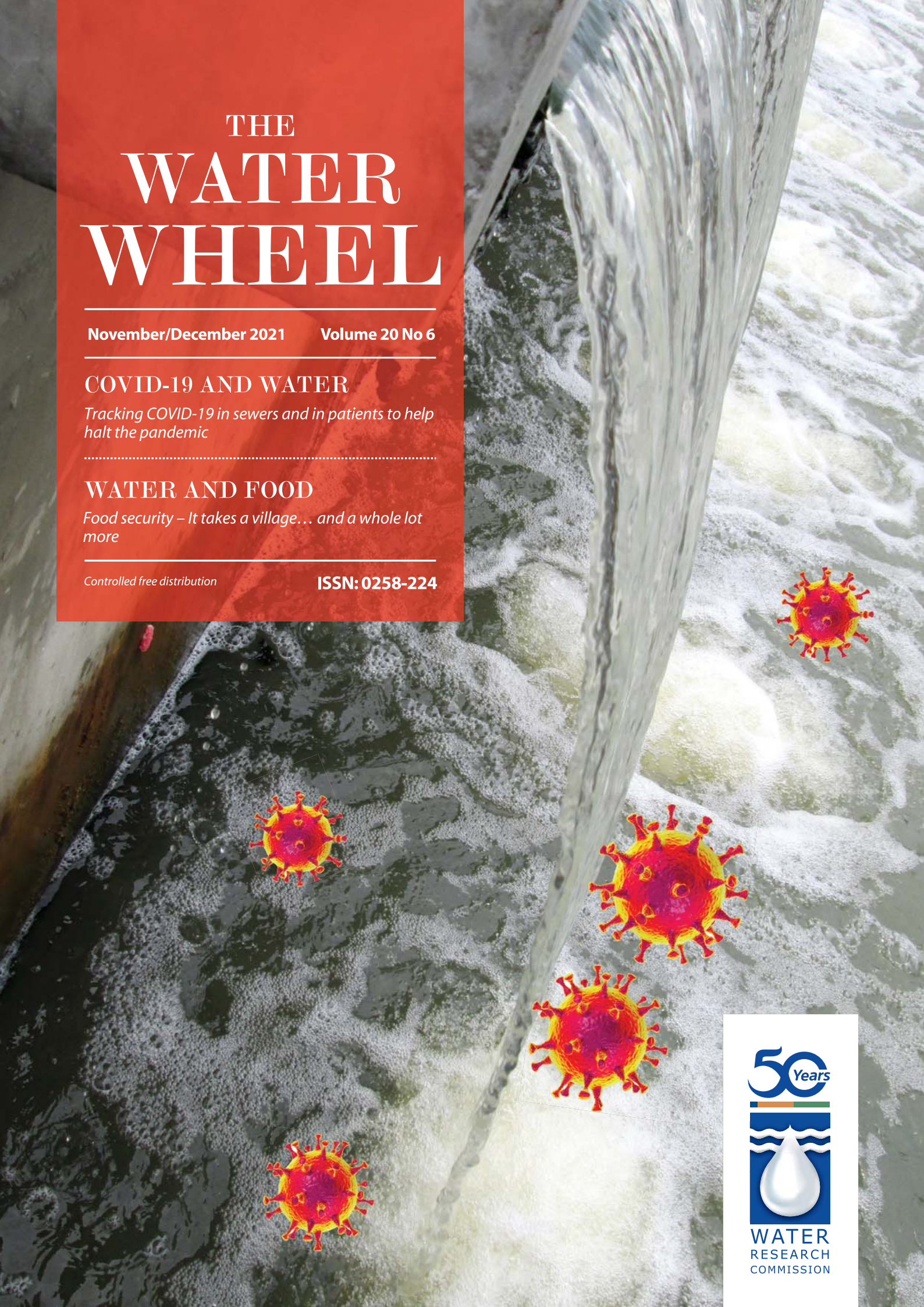

THE WATER WHEEL

November/December 2021 Volume 20 No 6

COVID-19 AND WATER

Tracking COVID-19 in sewers and in patients to help halt the pandemic

WATER AND FOOD

Food security – It takes a village… and a whole lot more

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WATER RESEARCH COMMISSION

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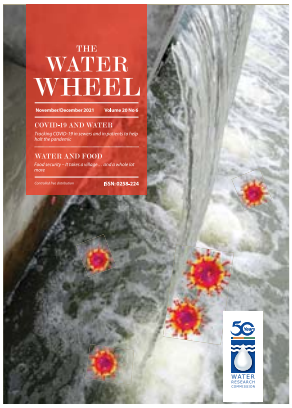

Wastewater-based epidemiology is proving to be a valuable in the fight against the COVID-19 pandemic. *See story on page 10.*

NEWS

Cape Town's first floating solar pilot project paving the way for a more sustainable city

The City of Cape Town has become the first municipality to install a floating solar photovoltaic (PV) system with partners Floating Solar (Pty) Ltd, the Water Research Commission and the University of Cape Town.

The floating solar PV pilot, which has been established at the City's Kraaifontein Wastewater Treatment Works, includes a floating solar PV array as well as a ground-mounted PV system to determine evaporation savings and relative energy generation performance of floating solar PV technology. This is an innovative research study where data is being collected over a 12-month period to potentially inform the design of larger utility scale floating solar PV projects over the next few years through competitive bid processes.

"The City has a target to achieve 300 MW of renewable energy generation by 2030, with 50 MW of this comprising of City-owned solar PV plants. The City has been fighting to move away from the sole reliance on Eskom and to diversify the energy mix for cleaner and more affordable and secure power for all. In addition, given that vacant land in the city is very expensive and rooftop solar PV systems are relatively small, Cape Town aims to explore floating solar PV systems for larger scale solar PV installations as part of its pioneering work to diversify the energy mix, to lead by example and to take climate action leadership. Importantly, great things can only be done with great partners. We thank Floating Solar, the Water Research Commission and the University of Cape Town for helping to enable this project and driving it forward with the city.

"This exciting pilot project not only looks at the amount of energy that can be generated by floating panels, but also investigates how much can be generated compared with the ground-mounted panels. The other important pillar of the research is to see what impact the floats have on water evaporation. Generating clean power and reducing evaporation rates of water bodies could be a great double-win for sustainability. This type of project is a tangible example of how we can build a more sustainable future city and how the green economy can be harnessed for the sustainable, and inclusive, economic recovery we require especially after COVID-19," said the City's Mayoral Committee Member for Energy and Climate Change, Councillor Phindile Maxiti.

Wastewater treatment plant audit start as part of Green Drop programme

The Department of Water and Sanitation has begun assessing wastewater treatment plants in several municipalities across the country. This follows the relaunch earlier this year of the Blue and Green Drop Certification Programmes, which advocate for excellent drinking water and wastewater quality management. The department said the assessments are mainly for the Green Drop Certification Programme, which is aimed at ensuring that municipalities improve their maintenance and management of wastewater infrastructure. The Green Drop assessments will be conducted at 963 wastewater systems and will be finalised by February 2022.

"What we look for during these assessments are effluent and sludge quality compliance; the environmental, technical management, financial provision for operations and maintenance of the infrastructure, among other things," said the department's acting Chief Director Siboniso Mkhaliphi.

Mkhaliphi said to assess the maintenance capacity of wastewater systems, water services institutions (WSIs) are required to provide evidence of a maintenance team used for general maintenance work at the plant and pump stations. They are also required to provide evidence of proof of competency of the team.

"The reason for this is that the lifespan of the infrastructure partly depends on professionals who know what they are doing when carrying out operations and maintenance. Most importantly, the department has financially supported many WSIs in refurbishing wastewater treatment plants," Mkhaliphi said.

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Maloti-Drakensberg part of global research project on climate change

The deepening effects of climate change on the environment has had devastating consequences for communities in recent months, with changing weather patterns giving rise to major floods and droughts globally.

To mitigate such impacts, countries are increasingly pooling resources and collaborating on projects. One such initiative is a research project focusing on the Maloti-Drakensburg range in the Free State, which aims at a better understanding of the ecological drivers of range-expanding plant species at high altitudes. Here, at 3 100 metres above sea level, the researchers will seek to determine whether typical range-expanding species might colonise the alpine zone above 2 800 metres under simulated warmer conditions such as might exist in the not-too-distant future.

Titled 'RangeX', the project is being undertaken by a multi-institutional research consortium under the Mountain Invasive Research Network (MIREN), with Switzerland leading the research. The Department of Science and Innovation (DSI) is funding South Africa's participation, which is being led by the Afromontane Research Unit (ARU) based at the University of the Free State's Qwaqwa Campus.

According to research leader, Dr Vincent Clark, little is known about the alpine zone in the Maloti-Drakensburg. "We could be 100 years behind Switzerland with alpine research, in terms of what we know about the ecosystem. Yet this system is critical for water security for two countries, Lesotho and South Africa," Dr Clark said.

He added that, with climate change and increasing human pressure, it is not known what the system will look like in several decades – whether or not ecosystems will collapse, resulting in total alpine desertification.

"We are using RangeX as a pilot to see if we can establish a 50-year research traction and really understand the system holistically and provide solution-oriented research for this whole environment, including social interventions and geopolitical discussions."

Applying forensic science to unlock the mysteries of fatal lightning strikes

New research by scientists from South Africa and the UK could help forensic teams understand whether people or animals were the victims of fatal lightning strikes, based solely upon an analysis of their skeletons. Their study is published in the journal ***Forensic Science International: Synergy***, titled 'Harnessing Thor's Hammer: Experimentally induced lightning trauma to human bone by high impulse current'.

Climate change is increasing and there is evidence to suggest the incidence and severity of thunderstorms and lightning strikes could increase. Sadly, fatal strikes are common on wild animals, livestock, and people – with African countries having some of the highest fatality rates in the world.

In South Africa, more than 250 people are killed annually by lightning. When a lightning death is suspected, the forensic pathologist determines cause of death by looking for signs of lightning – trauma to skin and organs of the deceased. However, when the body is skeletonised, soft tissues are absent and cause of death by lightning cannot be attributed.

This new research provides a tool to investigate cause of death when skeletonised remains are recovered as part of accident or death investigations.

According to Dr Nicholas Bacci, Lecturer in the School of Anatomical Sciences at the University of the Witwatersrand and lead author of the paper, "identifying a fatality caused by lightning strike is usually done though marks left on the skin, or damage to the internal organs – and these tissues don't survive when bodies decompose. Our work is the first research that identifies unique markers of lightning damage deep within the human skeleton and allows us to recognise lightning when only dry bone survives. This may allow us to recognise accidental death versus homicide in cases where cause is not apparent, whilst at the same time allowing us to build a more complete picture of the true incidence of lightning fatalities."

The research was undertaken as collaboration between specialists in forensic anthropology, anatomy, lightning physics, and micro-computed tomography (micro-CT) from Wits University in South Africa, Northumbria University in the UK, and the Nuclear Energy Corporation of South Africa (NECSA).

To access the original article, Visit: https://www.sciencedirect.com/science/article/pii/S2589871X21000760?via%3Dihub

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GLOBAL

AfDB loan boost for Lesotho water project

The African Development Bank (AfDB) Group's Board of Directors has approved a loan of US$86.72 million to co-finance the second phase of the Lesotho Highlands Water Project.

The multi-phase project will provide water to the Gauteng region of South Africa and generate hydroelectricity for Lesotho. The project entails harnessing the waters of the Senqu/Orange River in the Lesotho highlands by constructing a series of dams for the mutual benefit of the two countries.

The Trans-Caledon Tunnel Authority, a state-owned entity in South Africa charged with financing and implementing bulk raw water infrastructure projects, will use the funds to construct the Polihali Dam and reservoir, a 38 km-long water transfer tunnel, roads and bridges, telecommunications infrastructure, and to extend electricity and other development infrastructure to Lesotho. The new construction will complement facilities built during the project's first phase. The Lesotho Highland Development Authority will implement the part of the project that falls within Lesotho's borders.

"The two governments' partnership on this project around the shared water resources from the Orange-Senqu River Basin serves the interests of their mutual development agenda and also deepens regional integration," said Dr Beth Dunford, AfDB Vice President for Agriculture, Human and Social Development.

"The intervention will be the first major project to be financed by the Bank in the water sector in South Africa and it will complement the Bank's current support in the energy and transport sector, diversify the Bank's portfolio and consolidate the Bank's strong partnership with the country," she added.

Once completed, the project is expected to boost transfer capacity between Lesotho and South Africa to 1,260 million m^3/year, up from the current 780 million m^3/year, and enable additional generation of hydroelectric power in Lesotho. Expected project benefits include greater water security in South Africa's Gauteng region and a boost to Lesotho's socio-economic development due to infrastructure improvements and increased hydropower capacity.

Comprehensive assessment on plastic pollution confirms need for urgent global action

A drastic reduction in unnecessary, avoidable and problematic plastic is crucial to addressing the global pollution crisis, according to a comprehensive assessment released earlier this year by the UN Environment Programme (UNEP).

