveys, revealing how vegetation copes with recovery under stress. These results suggest it could be employed as a valuable indicator species for future pollution monitoring in wetland systems.

What the findings reveal

What is worrying, though, is that even after three years, the uMhlanga Estuary is still struggling. Surprisingly, the uMdloti, untouched by the chemical spill, showed similar levels of ecological degradation. This points to a sobering reality: Chronic pollution from sources like untreated sewage and failing infrastructure is just as damaging, and perhaps even more insidious. Fish populations in all three estuaries were also in poor condition, signalling deep systemic stress across these ecosystems.

The study showed that even though different tools provide different insights, all are needed. There is no silver bullet:

- SASS5 is practical and cost-effective for macroinvertebrate

INR

Figure 3: Sentinel-2 satellite image of the uMhlanga estuary and surrounding areas before the spill event (A), the smoke plume during the warehouse damage (B), the impact of the spill (C) and system recovery after the spill (D). The red rectangle shows the overall area that was assessed by remote sensing techniques.

assessment of rivers.

- FRAI is essential for both river and estuary fish community assessment.
- Diatoms offer a longer-term view of pollution.
- Remote sensing gives a fast, affordable way to flag problem areas for closer inspection.

A call to action

This study tells a compelling story of science in action. It shows that South Africa has the tools to monitor estuarine health, but these are not being used proactively or consistently. Too often, biomonitoring is reactive, launched only after a disaster strikes (as in the case of the uMhlanga Estuary). We need ongoing, strategic monitoring to spot red flags before they escalate into crises, and data to inform policy and decision-making. Most of all, we need action. Government, business, scientists, and communities must come together to tackle pollution at its source. Monitoring is not enough without the will to act on what we learn.

INR

*Figure 4: Vegetation surveys around the common reed (*Phragmites australis*).*