An accelerated transition from fossil fuels to renewable energies, the removal of subsidies and a shift towards circular approaches will help reduce plastic waste at the needed scale.

The publication, ***From pollution to solution: a global assessment of marine litter and plastic pollution***, shows that there is a growing threat in all ecosystems from source to sea. It also shows that while we have the know-how, we need the political will and urgent action by government to tackle the mounting crisis.

Plastic pollution leakage into aquatic ecosystems has grown sharply in recent years and is projected to more than double by 2030, with dire consequences for human health, the global economy, biodiversity and the climate. The authors pour cold water on the chances of recycling our way out of the plastic pollution crisis. They warn against damaging alternatives to single-use and other plastic products, such as bio-based or biodegradable plastics, which currently pose a chemical threat similar to conventional plastics.

"This assessment provides the strongest scientific argument to date for the urgency to act, and for collective action to protect and restore our oceans from source to sea," said Inger Andersen, Executive Director of UNEP. "A major concern is the fate of breakdown products, such as microplastics and chemical additives, many of which are known to be toxic, and hazardous to both human and wildlife health, and ecosystems. The speed at which ocean plastic pollution is capturing public attention is encouraging. It is vital that we use this momentum to focus on the opportunities for a clean, healthy and resilient ocean."

To access the report, Visit: https://www.unep.org/resources/pollution-solution-global-assessment-marine-litter-and-plastic-pollution

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Extreme heat affects 2 billion people living in cities

Extreme heat already affects around 2 billion urban residents around the world, according to a new study.

The new research is the first to examine in fine detail global trends in extreme heat exposure across urban areas. The study spanned more than 13 000 settlements over nearly three-and-a-half decades. The authors found that exposure to dangerous temperatures increased by 200% since the mid-1980s, with poor and marginalised people particularly at risk.

"Our study reveals that exposure to extreme heat in urban areas is much more widespread — and increasing in many more areas — than we had previously realised," says co-author Kelly Caylor, director of the Earth Research Institute at the University of California, Santa Barbara. "Almost one in five people on Earth experienced increases in exposure to urban heat over the past 30 years."

The study, published earlier this year in the ***Proceedings of the National Academy of Sciences***, is only the first of many that will delve into the rising threat of extreme heat and its impacts on society and the environment.

Lead author Cascade Tuholske was initially curious how climate change could directly affect urban food security, especially among low-income households. "Many of these people are not necessarily food insecure in terms of, say, a calorie deficit, but they spend a huge percentage of their income on food," he explains. This leaves them vulnerable, especially since extreme heat often drastically reduces labour output, and in turn, income and food security.

Throughout their analysis, the researchers used a metric called the wet bulb globe temperature (WBGT) to quantify extreme heat. WBGT is an index that accounts for temperature, humidity, wind speed, and radiant heat. Similar to a "feels like" index, it was developed to more accurately reflect how ambient conditions affect the human body.

To calculate this, Tuholske divided the Earth's surface with a grid. For each cell, he used his models and datasets to calculate the maximum temperature and relative humidity for each day from 1983 through 2016. This enabled him to calculated the WBGT. Next, Tuholske overlayed this grid on the map of urban populations. He chose a wet bulb globe temperature of 30° Celsius (86° Fahrenheit) as the threshold for extreme heat exposure. This value is commonly used as it's considered to pose a high risk of occupational heat-related illness by the International Standards Organisation.

For each year, he counted how many days each cell exceeded a WBGT of 30°C, and then multiplied that by the population in that cell. The result was the number of person-days per year of extreme heat exposure at a resolution of 0.05° of latitude by 0.05° of longitude.

"We found that, in 34 years, urban extreme heat exposure increased 200% globally," Tuholske says. The researchers were further able to distinguish between the contributions from population growth and rising temperatures. They found that population growth contributed two-thirds of the year-to-year increase, with warming accounting for one-third.

"This study emphasises that extreme heat exposure is already increasing for about half of all the world's cities and towns," says co-author Chris Funk. "And population growth is a major driver of increased risk. We need to think about these demographic factors as well as climate change."

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NEW WRC REPORTS

Machine learning models for groundwater availability – Incorporating a framework for a sustainable groundwater strategy

This report is the outcome of one of four projects carried out under an initiative called "Big Data Analytics and Transboundary Water Collaboration in Southern Africa". This project developed a strategy for sustainable groundwater use (SGS) which is an approach for achieving best practice groundwater management. The SGS sets out the benchmark for an approach to achieve sustainable groundwater use. The SGS is essentially a list of actions necessary for achieving sustainable groundwater use and is applicable to any aquifer or group of aquifers (a groundwater basin). It is recommended that the approach be implemented particularly in heavily used aquifers, in aquifers with sensitive receptors, and the approach would support improved groundwater management in transboundary aquifers.

WRC Report No. TT 845/20

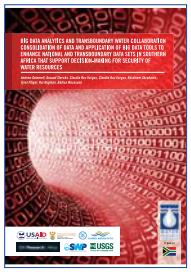
Web link: https://bit.ly/3nX6UqR

Big Data analytics and transboundary water collaboration – Consolidation of data and application of Big Data tools to enhance national and transboundary data sets in southern Africa that support decision-making for security of water resources

Effective management of groundwater resources requires ease of access to reliable data to support decisions. This is particularly important for transboundary systems where different environmental data are collected and managed by different institutions in different countries; thus, impeding the sustainable management of transboundary water resources. The objective of this project was to utilise Machine Learning tools; however, the amount data available for our study area was insufficient for pure Machine Learning. As a result, the Big Data tools used focused on statistics, visualisation, and data comparisons using the Python programming language. The project developed software tools to automate the collation and quality control of data from existing online databases into a format suitable for our primary repository, the existing SADC-GIP platform.

WRC Report No. TT 844/20

Web link: https://bit.ly/2YjgnzT



Big Data analytics and modelling – Localising transboundary data sets in southern Africa: A case study approach

In the groundwater discipline Big Data can provide new methods of information discovery, that can support efforts of sustainable groundwater management. However, the application of Big Data analytics is particularly nascent in the groundwater discipline. The purpose of this research is to investigate the use of Big Data analytics to integrate, match and model groundwater data, especially at a local scale, to improve sustainable groundwater management. A case study application is undertaken, with a focus on transboundary aquifers in the Southern African Development Community (SADC). These aquifers are vital water resources for region, but their sustainable management is hindered, in part due to a lack of relevant groundwater data. The unique challenges experienced in SADC provide an opportunity to test Big Data analytics in data scarce regions, by augmenting the data gaps with new sources of data.

WRC Report No. TT 843/20

Web link: https://bit.ly/3k8aWeU

Imagining solutions for extracting further value from existing datasets on surface and groundwater resources in southern Africa

Groundwater is an important source of freshwater for several semi-arid countries, including South Africa and Botswana. This is important for the rural communities that lie on the periphery of local water scheme pipelines and make direct use of groundwater in such regions. The Ramotswa Transboundary Aquifer (RTA) stretching between South Africa and Botswana supplies nearby rural communities, local municipalities and cities in both countries with fresh groundwater. Disparate water datasets have been compiled for the area, but with analytical tools such as Big Data analytics lacking that could yield valuable information for use in policy-making and water management. To this end, the study pursued the following aims: Engagement with stakeholders (water experts and municipal officers) to assess their understanding of the importance of Big Data analytics and citizen science; collection of analytical water data; conducting a confirmatory survey; and collection of citizen science from the community; conducting Big Data analytics on the data; text mining on citizen science; and building citizen science into the big data context.

WRC Report No. TT 842/20

Web link: https://bit.ly/3bH2JcX

Design of acid mine drainage remediation plant

Despite its acknowledged economic contributions, mining causes significant environmental degradation and generates multiple waste streams that are disposed of in tailings dams or stored in impoundments. Acid mine drainage (AMD) is an example of one such mining waste and the amount of this that is produced daily as well as the high cost associated with its treatment, has necessitated the development of new, viable and cost-effective remediation schemes. Basic oxygen furnace slag (BOFS) is a final waste material in the steelmaking process and contains high concentrations of oxides which have the ability to substantially increase the pH and alkalinity of acidic waters. This research investigated AMD treatment or pre-treatment

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using BOFS by assessing the extent of remediation achieved in a laboratory (1-25 ℓ/day) and pilot-scale (200-1000 ℓ/day) system. Another industrial by-product, sugarcane bagasse, was also used in the study to further remediate AMD after the BOFS treatment step and the efficacy of this biological treatment step is also evaluated.

WRC Report No. 2757/1/21
Web link: https://bit.ly/3CPLeD9

The status of wastewater as an untapped resource in South Africa

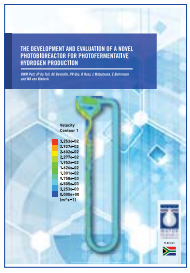
This study reviews municipal wastewater management in South Africa and assesses the country's progress toward the United Nations Sustainable Development Goal 6 (SDG 6), specifically SDG Target 6.3, which defines indicators for sustainable management of wastewater and ambient water quality. The study's starting point is that wastewater should be seen as an 'untapped resource', rather than a liability. The project's aims are to map out current challenges associated with sustainable wastewater management, including quantifying the national environmental and health impacts, using specific case studies; to consolidate key research work achieved to date in South Africa in support of achieving Target 6.3 and also identify current gaps; and to establish a more detailed analysis of existing opportunities within the wastewater sector as part of tracking national progress on Target 6.3 in support of achieving SDG 6.

WRC Report No. TT 860/21
Web link: https://bit.ly/3ERamu1

WET-EcoServices (Version 2) A technique for rapidly assessing ecosystem services supplied by wetlands and riparian areas

Wetlands and riparian areas are globally threatened ecosystems and are well-recognised for the ecosystem services which they supply. There is a need to assess and compare wetland/riparian areas in terms of ecosystem services delivery. Recognising this need, a rapid assessment technique, termed WET-EcoServices (Version 1) was developed 10 years ago to help non-specialists assess the ecosystem services that individual wetlands supply. The technique has been revised through a Water Research Commission project to produce WET-EcoServices Version 2.

WRC Report No. 2737/1/21
Web link: https://bit.ly/3wmq5Ov



The development and evaluation of a novel photobioreactor for photofermentative hydrogen production

Industrial and municipal wastewaters often contain significant concentrations of organic compounds, which require treatment or removal before the water can be safely reused or disposed of in natural waterways. There is a growing need to develop water treatment technologies which can purify wastewaters, to allow for their reuse. This project saw the successful development of a novel photobioreactor at bench scale, following metabolic and fluid mechanic modelling and experimentation. This purpose of this reactor is to allow for integration of photofermentative treatment of wastewater, with simultaneous hydrogen production.

WRC Report No. TT 851/21
Web link: https://bit.ly/3mNhdhP

Water use of macadamia orchards

It is estimated that close to 44 800 ha are planted to macadamia in South Africa, with just over 5 000 ha planted in 2020. The most important established growing areas for macadamias are found in Limpopo, Mpumalanga and KwaZulu-Natal, with smaller plantings in the Eastern Cape and Western Cape. Macadamia orchards therefore represent a significant user of freshwater, with optimal irrigation of orchards required for optimal production. Importantly, some evidence suggests that macadamias may be sensitive to too much water. Accurate information on the water use of macadamia orchards is therefore important for water management in these orchards, to ensure that orchards are optimally irrigated, to develop water savings strategies to cope with water shortages caused by droughts and to know how to allocate water during different phenological phases with minimal impact on yield and quality.

WRC Report No. 2552/2/21
Web link: https://bit.ly/3k62IDS

Water use of avocado orchards

A census in 2020 confirmed that 14 700 ha are planted to avocados in South Africa, with annual growth of approximately 800 ha. The most important established growing areas for avocados are found in Limpopo, with smaller plantings in Mpumalanga, KwaZulu-Natal, Eastern Cape and Western Cape. Avocado orchards therefore represent a significant user of freshwater, with optimal irrigation of orchards required for optimal production. Accurate information on the water use of avocado orchards is therefore important for water management in these orchards, to ensure that orchards are optimally irrigated, to develop water savings strategies to cope with water shortages caused by droughts and to know how to allocate water during different phenological phases with minimal impact on yield and quality.

WRC Report No. 2552/1/21
Web link: https://bit.ly/3o2xXAT

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COVID-19 AND WATER

Tracking COVID-19 in sewers and in patients to help halt the pandemic

Wastewater-based epidemiological surveillance (WBE) offers an opportunity for the near real-time collection of data on tracking COVID-19 infections. In addition, it can provide early warning on the increases in infections, as well as the emergence of new variants. Article by Jorisna Bonthuys.

Measuring coronavirus levels in wastewater offers an early warning tool against the rise of COVID-19 infections in South Africa.

This is the finding of health and water experts who have been involved in a national COVID-19 environmental surveillance collaborative initiative since 2020.

During a recent online symposium, these experts highlighted their experiences with employing a WBE approach to track coronavirus infection levels in local communities. The symposium was organised by the Water Research Commission (WRC).

The age of coronaviruses

Since the beginning of the twenty-first century, three types or variants of coronaviruses have crossed the barrier to cause deadly pneumonia in humans, including severe acute respiratory syndrome (SARS-CoV-1), Middle East respiratory syndrome coronavirus (MERS-CoV), and now severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2 or COVID-19).

The SARS-CoV-2 virus is the newest member in the coronavirus family, associated with human infections grouped into the beta-CoV genus, and with a 79% genetic similarity to SARS-CoV-1.

While researchers use genetic changes in SARS-CoV-2 to document and analyse its spread across the globe, the emergence of several SARS-CoV-2 variants has become a significant challenge for COVID-19-related policies and vaccination rollouts. In this context, the design of new epidemiological tools and the refining of existing ones –

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including the use of WBE to inform healthcare decision-making – has received much attention.

Wastewater profiling for virus detection

Wastewater-based epidemiology has been a valuable tool for monitoring substance use in communities (for instance, the use of prescription and illicit drugs). This approach employs the analysis of human metabolic excretion products in wastewater. Recently, WBE has been extended to serve as a tool in tracking the prevalence of non-communicable diseases (such as cardiovascular disease) and communicable diseases (including diseases caused by microorganisms that are resistant to antimicrobial agents).

COVID-19 infections too can be traced and monitored in wastewater samples. This is because infected people shed the virus through faeces. While the risk of transmission via contaminated stools is unlikely, wastewater that contains such particles is a marker of infection. Therefore, the presence of SARS-CoV-2 in wastewater treatment plant influent can help determine the presence of infected individuals in a local community.

This is because the detection of SARS-CoV-2 genetic material in wastewater typically precede a rise in diagnosed cases and thus presents a warning that spikes in infections and local hospitalisations should be expected. This information can be used as an early epidemiological indicator of COVID-19, especially where community testing is not possible.

During the pandemic, many studies have shown the value of this approach in tracing and monitoring changes in the prevalence of infections in human populations feeding into wastewater streams. The detection of SARS-CoV-2 RNA in untreated domestic wastewater has, for instance, been reported in the Netherlands, France, China, Israel, Turkey, and Italy.

WBE surveillance during the pandemic

The objective of the WRC-hosted symposium was to share knowledge on the progress that has been made in South Africa in monitoring the spread of COVID-19 using the WBE approach. Since 2020, researchers, healthcare practitioners and epidemiologists have formed a multidisciplinary network to evaluate the spread of the novel coronavirus in local communities.

Initially, it had to be established whether WBE could be successfully applied locally to track this coronavirus, given the high number of households without access to formal sewerage networks. For this reason, the implementation of the wastewater surveillance initiative is following a three-phased approach.

The first phase of this approach entailed a proof-of-concept study to optimise sample design and testing, as well as finetune the sampling protocol. This study included the preliminary sampling and analysis of wastewater samples from metropolitan areas. In the second phase, a collaborative monitoring initiative was set up with what has become known as the SACCESS (South African Collaborative COVID-19 Environmental Surveillance System) network in provincial hotspots (in Gauteng, KwaZulu-Natal and the Western Cape), using the sampling and testing protocols developed in the first phase. The third phase will entail a national wastewater surveillance programme roll-out.

Although WBE surveillance is not yet fully integrated into the national COVID-19 surveillance programme, researchers have made huge strides with this approach since 2020, presenters indicated.

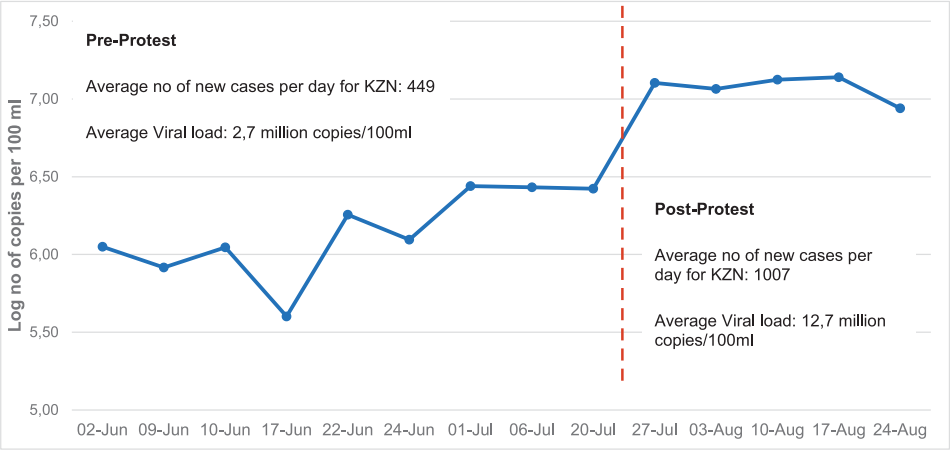
Collaborating partners provide new insights

Notable regional and national efforts are underway towards the early detection of COVID-19 cases by looking for the viral signature of SARS-CoV-2 in wastewater. This was highlighted by Lynn Bust, a public health professional from the University of Cape Town. She said there is scope for both informal and formal surveillance networks to ensure public health responsiveness to the pandemic.

In the Western Cape, the South African Medical Research Council — together with scientists from the City of Cape Town, the Western Cape Provincial Government, and universities — perform routine wastewater surveillance for the metropolitan area and beyond. Viral genome detection in wastewater is reported routinely by the provincial health authority. Since early December 2020, ongoing surges in COVID-19 infections in parts of the province have been confirmed by using WBE.
Although most of the data collection includes samples from influent wastewater at wastewater treatment plants, communities without access to formal sewerage networks are also being tracked. In addition, primary sludge and grab samples are collected from industry sewage treatment plants, prisons, student residences, and hospitals.

Ultimately, one of the most significant development to date in terms of WBE surveillance in South Africa has been the establishment of the SACCESS network, noted WRC Executive Manager for water use, wastewater resources and sanitation futures, Jay Bhagwan. This network facilitates knowledge sharing and capacity building amongst its members, who collaborated to standardise the methodology and sampling methods for the national wastewater surveillance initiative.

South Africa was one of the first countries in the world to investigate COVID-19 monitoring of wastewater in non-sewered areas.



The effects of civil unrest on SARS-CoV-2 viral loads in wastewater. (Source: DUT)

The SACCESS list of partners includes researchers from the National Institute for Communicable Diseases (NICD), the Council for Scientific and Industrial Research (CSIR), the South African Medical Research Council (SAMRC), the National Institute for Occupational Health (NIOH), Lumegen Laboratories, Greenhill Laboratories, Waterlab, and several other institutions providing higher education or doing health and water research.

The science and research community under the auspices of the SACCESS network has made significant progress in detecting and quantifying the SARS COV-2 virus and its emerging variants.

Dr Nkosenhle Ndlovu, a medical scientist at the NICD's Centre for Vaccines and Immunology, said the surveillance of defined communities can help direct community screening efforts and alert medical facilities to potential increases in patient numbers.

Ndlovu said what started out with 18 treatment sites monitored by the NICD in five provinces (Gauteng, the Western Cape, Free State, Eastern Cape and KwaZulu-Natal) soon expanded to 49 sites across all nine provinces. As a result, the SACCESS network collectively investigated 798 cases from early in 2020 to August 2021, with the bulk of these handled by NICD researchers. In total, 72% of the samples tested during this period were positive.

Advance warning about outbreaks

In KwaZulu-Natal, since July 2020, WBE monitoring has been carried out by the Institute for Water and Wastewater Technology, with the assistance of the eThekwini Municipality and Umgeni Water in Durban and Pietermaritzburg. This year, WBE-related research efforts in this province focused on collecting data from Durban's main wastewater treatment plants.

Dr Leanne Pillay from Durban University of Technology's Institute for Water and Wastewater Technology said their monitoring data showed a good correlation between the number of active clinical cases of SARS-CoV-2 in the eThekwini Municipality and those in the province of KwaZulu-Natal. Data collected using the WBE approach enabled researchers to predict the surge in clinical cases in April in KwaZulu-Natal three weeks before it happened. Likewise, the second surge in clinical cases in the province (reported on 9 June) was also predicted three weeks prior (on 18 May).

Pillay also highlighted the effect of the large-scale civil unrest in KwaZulu-Natal in July this year on COVID-19 infections in the province. The unrest turned out to be a superspreader event.

Viral loads in wastewater are dynamic and respond to changes in lockdown levels, Pillay said. In addition, research findings suggest that there may be more infected individuals than what is clinically reported. WBE data, therefore, provided a more accurate representation of infections at the community level than clinical data at this time, as clinical testing came to a halt during the unrest while WBE testing did not.

Understanding the risks

Dr Noncy Gomba, a senior research scientist at the National Institute for Occupational Health's Immunology and Microbiology Department (in the National Health Laboratory Service), discussed the health risks for wastewater workers or in the reuse of treated effluents. Gomba and others assessed the presence, prevalence and removal of SARS-CoV-2 genetic fragments in wastewater at three wastewater treatment plants in Gauteng. They also considered the viability of SARS-CoV-2 in wastewater. She said that positive detection of viral RNA alone does not point to a health risk for wastewater workers or in the reuse of treated effluents.

Research to develop a framework for WBE surveillance in non-sewered communities also came under the spotlight.
Dr Gina Pocock from the Waterlab and Dr Bettina Genthe, a CSIR researcher focusing on water-related health issues, outlined efforts to refine sampling methods in polluted rivers and water run-off from within communities, and in on-site sanitation systems. Their presentation, 'Development of a framework for wastewater-based COVID-19 epidemiology surveillance for non-sewered communities', highlighted that WBE could also be applied in communities without access to formal sewerage systems.

In South Africa, more than 40% of the population does not have access to a municipal sewage system. These communities are usually the most vulnerable, lacking healthcare and financial resources. About 81.9% of households in metropolitan areas live in formal dwellings, while 16.8% live in informal dwellings. In communities lacking sewerage networks or with non-functional or poorly performing wastewater treatment plants, raw or poorly

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treated sewage and greywater are disposed of on the ground or into a nearby stormwater channel. In most cases, it ultimately enters rivers and streams.

Nearly all municipalities in South Africa have informal and low-income settlements that do not have access to sewage or stormwater systems. Many developing countries share a similar challenge.

Since 2020, researchers have been developing and optimising the methodology for SARS-CoV-2 detection, quantification and monitoring in different types of samples from non-sewered environments. Sampling sites were selected in Gauteng (including the Jukskei River and Kaalspruit), the Western Cape (including the Plankenbrug River near Stellenbosch), KwaZulu-Natal (including the Quarry Road informal settlement and Palmiet River in the eThekwini Municipality), and in Mpumalanga.

Data was collected using grab samples (from, among other sources, surface water, greywater run-off, and chemical and portable toilets) and passive samples (from rivers, run-off channels in informal settlements, and emptying tankers that collect waste from portable toilets).

Some of the challenges in doing this kind of research included sampling logistics, the cost of transporting large volumes of water, and maintaining the cold chain in rural areas. During the rainy season, the dilution of samples may also hinder the detection of the novel coronavirus. Sampling from on-site sanitation systems is costly and impractical. It is also challenging to correlate viral loads with clinical cases. One of the main issues is that there are gaps in the reporting of data for the province regarding situational reports.

However, researchers can still successfully monitor trends in viral loads to implement an early warning system and assess community infections. Passive sampling methods may overcome issues of low yield during high-dilution periods, allow for the easier and cheaper transport of samples, and improve the consistency of the data generated.

Future applications

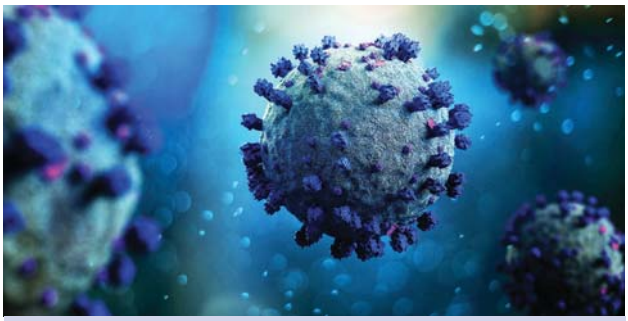
The detection of SARS-CoV-2 RNA in 98% of the wastewater samples collected has demonstrated the proof of concept for using WBE surveillance to track COVID-19. Continued WBE sampling at priority sites will allow for the expansion of pandemic trend monitoring. In terms of the impact on public health decision-making, only the City of Cape Town and the Western Cape Provincial Department of Health have incorporated WBE into their local responses. This is helping the City and province understand the emergence and patterns of infections. Efforts are also underway to get municipalities that are considered COVID-19 hotspots to incorporate the WBE approach into their actions to manage the pandemic.

Many of the presenters indicated that sampling in defined populations could provide a cost-effective and less invasive means of continuous screening. Where an increase in viral load is detected — signalling an early warning — additional clinical test methods could be rolled out. Bhagwan said the WBE monitoring systems that have been established offers the future potential to transition to monitor environmental water quality in the country. In addition, as the water and health sector is learning and looking beyond the pandemic, opportunities are emerging for researchers to help improve the provision of water and sanitation services in the country.

Monitoring of COVID-19 infections within communities using WBE could provide a cost-effective alternative to clinical testing. This approach, however, still requires improvement if it is to be applied efficiently.

Bhagwan concluded that COVID-19 and its surveillance responses offer the water sector "an opportunity to organise itself for a robust water quality compliance future".

Visit www www.wrc.org.za/corona-virus for information and regular updates on the WBE programme.



More about coronavirus

- Authorities have reported about 241.17 million COVID-19 cases and 4.9 million deaths since December 2019.
- The term 'coronavirus' refers to a family of viruses that causes many different types of illnesess, including the common cold, Sars, and Mers.
- The virus spreads by respiratory droplets released when someone with the virus coughs, sneezes, breathes, sings or talks. These droplets can be inhaled or land in the mouth, nose or eyes of a person nearby.
- In some situations, the COVID-19 virus can spread by a person being exposed to small droplets or aerosols that stay in the air for several minutes or hours — called airborne transmission. It's not yet known how common it is for the virus to spread this way. It can also spread if a person touches a surface or object with the virus on it and then touches his or her mouth, nose or eyes, but the risk is low.
- A SARS-CoV-2 virus particle is about 100 nanometers in diameter – visible only with an electron microscope. It is a near sphere of protein inside a fatty membrane that protects a twisting strand of RNA (a molecule that holds the virus's genetic code). Coronaviruses are a type of enveloped virus encased within a lipid (fatty) membrane that is susceptible to heat.
- Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. Older people and those with underlying medical problems like cardiovascular disease, diabetes, and cancer are more likely to develop serious illnesses.

Source: John Hopkins Coronavirus Resource Centre; www.who.int; www.scientificamerica.com

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WATER AND POWER GENERATION

Despite ageing infrastructure Eskom still on par with world water efficiency levels

What to make of Eskom? The loadshedding it unleashed 13 years ago continues to grip the country's economy. We've grown resigned to our lights going out, even as revelations about the public power utility emerging at the Zondo Commission into state capture and corruption still possess the power to shock us, writes Matthew Hattingh.

Spectacular debt saddles Eskom, yet it needs to find ways to spend even more while somehow reining in tariff hikes. It's enough to blow the biggest of fuses, but at the same time, there's a different Eskom to consider, one that's a world leader in certain water-saving energy generation technologies.

The utility is the largest producer of electricity on the African continent. While producing 95% of South Africa's electricity and, in the face of a difficult set of circumstances, it manages to stay in line with world power sector averages for water consumption. It also holds itself to some exacting, even laudable, standards for water use.

In the mid-1990s the power giant adopted a philosophy of zero liquid-effluent discharge. Under normal circumstances operations at its power stations do not lead to spillages into the environment.

Eskom has put in place systems to recover, recycle and reuse water in a number of often complex ways, particularly for cooling at its 13 completed coal-fired stations. And the utility ticks boxes, or was aiming to, for more than a dozen best-practice indicators.

These and a host of other water-related insights are the stuff

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of one of the latest reports published by the Water Research Commission (WRC) titled ***Natsurv 16: Water and Wastewater Management in the Power Generating Industry*** (**Report No. TT 853/21**). The report is the second edition of this survey of water use in South Africa's power generating sector. It continues the work of the previous edition – published in 2005 – which looked at national electricity production and capacity as well as intake and management of water, including quality and treatment. That was a couple of years before rolling blackouts became a way of life in South Africa and in other ways too, much water has flown under the proverbial bridge.

Climate change now occupies a more prominent place on the world's agenda so its implications for electricity generation, including possible shifts in rainfall patterns, received attention in ***Natsurv 16***. Similarly, while the previous survey did not consider renewables, the latest one does in some detail. And it may come as a surprise to many to learn that South Africa leads the world in spending on renewable energy as a percentage of its gross domestic product (1.4% in 2015).

From a water-use perspective, some renewables, including wind and solar photovoltaic generated electricity, have much to recommend them. Once installed they need little water to operate beyond an occasional wash of turbine blades or panels. But in at least one fundamental way South Africa's power generating landscape has not changed significantly since the last survey. The report's authors, Gina Pocock and Hannes Joubert, observed that the central role of coal in electricity generation would continue until locally available resources start to diminish. (And this seems unlikely any time soon given that the country's coal reserves rank among the world's top eight.) "However, technologies that utilise water efficiently will have to play a more dominant role in order to preserve national water security," they said.

So how much power and water are we talking about? At the time of the previous Natsurv, South Africa produced 192 000 gigawatt hours (abbreviated as GWh) of electricity. A single gigawatt hour is one billion watts delivered over an hour. Put differently, it's the power you would get from roughly 1.3 million horses working together, based on a horsepower to watts conversion where 746 watts equals 1 horsepower.

By 2018/19 many more horses had been roped in. Power production grew 18% to 234,407GWh. Over the same period, water use rose too, from 245,000 to 292,344 megalitres (abbreviated as ML) a year.

Is that a lot of water? It's a matter of perspective. The 2018/19 figure amounts to a little more than, for example, the capacity of Pietermaritzburg's Albert Falls Dam – the country's 16th largest impoundment by volume. But it's more useful to consider water used for power production as a percentage of the country's total water use or to look at in terms of efficiency. In other words, how many litres of water does it take to produce a given amount of electricity, typically expressed as litres per kilowatt-hour (abbreviated as ℓ/kWh).

This is precisely what Pocock, a specialist consultant at Waterlab, an analytical chemistry and multidisciplinary water services company, and Joubert, of water treatment innovation company VitaOne8, have done.

The authors sent questionnaires to Eskom and renewable energy producers to gauge water quality, specific uses

Graeme Williams/Media Club

Kendal power station, outside Witbank in Mpumalanga is one of the largest dry cooled power stations in the world. The water consumption of South Africa's dry cooled power plants is among the best in the world.

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The cooling towers of the Grootvlei power station. While the old, recommissioned Eskom power stations are helping to meet the demand for electricity they are not as water efficient.

and consumption versus power production at different plants employing different technologies. They completed a literature review of the industry in South Africa and boned up on international practice. This gave them benchmarks for comparisons and supported a broader analysis.

The generation of power represents about 15% of the country's gross domestic product and Eskom is classified as a strategic water user. It's a level of importance reflected in the many schemes developed over the years to transfer water among catchment areas to supply power plants.

Power generation accounts for a modest 2% of South Africa's freshwater use – irrigation mops up the lion's share (60%), followed by municipal-urban use (24%). But water is scarce, partly due to a growing population and economy. And the authors reminded us of the looming spectre of climate change and the consequences this may have in the future.

"Water supply to South Africa's coal-fired stations is not considered to be at risk over the short to medium term due to healthy dam levels," the report said. "However, the Department of Water and Sanitation is experiencing severe financial constraints, which may affect its ability to manage existing and implement new bulk water infrastructure to ensure water security to Eskom."

So there's no time for complacency and Eskom is under the cosh to curb its consumption. How then, were the utility's water-saving efforts working out and what about those efficiency figures?

On average in South Africa, production of 1kWh of electricity consumed about 1.4 litres of water across all technologies. This puts the country in line with the world average of 1.2-1.5 ℓ/kWh. But according to Natsurv 16, it also represented an increase in water use of 0.27 ℓ/kWh (9.2%) in the 16 years since the previous survey.

To understand why things have slipped, it's helpful to consider how Eskom generates electricity. Leaving aside renewables, nuclear energy and a few other sources, it's chiefly done by burning coal to heat water to make steam. This in turn, turns turbines which drive giant electrical generators.

In 2018/19 Eskom produced 200 210 GWh of coal-fuelled thermoelectric power. The figure represented 83% of the total electricity the utility made available for distribution or own use. Coal, clearly, is king. But a bit like those ***Animal Farm*** pigs, some coal-fired stations are more equal than others.

The water used to make steam is only part of a bigger power station water-use equation. By far the largest use of water is for cooling turbine exhaust steam. For the purposes of South Africa's coal-fired stations, cooling comes in three varieties:

- Recirculated wet, which uses relatively large quantities of water;
- Dry cooled, which uses much less than the wet variety; and
- Hybrids, which combine elements of both and are somewhere in the middle so far as usage.

Each variety (and a bunch of sub-varieties) has its pros and cons and the report spells these out. It also looks at the cooling systems currently in place at each of Eskom's power stations and explains why the composition of its fleet (an energy geekspeak collective noun) has changed over the years and its effect on water use.

Eight of Eskom's 13 coal power stations use wet recirculation systems. In a nutshell, it circulates cold water through what is known as a condenser, to cool the exhaust steam exiting the turbine. This is necessary to squeeze maximum efficiency out of the turbine itself and so that turbine steam can be cooled back into water and reused.

It's a heat exchange process and the cooling water gets hot in the process and must be cooled for reuse too. To do this, it is pumped to a cooling device, such as a pond or a tower (picture those vast, wide-based-pinched-waisted concrete structures we associate with power stations). In an airstream within the tower, a portion of the water is evaporated, promoting cooling.

Evaporation and other factors lead to a loss of water from the system. "Water demands of between 2.04 and 2.38 from the predominantly wet-cooled closed loop thermal power plant fleet are somewhat above the typical mean intensity of 1.7 ℓ/kWh [for comparable plants]," said the report, citing the National Renewable Energy Laboratory, a US federal government-funded research facility.

In the case of dry cooling, air is used in the place of water to bring down the temperature of turbine exhaust steam. Water consumption with this system is between one-tenth and one-twentieth of a wet recirculation system.

According to the report, the water consumption of South Africa's dry cooled power plants is among the best in the world. It

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On average in South Africa, production of 1kWh of electricity consumed about 1.4 litres of water across all technologies. This puts the country in line with the world average.

quoted water-use figures for the country's direct dry stations of 0.12 ℓ/kWh, which were "in line with international estimates of 0.1 ℓ/kWh". Kudos for Eskom.

But as the economists like to remind us: there ain't no such thing as a free lunch. Dry cooling systems are more expensive to build and, crucially, don't work as well as wet cooling systems in hot and dry conditions. Air is less efficient as a coolant than water so massive fans are needed to help things along. This results in a parasitic drain on electricity production and the report puts the loss at 2% a year on average, but up to 25% at the peak of summer – the very time when electricity is needed most.

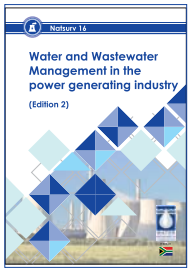
Back to the question: why have overall water-use figures slipped? "This can be attributed to the decreasing thermal efficiency and increasing age profile of the power plants," said the report. In other words, Eskom's power stations, particularly its wet-cooled ones, were getting long in the tooth. The old fellas didn't work as well as they used to and some had developed a bit of a drinking problem.

But Eskom's stations weren't merely old, cranky and thirsty. There weren't enough of them. From 2006 to 2009 (remember, loadshedding began in the later months of 2007) the utility took three retired coal-fired stations out of mothballs to help meet peak-hour demand.

Trouble was, the return-to-service power stations – Grootvlei, Camden and Komati – were not so much old themselves, as positively geriatric. Ground was first broken on Grootvlei in 1969; Camden was built from 1967 to 1969; and work first began on Komati in 1961. Heck, back then Elvis 7-singles were topping the charts; today, the kids are listening to who-knows-what on Spotify. Little wonder then that water consumption for the three was expected to reach 3 ℓ/kWh by 2020. And there's another problem: the three water-intensive power plants are all in severely constrained water management areas, namely Olifants and Inkomati.

Pocock and Joubert argue that from a water perspective they need to be retired while new build power plants are commissioned. Work on two new dry cooled power stations, Medupi and Kusile, began in 2015 and 2017. These are being equipped with the latest in dry cooling and boiler technology and as more generators come on stream at the two and ultimately as the return-to-service stations are decommissioned, net savings of about 35 gigalitres are expected.

However, the authors cautioned that decommissioning and switching to more water-thrifty power generation must be carefully considered. The taps must be tightened, even as the lights are kept on.



Download the report, ***Natsurv 16: Water and Wastewater Management in the Power Generating Industry,***
Visit: https://bit.ly/3o1udzO

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WATER AND FOOD

Food security – It takes a village… and a whole lot more

A project funded by the Water Research Commission sought to assess the potential of integrating water, agriculture and biogas to improve food security in a rural area of the Eastern Cape. Article by Sue Matthews

All images courtesy the research project team

In the undulating foothills of the Eastern Cape's Amathole mountains, the village of Krwakrwa lies a little way off the road between Alice and Hogsback. As in many rural villages in South Africa, the residents survive largely on social grants. Most people of working age – particularly men – have gone to urban centres to find employment, so the population is dominated by older women, some of whom tend homestead gardens. Much of the extensive cropland surrounding the village lies fallow today, and livestock farming is now the main agricultural activity, but the communal rangelands are in poor condition due to overgrazing.

Few households have a monthly income exceeding R2 000, so poverty and food insecurity is rife. Electricity is expensive so it is typically only used for lighting, while cooking and heating is done with firewood collected from the veld. This not only results in deforestation, but is a health and safety hazard through exposure to smoke and the risk of accidental burns and house fires.

It was here that a Water Research Commission (WRC) funded project was conducted over the past six years to assess rainwater harvesting and conservation practices for production of food as well as renewable energy in the form of biogas. The village was selected from a shortlist of five that met a set of criteria and were all visited by the project team, made up of staff and students from the Agricultural Research Council (ARC), the provincial Department of Rural Development and Agrarian Reform (DRDAR), the Fort Cox College of Agriculture and Forestry, and the University of Fort Hare. Ultimately, the neighbouring village of Upper Ncera showed so much interest in the project that it was included too.

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Within the villages, demonstration plots were established to show how water harvesting, vegetable crops, cow dung and bioenergy can be integrated. Thanks to additional funding from DRDAR, 14 biodigesters – seven in each village – could be installed at households that had their own water storage tanks as well as ready access to cow dung. Fortunately, livestock are kraaled by their owners close to homes overnight, which made dung collection easier, but the selected households needed to be willing and able to carry or transport this somewhat smelly haul back to their biodigesters. The water storage tanks were necessary not only for irrigation, but because the biodigesters need to be 'fed' with both water and dung every five days at least.

Project team members helped the households to construct in-field rainwater harvesting (IRWH) basins in their gardens and provided them with seeds and seedlings. Having learned from previous experience in rolling out the IRWH technique within communities, the team tried to avoid promoting 'dependency syndrome' by informing the households that they should not expect ongoing handouts. As a result, some started buying their own inputs from an early stage, and there was a marked improvement in food supply.

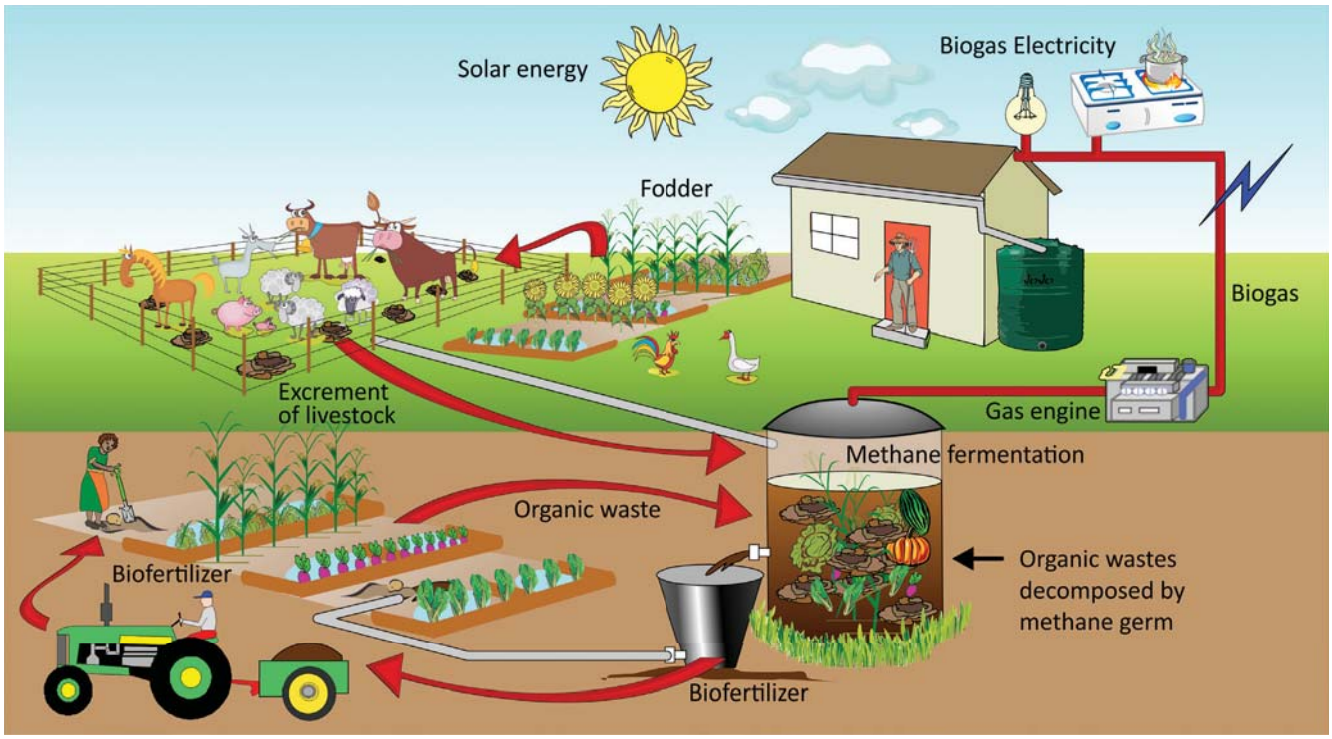
"Previously, most of the backyard gardens were either not utilised or only used to produce one or two crops, mostly just a small patch of maize and perhaps some spinach," explains Dr Kobus Anderson, who took over as project leader after Dr Cobus Botha resigned from the ARC. "With the IRWH technique they were able to produce a variety of vegetable crops throughout the year, because they could now use water from the tanks for supplemental irrigation during the dry season."

The project team wanted to assess whether tank water emanating from roof runoff was sufficient to meet the requirements for irrigation, biodigester operation and domestic use, and asked householders to keep detailed records, even supplying them with rain gauges. Most neglected to do so, and the data was also compromised by the fact that tanks were filled from the municipal water supply whenever it was available – taps in the area remain dry for long periods because municipal services have collapsed in the area.

Bioslurry effluent from the biodigesters was used as a fertilizer source, and the improved soil water and nutrients in the gardens meant that they quickly became infested with weeds. "The majority of beneficiaries were elderly, and sometimes the situation got too much for them to keep up with effective weed control," says Anderson. "Weeds were then competing with the main crop for available water and nutrients."

In a few cases, weeding and basin maintenance was done by grandchildren, who had been exposed to the technologies at school as part of the project team's capacity-building and knowledge dissemination efforts. Teachers arranged for the school gardens to be ploughed by local tractor owners, some of whom were parents of learners at the schools, before IRWH basins were constructed by members of the project team and the learners themselves. The learners were asked to bring spades and rakes from home on the designated day, and were shown how to reshape the ground and plant various crops. Over the following months they maintained the gardens and recorded data on crop production, rainfall, water storage and water usage, before presenting the results at a mini-conference and receiving a cash prize for the school, enabling them to buy more seedlings for the school garden.

The school and homestead gardens were only one aspect of the project though, because the research sought to upscale the techniques to croplands and rangelands. Viewing the villages on



A diagrammatic representation of the aim of the project.

In-field rainwater harvesting (IRWH) basins have proven potential to increase maize yields, particularly when used in conjunction with supplemental irrigation and fertilizer application.

Google Earth reveals rows of fallow fields that were intensively cultivated in the past. During the apartheid era, when the area formed part of the Ciskei homelands, villagers were given government assistance in the form of extension services, access to tractors and other farming implements, and the ability to sell their produce through the Ciskei Marketing Board.

When that support fell away in the new dispensation, most crop-growers struggled on for a while, until drought put paid to any hope of getting back on their feet. Even when good rains returned, they could not afford to have the land ploughed, or to buy seeds and fertilizer. Nowadays, only the chief, who has a tractor, and a few villagers cultivate their croplands, growing mainly maize and beans. Yields are generally low, though, so the project team wanted to assess how well rainwater harvesting and conservation practices, together with bioslurry application, could boost production.

Unfortunately, the croplands are mostly unfenced, and livestock owners would allow their animals to graze in the fields, destroying the crops and the IRWH basins. The project team therefore opted to conduct experiments under controlled conditions at Fort Cox College, 10–12 km away from the villages as the crow flies. The IRWH basins constructed there were managed in three different ways before maize was planted: left bare, planted with a cover crop of buckwheat, or covered with mulch in the form of maize leaves and stalks. Bioslurry was applied as a liquid fertilizer at three different doses, but another treatment used manure instead. Contrary to expectations, the manure treatment resulted in the lowest yields. The cow dung simply dried out and caked on the surface because there was too little rain to moisten it and leach nutrients.

The bioslurry also tended to form a cake as it dried out, acting as a mulch that helped reduce evaporation from the soil surface. Its nutrients improved maize biomass and grain yield slightly, but even at the highest application of seven tonnes per hectare the increase was not significant. The normal maize-based mulch also didn't perform as anticipated, because it soaked up the sporadic, light rainfall and allowed very little water to infiltrate the soil. It did at least create a cooler soil microclimate, and was found to have a greater impact on grain yield than bioslurry application, followed by the cover crop management option. Although bioslurry might be more effective at much higher application rates, the project team concluded that its use isn't very practical beyond the homestead gardens, given the effort required to get it from the biodigesters to the croplands.

For the rangelands component of the research, the project team constructed IRWH basins in the abandoned croplands and established experimental plots within them in which four leguminous (and hence nitrogen-fixing) pasture species were intercropped with one grass species. The aim was to improve grazing quality for the villagers' livestock, not only by growing palatable fodder but also by increasing soil water and nutrients. However, neither intervention had a significant effect on forage dry matter yield, partly because the trial period coincided with a drought, so survival of the legumes was rather poor.

The project team also placed GPS collars on a number of cattle from different herds, and tracked the animals' movements during the wet and dry seasons. This revealed that the cattle spent most of their time grazing close to homesteads, water points and riparian vegetation, where more palatable grass species were available compared to those in the veld further afield. Since the cattle were left to wander freely in the veld and overgrazing was evident, the team fenced off a number of 2x2 m exclosures at various positions to protect them from grazing, and recorded production and species composition within and outside them. The highest production values were from inside the exclosures during the summer and autumn months, which indicates that implementing a rotational grazing strategy in the area would be beneficial. Although it would be ideal if the livestock owners could establish larger grazing camps or exclosures themselves, the project team note that this may not be feasible in the area as fencing is often stolen. A better option might be to employ herders to move livestock into lightly grazed areas, ensuring more even grazing distribution, although this too is costly.

Alternatively, the villagers could elect a committee to oversee the rangeland use. Over the six years of the study, the project team engaged extensively with the community through meetings

The villagers were shown how to construct IRWH basins and were initially given seeds and seedlings, but needed to take responsibility for maintaining the basins, irrigating the plants using water from their storage tanks, applying fertilizer in the form of biodigester effluent, and ensuring weeds were removed.

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and discussions, and repeatedly emphasised the importance of institutional arrangements in the form of rules, regulations and organisational structures. Ultimately, committees were formed to help implement the project, assist with monitoring and evaluation, and issue fines to those who failed to comply with the rules – for example, letting their cattle graze in the maize crops. Nevertheless, adherence to institutional arrangements remained a challenge, largely because of the poor health status of the area's chief and the fact that some villagers no longer acknowledge the authority of the traditional leadership, due to political interference.

Now that the project has been completed, one wonders whether the interventions will be sustained, but Thabiso Koatla, the ARC's team member tasked with the socio-economic aspects of the project, says that the extension officer in the area has been asked to continually follow up with the households to check on their progress.

"What the ARC normally does when we conclude a project is draw up an exit strategy, whereby we plan – together with all the stakeholders that were involved in the project – what to do to make sure that whatever we achieved doesn't die off when the ARC team leaves," he explains. "We have already compiled the exit strategy, but the implementation has not been done due to Covid. Our meeting with stakeholders had to be postponed but should take place before the end of the year."

"The villagers are very keen on the biodigesters though. The beneficiaries are using the biogas piped into their kitchens now, but they need regular training. We've been told some of the biodigesters are blocked, and although we provided training on how to unblock them, some people have forgotten how to do it, so we need to give refresher courses."

As for the broader food production issues, Anderson feels that community members need to be further empowered with the necessary knowledge and skills to implement rainwater harvesting and conservation systems, and supported with effective extension services, but without contributing to dependency syndrome.

Biodigesters were installed at 14 households that already had water storage tanks and access to cattle nearby, since the biodigesters needed to be 'fed' with water and cow dung at least every five days. Two control digesters with full-gas profiling and meteorological measurement capability were installed at SolarWatt Park on the Alice Campus of the University of Fort Hare.

The project team conducted cropland experiments at Fort Cox College in nearby Middledrift, and provided training to the second-year students studying crop sciences and agri-business for three years, reaching some 300 students. The experimental plot was also visited by project beneficiaries and stakeholders during annual 'information days'.

Farmers' days were held to allow the selected beneficiaries to display the fruits of their labour and share their knowledge and challenges with stakeholders and other villagers.

"In an ideal world you want to teach people how to fish, but initially you will need to give them a kickstart by supplying them with the fishing rods and hooks," he says. "It needs to be made clear that if inputs are given, it's a once-off – in other words, we will teach you how to catch fish, but we will not be here forever. At some point, you'll need to stand on your own two feet."

FRESHWATER CONSERVATION

Race on to save SA's unique eel species before they slip into extinction

Research efforts are underway to understand more about the diversity, distribution and spatial ecology of Africa's freshwater eels. These enigmatic creatures are considered key indicator species, offering unique and valuable insights into the diverse range of habitats they are found in. Article by Jorisna Bonthuys.

"There is a lot we still don't know about Africa's eels," says Dr Céline Hanzen from the University of KwaZulu-Natal's Centre for Functional Diversity in the School of Life Sciences. "What we do know is that there are indications that they are on a slippery slope in their survival race."

Hanzen is the lead author of a paper titled 'Spatial ecology of freshwater eels in South Africa: implications for conservation', publisher earlier this year in the journal ***Hydrobiologia***. The paper contains the findings of the researchers' preliminary investigation of the spatial ecology of three eel species in the Thukela River. This is the first study to have measured the home range and quantified habitat use of freshwater eels in African freshwater habitats.

The researchers focused their efforts on the Thukela catchment. This catchment is the largest in KwaZulu-Natal (30 000 km^2). It flows from the Drakensberg Mountains for about 500 km before ending in the Tugela Mouth in the Indian Ocean. The river itself is highly dynamic, with substantial differences in water levels between the low flow season (winter) and the high flow season (summer).

The researchers' study area was a 6 km river reach, located at Zingela, a private nature reserve, approximately 300 km upstream from the river mouth. This particular stretch of the river included glides and deep pools with large boulders in it, providing good cover for the eels.

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The science of tagging eels

Capturing the eels for tagging purposes was no easy task. "Catching eels involved a lot of paddling on the Thukela and a lot of teamwork," Hanzen says. "Eels can be rather large, very strong, and slippery. They are also almost impossible to handle if they're not sedated."

The researchers sampled the eels with fyke nets and electrofishing methods. They briefly kept the eels in a sizeable 50-litre bucket containing aerated water after capturing them. The eels were sedated, weighed, measured, and photographed. Nineteen yellow-stage eels were surgically implanted with radio-tags, comprising ***A. mossambica***, ***A. bengalensis*** and ***A. marmorata***.

The researchers also extracted genetic material from individual eel fin clips. This allows them to do DNA barcoding, using a short section of DNA from a specific gene or genes to identify species. Hanzen says this genetic information could provide useful information about species of eel that are harvested and traded. This field of research that includes the use of molecular techniques was also the focus of her PhD study on eels.

In the Thukela study, most of the eels were released back into the water after the radio-tags were implanted. "We then tracked the tagged eels from the riverbank or a kayak using a wideband receiver with an antenna," Hanzen says. "For safety reasons, our tracking sessions were flexible." The researchers had to be mindful of factors like the movement of poachers, fire, dangerous wildlife and high water levels.

Dr Céline Hanzen from the Centre for Functional Diversity in the UKZN School of Life Sciences with one of the eels she studies.

"Where we worked, the water was relatively turbid all year round," Hanzen says. "The water visibility in was less than half a metre making any visual observations of eel behaviour very difficult."

The scientists employed radio telemetry techniques to track the eels from October 2018 to August 2019. At river level, the detection range was 200-300 m depending on habitat, and up to 1 000 m when tracking from higher ground.

The researchers used the geographic coordinates of the tracked eels to analyse their home range, spatial overlap and habitat preferences. They also created a high-resolution digital map of the recorded, tagged eel locations from drone footage.

Some of the research findings of this project were unexpected. "We observed seasonal change in home range, core area and habitat use," Hanzen explains. The tagged eels exhibited high individual variability in the habitats they used, and all species had relatively low activity in winter.

"We also recorded very small home ranges in winter for all species," Hanzen says. "A lack of apparent territoriality among species found in the same area was observed."

The three eel species tended to use similar glides in the river. Their habitat preferences, however, changed across seasons and between species. "This means that the management of river flows needs to be sensitive to their habitat requirements all year round," Hanzen says. "But in many water-stressed South-African rivers, this may be unlikely."

Conservation challenge

Africa's freshwater eels are habitat generalists and can use many aquatic realms through their long and complex lifecycle, including oceanic waters, continental shelves, estuaries and freshwater environments. This unique feature, coupled with difficulty in separating species based on morphology, makes them complex targets for conservation.

After spawning in the Indian Ocean in the Mascarene Plateau, pelagic larvae proceed through several developmental stages into glass eels (subjuveniles) before migrating into southern African river systems. In freshwater systems, they develop into elvers (juveniles), followed by the resident yellow eel stage (subadult form). Following the progression to silver eels (adult or mature form), individuals will leave the freshwater river systems and return to their marine spawning grounds off the coast of Madagascar to breed and die.

"As long-distance migratory species with a widespread distribution across the highly diversified South African landscape, freshwater eels represent important and unique ecological indicators yet are potentially in dire need of conservation," Hanzen says.

Globally, there is concern about the stock status of many eel species. Freshwater eels face multiple stressors from sea to source and back, including habitat loss and fragmentation, pollution, overexploitation, pollution, climate change, diseases and parasites, and barriers to their movement.

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Eels who had been radio tagged were monitored from the riverbank or a kayak using a wideband receiver with an antenna.

A worrying decline and contractions in the four eel species distribution ranges have also been observed in recent years. In KwaZulu-Natal, a decline in the distribution range of ~50% over three generations (30 years) has been estimated for ***A. mossambica*** in some rivers, according to the IUCN ***Red List of Threatened Species 2020***. These records indicate a decline in distribution – and very likely abundance – of this species in some rivers in the province. This pattern, if reflected in other areas across the range of this species, would be a significant cause for concern.

Given the dramatic declines in temperate eel stocks in recent years, the demands for alternative resources are relatively high. Many eel populations are now under threat and highly traded. In Europe, the illegal eel trade also remains high despite the dramatic declines in their stock and the increased arrest of smugglers. In 2019, EUROPOL even described the illegal traffic of freshwater eels as the "world's greatest, yet least know, crime".

Following the ban on freshwater eel exports from the European Union in 2010, some African countries have entered the global trade. As a result, the endemic ***A. mossambica*** is now under scrutiny from international investors. In this regard, DNA barcoding could provide useful information on what species of African eel are harvested and traded, Hanzen points out.

More research is needed, given that ten species of anguillids occur in the tropics/subtropics, including the four species in South Africa. "It is likely that tropical and subtropical anguillids also face a broad range of threats," Hanzen says. "Still, the level of understanding of these is poor."

Sustainable conservation will only be possible through coordination with all countries within the distribution of the four African species. Unfortunately, most countries in the region lack data on eels, Hanzen believes.

Réunion Island is currently the only country in the region where a conservation plan for the African eel species has been implemented. "It is now more urgent to obtain basic knowledge on aspects of the ecology, biology, and well-being of the African eel species before it is too late," Hanzen says.

Ecosystems remain key

Although migratory fish are largely understudied in South Africa, it is estimated that more than 100 species have requirements for migration (to varying degrees). These species have been directly affected by water quality and habitat stressors and reduced river flows, affecting connectivity between the rivers and sea.

African eels are the only long-distance migrating catadromous species in the region, making them particularly vulnerable to river connectivity disruption. As a result, and owing to existing and planned dam development, they represent a particularly vulnerable component of the regional fish community.

"River connectivity and fish migration management practices should be elevated to contribute to the sustainable use of water resources and ensure the resilience of eel populations in the region," Hanzen says.

Freshwater eel species are a taxon that is particularly vulnerable to environmental changes. Where they do occur, these eels play an essential ecological role. In rivers in the Eastern Cape, they are, for instance, the only native top predator, Hanzen points out.

Anguilla spp. offer a unique insight into the physical, chemical and hydrological connectivity at a catchment scale, Hanzen says.

Maintaining river connectivity and the associated ecosystem service is a challenge in regions prone to drought. In South Africa, fish migrations are not clearly linked to ecosystem sustainability and, as such, have not specifically been addressed in water resource management.

Overall, studies of the ecological role of eels living in marine habitats and the extent to which trends in abundance of the marine resident mirror those in freshwater are still at an early stage. This will be an important area for future research, Hanzen adds. More research is also needed to ensure science-based decision-making and natural resource management, she points out.

Knowing the locations of spawning areas is an important first step for understanding life histories and population dynamics, simply because the characteristics of these locations influence the reproductive success of adults and the eventual recruitment of glass eels.

"There is a huge variety in our understanding of these eel species," Hanzen says. "We need more research to review and synthesise existing knowledge to help develop and inform management or recovery plans and to collect new information where knowledge gaps exist."

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Catching eels involved a lot of paddling on the Thukela River and a lot of teamwork.

More about freshwater eels

- Anguillid (freshwater) eels are elongated fish with snake-like bodies. Their long dorsal, caudal and anal fins form a continuous fringe.
- These eels are found across the globe except in the eastern Pacific and South Atlantic.
- Four freshwater eel species (***Anguilla*** spp.) occur in South Africa. These species are the longfin eel (***A. mossambica***), which is endemic to Africa, the shortfin eel (***A. bicolor***), the African mottled eel (***A. bengalensis***), and the giant mottled eel (***A. marmorata***).
- Freshwater eels are catadromous fish, meaning they spend their adult lives in freshwater sources but migrate to the ocean to spawn.
- The spawning areas of most of these eels are typically located in the open ocean, tens to thousands of kilometres offshore from their growth habitats.
- The yellow eel stage, during which eels grow towards maturity in fresh or coastal waters, can last between 7 and 50 years, depending on the species, sex, and geographic location.
- In the 19th century, eels made up about a third of the total European freshwater catch by value. Today, eels are still an important food fish in many countries. Some species are now farm-raised but not bred in captivity.
- Since 1970, migratory freshwater fish (including eel species) saw a 76% decline in numbers.
- Nearly a third of all freshwater fish, including many eel species, are threatened with extinction.
- Some migratory fish affect the local culture and spirituality, as is the case with the freshwater eels, which are believed to have inspired the mythical creature 'Inkanyamba' that is part of the Zulu and Xhosa cultures.

Sources: *The World's Forgotten Fishes; Hydrobiologia; Fish and Fisheries*

Africa's freshwater eels can use many aquatic realms through their long and complex lifecycle, including oceanic waters, continental shelves, estuaries and freshwater environments.

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IRRIGATION AND WATER QUALITY

Drug resistant pathogens – Are we ingesting more than nutrients with our vegetables?

Spinach – it helped Popeye sprout supersized muscles. And your ma might have made you swallow it down or certainly ordered you to eat your greens. Turns out, Sailor Man and mother were right. Fresh vegetables are a valuable source of nutrients and vitamins, writes Matthew Hattingh.

Increasingly, people in sub-Saharan Africa have become aware of the nutritional benefits of fresh fruit and veg. In South Africa, its affordability relative to meat and other foodstuffs only adds to the appeal.

Department of Agriculture, Land Reform and Rural Development figures show a growing harvest of almost all the most popular vegetable types. An eye-watering 709 000 tons of onions came to market in 2017/18 compared with 619 000 tons 2013/14. Cabbage was on a roll too – up from 146 000 to 160 000 tons over the same period. And South Africans got sweeter on sweet corn and green mealies, with production rising 28 000 tons to 390 000 tons, also over the five years.

But there's a worm in the public health apple.

Fresh vegetables, especially the leafy green kind, often get little in the way of washing or other processing or are eaten raw. This puts consumers at risk of illness or worse from the potential disease-causing bacteria – pathogens – these vegetables may carry. Over the past decade food-borne illnesses have attracted considerable publicity in Europe and the US, with thousands of people falling ill, scores hospitalised and a number of deaths.

Where do these pathogens come from? Irrigation water is increasingly polluted. This is in part the consequence of poorly-performing sewage systems in our cities and townships. But throughout the process of growing, harvesting, washing, cutting, preparing, packing and transporting produce, bacteria can latch on and multiply. And these bacteria are becoming increasingly resistant to treatment with antibiotic drugs.

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It's a vexing matter and the subject of a report, ***Measurement of water pollution determining the sources and changes of microbial contamination and impact on food safety from farming to retail level for fresh vegetables***. The report (**WRC Report No. 2706/1/21**), published by the Water Research Commission earlier this year, was particularly interested in how the processing of vegetables affected food safety and took a detailed look at the occurrence of multidrug resistant human pathogenic bacteria.

Its authors, Erika du Plessis, Stacey Duvenage and Lise Korsten, of the University of Pretoria's Department of Plant and Soil Sciences, focused on fresh veg grown for the Cape Town and Tshwane metropoles. They noted the presence of pathogens on produce in formal markets, which were similar to previously reported pathogens that cause foodborne disease outbreaks internationally. But remarked that little was known about how the problem was affecting the informal sector, despite its economic importance.

Their research teams worked to fill the gap. They collected samples for testing from street-side sellers and used questionnaires to gauge the food safety knowledge and views of vendors and consumers.

Perhaps unsurprisingly, the researchers learnt that informal vendors often operated under rough-and-ready conditions. Storage was frequently found to be rudimentary, potable water in short supply and refrigeration non-existent. The surroundings might be less than salubrious too, as was the case of the vendor trading near a well-known shopping centre in Pretoria's Mamelodi township. "Behind the stall," noted the report, "there was a rubbish dump."

Another veg vendor, this time in Pretoria's Atteridgeville township, set up shop near a cooked-chicken joint that also happened to slaughter its birds on site. Yet another, in the Brazzaville quarter of the same township, was "located along a busy main road that is dusty and always wet with water that flows from busted pipes". Fresh veg was sometimes stored on or near the floor or in the case of spinach, dipped in bins or bowls of water to stave off wilting.

As for the vendors themselves, many do not have access to clean toilets and wash hand basins.

But amid the difficult conditions, it was heartening to note a general appreciation of the need for good hygiene – both among the vendors and their customers. The majority of those surveyed in Tshwane and Cape Town's informal settlements possessed a "good general attitude towards food safety".

Among consumers in the formal sectors this was even more the case. "Most people know about the importance of fresh produce safety and most show a good general attitude towards hygienic practices. They realised the importance of washing hands and clean environments to prevent cross contamination."

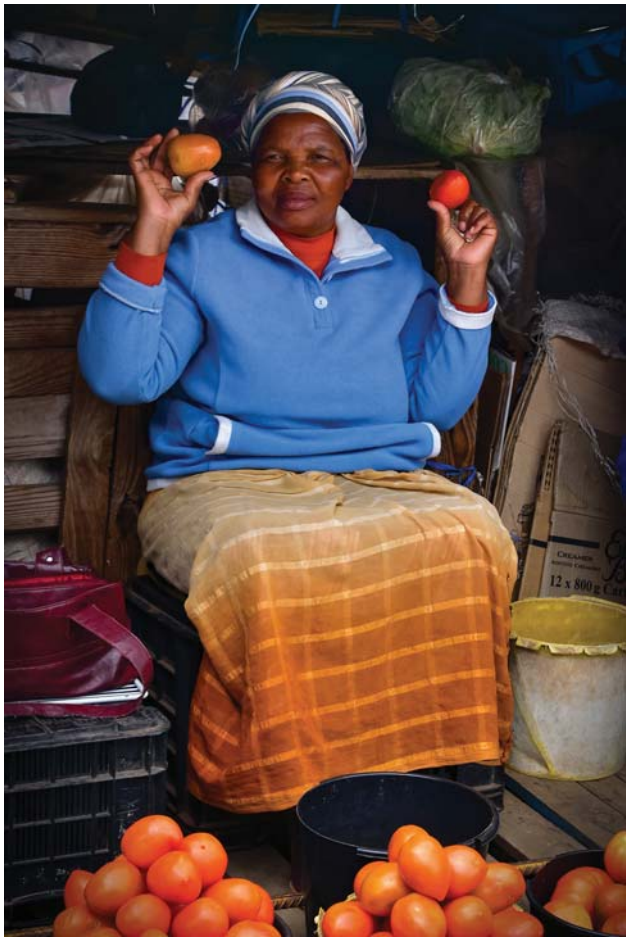
That said, less than half of those surveyed in the informal sector reported washing their hands with soap. "Another concern is that most people use the same cutting board for raw meat and fresh produce and a large proportion just use water to rinse in between the two different products."

The route fresh veg follows from field to plate varies. A big commercial farm might supply a supermarket group directly, for distribution to stores through the group's central procurement operation. Produce might pass through a packing or processing plant along the way. Or the groups (Shoprite being the biggest) might buy from one of the country's 19 local fresh produce markets, which in 2017/18 handled 47% of the country's veg (excluding potatoes).

Informal traders also buy from local fresh produce markets or often directly from small-scale farmers. Farmers' markets are increasingly popular too, particularly for the direct supply of organic produce to well-heeled consumers.

So, there was much ground to cover – and many points along the way where pathogens might enter. Initially the water and food safety research team from the University of Pretoria and Stellenbosch University collected fresh vegetables from 10 retail suppliers; 20 informal markets (half of which were street traders and the balance mobile vendors); and 13 stalls at farmers markets in Tshwane. The researchers bought a total of 545 samples from September 2017 through to May of the following year. Depending on what was available, these included spinach bunches or baby leaves (including in pillow-packs), rape, chinensis, cucumbers, tomatoes, lettuce (heads and mixed leaves in bags) and green beans.

The deteriorating quality of irrigation water is a concern for researchers studying microbiological pollution.



The research team found a general appreciation of the need for good hygiene – both among the vendors and their customers in the areas they surveyed.

Following the food chain, the team visited Gauteng and North West farms where they collected water samples at source, irrigation point and during processing or washing. Source water included borehole inlet points, holding dams or reservoirs, pivots or sprinklers and flooding irrigation points.

Soil samples were taken and the team collected veg samples from the field, before or after processing (such as cutting and washing) and after packaging.

Packhouse crates, tables and conveyor belt surfaces were swabbed for samples, as were samples at traders and retailers. Similar sampling in Cape Town took in a commercial fresh veg processing and packaging facility in Philippi and informal vendors and retailers. The Philippi packhouse processed a variety of veg in different ways, including broccoli, cabbage, and carrots for fresh-cut coleslaw bags. The teams took samples at different stages in the packhouse to determine potential contamination points.

Lettuce and one other fresh vegetable were sampled at five different informal vendors over five weeks. Then, it was to the lab for testing and analysis.

What did the researchers discover? With so many samples of different produce and from different places the results were a bit like some of those salads mentioned earlier – a mixed bag. But a number of broad observations were made.

First up – fresh veg bought from Tshwane retailers. ***Escherichia coli*** counts ranged from 0 up to 5 log CFU/g, with the higher counts mostly at informal vendors and fresh produce markets. In layman's language, that's a maximum of 10 to the power of 5 colony-forming units per gram of ***E. coli***, a bacterium commonly found in faecal matter and in certain strains also causes food poisoning.

Average coliform counts on fresh vegetables exceeded the previous Department of Health limit guidelines. Coliforms are a type of bacteria whose presence indicates other pathogenic organisms of faecal origin may be present. Significantly, the authors noted, "the hygiene indicator bacteria counts were mostly not significantly different between formal and informal markets".

The researchers also looked specifically at leafy green veg supplied to Tshwane retailers. They followed five different supply chains, from commercial farms, through processing to retail. ***E. coli*** levels at the different production stages ranged from zero upwards. Coliform counts exceeded the maximum limit of 2.3 log CFU/g.

Enterobacteriaceae counts on the leafy green vegetables were similar to the coliform counts and counts of up to 6 log CFU/g were obtained. ***Enterobacteriaceae*** are a large family of bacteria that include pathogens such as ***Klebsiella***, ***Enterobacter***, ***Citrobacter***, ***Salmonella***, ***Escherichia coli***, ***Shigella***, ***Proteus*** and ***Serratia***.

Informal vendors in Cape Town were "well above the advised coliform limits". No Salmonella or ***Listeria monocytogenes*** were detected in any of the fresh produce, while ***E. coli*** was "sporadically detected".

Broccoli coleslaw (broccoli stems, carrots and cabbage) and lettuce samples were collected at different processing points at the Philippi packhouse and from retailers. Analysis showed that processing, including washing in a chlorine solution of 150-200 parts per million and peeling, lowered the microbial counts on the vegetables significantly. However, microbial counts increased significantly in shredded samples and bagged mix coleslaw samples.

"That the ***E. coli*** was only detected at such a late stage in the product cycle could either be due to ***E.coli*** growth from previously undetectable levels or through post-processing contamination," said the report. It cautioned that the coleslaw mix sold at retailers was consumed raw and sometimes with no further washing.

What about irrigation water and pathogens? ***Listeria monocytogenes*** was detected in irrigation water on occasion while none was detected on any of the fresh produce samples. ***E. coli*** levels in river water used on commercial fresh produce farms seldom exceeded the maximum limit of less than 1000 ***E. coli***/ per 100 ml for safe irrigation water.

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E. coli numbers were generally lower in water from holding dams and irrigation pivot points, with some exceptions blamed on bird droppings. Where river water contaminated with ***E. coli*** was used for overhead irrigation, ***E. coli*** was detected at low levels from the irrigation pivot point, wash water and from the spinach samples throughout the supply chain. However, to put things into perspective, the levels detected would be acceptable according to many international standards that allow 100 CFU/g of ***E. coli***/ for fresh produce. It should also be remembered that not all ***E. Coli*** are pathogenic.

An additional aim of the research was to gauge the extent to which pathogens found on vegetables and related samples were resistant to antibiotics. The report noted the increasing use of antimicrobials in healthcare and intensive livestock farming had raised levels of antibiotic resistance, "thus exerting selection pressures and inducing the transfer of antibiotic resistance genes to potential human pathogenic bacteria".

What did the analysis show? Briefly:
• Where ***E. coli*** was isolated on fresh veg samples and irrigation water, more than 40% of the isolates were multidrug resistant.
• Multidrug resistance was observed in 80-98% of ESBL/AmpC-enzyme producing ***Enterobacteriaceae*** isolated from water and irrigated fresh vegetables samples. These enzymes render a wide variety of antibiotics ineffective. There is also a risk of transfer of these harmful qualities to "friendly" commensal bacteria.

What should be done?
The authors want to see the guidelines for irrigation water expanded beyond the hygiene indicator microorganisms (coliforms, ***E. coli***) traditionally used. "Other members of, for example, the ***Enterobacteriaceae*** family such as ***Salmonella***… should also be considered."

Further investigation was needed to plan a response to antimicrobial resistance bacteria, they said. And they called for mapping of potential contributors to the problems, such as sewage plants and animal husbandry; and recommended a national database be established to bring together the results of antimicrobial resistance surveillance.

Risk assessments, training, education, and lobbying of policymakers and the government by scientists were needed. Better cooperation and communication among the different tiers of government and with academics would help too.

In short, plenty on everyone's plate. And not only greens.

Researchers did not find a significant difference in the hygiene indicator bacteria counts on vegetables sold in formal and informal markets.

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WATER AND WETLANDS

South Africa's swamp forests are very likely critically endangered wetland ecosystems

Latest study showed that South Africa's swamp forests are in danger of disappearing – along with the valuable ecosystem services they offer. Article by H van Deventer; J Adams; JF Durand; R Grobler; P-L Grundling; S janse van Rensburg; D Jewitt; B Kelbe; CF MacKay; L Naidoo; Jeanne L Nel; L Pretorius; T Riddin; & L Van Niekerk.

There is wide recognition that South African swamp and floodplain forests or forested wetlands, are unique biotypes and that they are threatened (Berliner, 2005; 2009; Jewitt, 2018; Mucina & Rutherford, 2006). The forested wetland extent has been mapped by at least eight different studies using methods such as heads-up digitising or remote sensing classification at various scales.

During the past year, this information was brought together and integrated into a single output, the areal extent, being used to assess the red list status of these wetlands. Following the criteria of the International Union for Conservation of Nature (IUCN) for the Red Listing of Ecosystems (RLE), this protocol was used to evaluate these forested wetlands, and the results recently published by Van Deventer et al. (2021). Here we provide an overview of the study and the implications of the work for South Africa.

Defining forested wetlands of South Africa

The first step of study was to define the type of forested wetlands of South Africa. The most recent typology of Global Ecosystem Types (Keith et al., 2020), published by the IUCN, was used as a basis with literature that distinguished coastal forests from inland forests (Burgess et al., 1998) and different forested wetland types (Martin-Smith, 2004), to characterise these wetlands as the Ecosystem Functional Group (EFG): 'Coastal subtropical-temperate forested wetlands' that includes swamp and floodplain forests.

Geographic extent of the coastal subtropical-temperate forested wetlands

South African forested wetlands extend from the Great Kei Estuary northwards along the coast to the Kosi Estuary on the border with Mozambique. The reference epoch of 2000 was identified as the wettest year with the highest rainfall in Kwazulu-Natal in the last 80 years, following the flooding resulting from Cyclone Eline. It was assumed that the maximum extent of tree canopies that remained after this cyclone should largely still be present to date.

Various aerial, ortho, and satellite images for the epoch of 2000 were used to map the maximum extent as the reference layer. The results showed that the maximum extent of the forested wetlands totalled 120 km^2 for the epoch of 2000, of which 116 km^2 is located on the Maputaland Coastal Plain (MCP). In many previous studies where the swamp and floodplain forests had been mapped, the canopies of key indicator tree species were used to identify the presence of these wetlands. These 13 indicator tree species were listed in Van Deventer et al. (2021).

Figure 1: A patch of swamp forest near the Maphelane node of the iSimangaliso Wetland Park. Photo by Heidi van Deventer.

Determining the threat status according to the IUCN Red List of Ecosystem (RLE) criteria

The IUCN has published guidelines for RLE (Bland et al., 2017), using five criteria for evaluation. The first two relate to spatial indicators, assessing (***a***) the losses or transformation that took place in an ecosystem; and (***b***) the degree to which it is range restricted. The following two relate to functional degradation observed, with (***c***) changes in abiotic processes and (***d***) biotic processes. Lastly, the ranks assigned in the previous criteria are integrated in (***e***), which provides an overall assessment. For all these criteria, qualitative information should be provided, with sub-criteria offering an evaluation period for criteria ***a***, ***c,*** and ***d***; and thresholds for ***b*** and ***e***. In addition, confidence ranks could also be assigned for each criterion.

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The study found that if the rate of decline observed at a landscape scale for the MCP was linearly extrapolated, >80% of the extent of Coastal subtropical-temperate forested wetlands could be lost in 50 years, and therefore be left critically endangered. In itself, the small maximum reference extent of 120 km^2 is critically endangered, since it is range restricted. Further issues following the full RLE approach were that environmental degradation indices, such as fragmentation metrics, were not fully appropriate as the coastal environment forests are normally very fragmented, and therefore a reference could not be determined.

Also, faunal Taxa of Conservation Concern (ToCC) that are associated with the forested wetlands of the MCP (Figure 2) are all generalists in the landscape, as are many palustrine wetland species. Thus, transformation and loss of MCP forested wetlands may not have a direct impact on these ToCC but could result in the species rather using other parts of the landscape mosaic or migrating further north to less degraded forests and forested wetlands.

Floristic species

(a) Raphia australis (Kosi palm)

Raphia palms, May 2013. Photo by Prof. Christoph Moning, University of Applied Sciences Weihenstephan-Triesdorf, Institute for Ecology and Landscape.

(b) Cassipourea gummiflua (Large-leaved onionwood)

Large-leaved onionwood tree, April 2014, KwaZulu-Natal, submitted to iNaturalist.org (https://www.inaturalist.org/observations/37485501). Attribution-NonCommercial 4.0 International (CC BY-NC 4.0), no edits done.

Vertebrate species

(c) Aonyx capensis (African clawless otter)

Cape Clawless Otter, 13 March 2021, Thrift Dam, Great Winterberg (Stormberg) of the Eastern Cape Province. Photo by Dr David J. McDonald Pr. Sci. Nat., Botanical Specialist, Director: Bergwind Botanical Surveys & Tours CC, www.bergwind.co.za.

(d) Hydrictis maculicollis (Spotted-necked otter)

Photograph by Simon Tonge taken in December 2019 KwaZulu-Natal, submitted to iNaturalist.org (https://www.inaturalist.org/observations/37485501) and in the public domain.

(e) Cercopithecus albogularis ssp. erythrarchus (Samango monkey)

Coastal forest Samango monkey, 12 August 2018, Catalina Bay Road, iSimangaliso Wetland Park. Photo by Tanja Milotić, uploaded to iNaturalist (https://www.inaturalist.org/observations/15636843); no rights reserved.

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(f) Natalobatrachus bonebergi (Kloof frog)

Kloof frog, Uthungulu, 2020. Photo by Dr Erwin Sieben, University of KwaZulu-Natal (UKZN).

Invertebrate species

(g) Potamonautes lividus (Blue River or Swampforest River Crab)

Swampforest River Crab, iSimangaliso Wetland Park, January 2014, submitted by Mr Ryan Tippett to iNaturalist (https://www.inaturalist.org/observations/35130324). Attribution-NonCommercial 4.0 International (CC BY-NC 4.0). No edits done.

Not shown, (h) Varuna litterata (Peregrine crab)

Figure 2: Threatened species and Taxa of Conservation Concern (TOCC) that show a close association with the subtropical-temperate, coastal swamp and floodplain forests of South Africa.

Concerns of increasing rate of transformation

Increasing temperatures associated with climate change, will very likely result in higher evapotranspiration levels and consequently excessive lowering of water levels across the MCP during dry cycles. During these times, rural communities are able to access previously inaccessible parts of the forested wetlands that were saturated or inundated.

Transformation occurs in activity succession of first land clearing, then planting subsistence crops (Figure 3a) and ultimately commercial crops (Figure 3b) for sale at markets. Crop selection also depends on favourable growing conditions, such as the availability of fertile soils, which include peat in the MCP. Saturated peat soils that are located on a slope can be drained to favour specific crops.

The modification of onsite hydrology through drains and other cultivation practices can result in the loss of soil organic matter through decomposition. A subsequent decrease in soil fertility is therefore also a driver of crop succession. The use of industrial equipment such as chainsaws, rather than the traditional panga, has resulted in an increase extent and rate of forested wetland transformation within the last 5–10 years (Figure 3c).

Figure 3: Examples of land transformation to (a) subsistence crop (Colocasia esculenta or Madumbes) and (b) commercial crop (e.g., bananas) production is increasing during dry cycles. (c) The rate and extent of timber felling increases with the use of chainsaws, compared with the historical use of pangas. (d) Channels are dug to drain water and soil moisture from the peatlands. Photographs (a-b) Heidi van Deventer, June 2021; (c-d) August 2017.

Implications for conservation

Wetlands are a rare and critical provisional habitat in South Africa, not only a valuable resource for the provision of water

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and food provision for people, but mostly for the resilience they offer under future climate change through carbon sequestration and flood buffers. The predicted increase in temperature and changes in rainfall associated with climate change in this region are expected to exacerbate the effects of the current anthropogenic pressures. Forested wetlands offer flood regulation and refugia during these extreme drought events and should therefore be prioritised as important ecological infrastructure. In this light, their conservation, rehabilitation and protection need to be a priority for stakeholders beyond conservation agencies.

This study showed that forested wetland transformation occurred inside and outside protected areas and that the current top-down approach to protecting these systems requires addressing. In contrast, the bottom-up approach of the IUCN RLE allows for engagement with all stakeholders, taking into consideration a wider landscape focus where there are many challenges in this instance (e.g., slash and burn agriculture, illegal influx of people).

Implications for associations between the freshwater ecosystems and the coastal zone

In the recent National Biodiversity Assessment of 2018 (NBA 2018), freshwater ecosystems were not considered in the coastal zone assessment (Harris et al., 2019), owing to a lack of information to understand the association of inland wetlands to the coastal zone explicitly. However, the extent of the rivers where aquatic faunal species move between the estuarine and freshwater (river) realms was subsequently mapped as river-estuarine transitional zones (Van Deventer et al., 2020), indicating the association of these rivers with the coastal zone.

This study on forested wetlands now offers as a next step in the realm integration, evidence of the functional association of wetlands to the coastal zone, from an abiotic (influencing habitat characteristics e.g., black-water habitats) and biotic (faunal connectivity between the freshwater inland wetland, estuarine, and offshore marine realms) perspective.

Contribution to the Maputaland EFTEON node

Our work contributes to the monitoring of environmental changes at a landscape scale, in particular to the Maputaland Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON) site. This is one of six EFTEON sites in South Africa, where long-term landscape-scale research and monitoring will be undertaken. These sites are managed and coordinated by the South African Environmental Observation Networks (see https://efteon.saeon.ac.za).

For more information on the forested wetlands article, please contact Dr Heidi van Deventer at HvDeventer@csir.co.za.

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CATCHMENT MANAGEMENT

Water pollution – Are farmers bearing the cost of poor catchment management?

Glynn Pindihama from the University of Venda elaborates on a study investigating the threats of eutrophication to irrigated farming.

Photo supplied

Eutrophication refers to the enrichment of a water body by nutrients and minerals. Eutrophication of lakes is a natural process and takes place over centuries. However in recent years, human activities have enhanced the eutrophication process due to discharges of nutrients (nitrogen and phosphorous) from various sources into the waterways (Chislock ***et al***., 2013).

Over the last few decades, aquatic scientists have related algal blooms to the enrichment of waters by nutrients as a result of human related activities such as industrial activities, disposal of sewage and agriculture. Among the unfortunate consequences of cultural eutrophication is the proliferation and the dominance of blue-green algae (cyanobacteria). These blooms reduce the aesthetic value of recreational waters, affect drinking water and deprive lakes of oxygen. Figure 1 shows some of the main causes and effects of human-induced eutrophication.

Some species of these cyanobacteria also have the ability to produce toxins, such as microcystins, nodularins, saxitoxins and cylindrospermopsin. Among the most common toxin producing cyanobacteria in South Africa are ***Microcytis***, ***Anabaena*** and ***Oscillatoria*** (***Planktothrix***).

Irrigated agriculture takes up about 60% of South Africa's available water resources, thus making it the largest consumer of water in the country. South Africa's water resources have deteriorated in recent years due to climate change, a rapidly growing population, poorly maintained and depilating wastewater treatment facilities (Mudaly and van der Laan, 2020). The increase in water shortages in South Africa makes management of this key resource of paramount importance.

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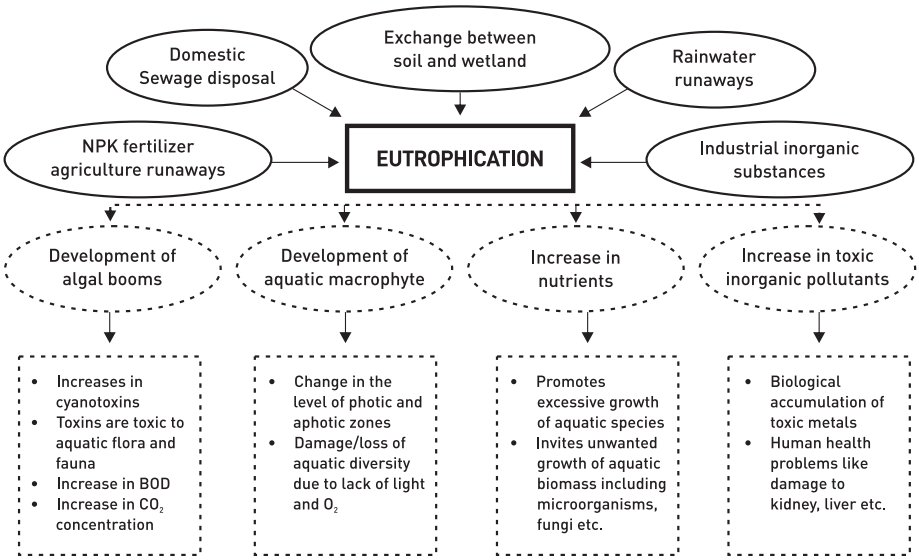

Figure 1: *The causes and effects of eutrophication (Adapted from Paul et al., 2020).*

The cost of eutrophication induced damage in the United States is estimated at around $2.2 billion annually (Chislock ***et al.***, 2013). In South Africa, an example is the Loskop Irrigation Scheme, where approximately R73.4 million per year is spent on mitigating eutrophication-related problems due to algae-related problems (Mudaly and van der Laan, 2020).

While emphasis and efforts have been placed on the impacts of eutrophication and the resultant algae on water quality related to drinking and recreation, little attention has been given to water intended for irrigation purposes. With the prevailing eutrophication levels in the country and lack of monitoring and legislation to govern the use of such water for agricultural purposes, there could be an inherent chronic threat to human health due to the exposure of low levels of cyanotoxins via food crops irrigated with cyanotoxin-contaminated water.

A current research project (**WRC Project No. K5/2972//14**) funded by the Water Research Commission under the research management of Prof Mugera Gitari, and led by a team (namely, Glynn Pindihama, Dr Rabelani Mudzielwana, and Salphina Sathekge) from Environmental Remediation and Nano Science (EnviReN), Department of Ecology and Resource Management, University of Venda, is investigating the effect of multiple stressors on the uptake of cyanotoxins by plants irrigated with cyanotoxins infested water and the potential health risks associated with consumption of such contaminated plants.

Cyanobacterial toxins do not occur in the aquatic environment separately, but they naturally interact with other toxicants. Terrestrial food crops could be exposed to numerous anthropogenic pollutants and other stressors, such as linear alkylbenzene sulfonate (LAS) and toxic metal species, which may enhance their accumulation from the surrounding environment after irrigation.

Figure 2 shows the multiple factors which need to be considered to make an informed decision about the suitability of the available water for irrigation use. There is a need to start with understanding irrigation water sources, their quality (particularly eutrophication status) and the prevalence of cyanobacteria and the resultant cyanotoxins. When plants are exposed to cyanobacteria-infested water, they are likely to be exposed to cyanotoxins, and these are likely to be taken up and bio-accumulate in the plant tissue. Plants have mechanisms to metabolize toxins and the ability to breakdown/eliminate these toxins.

However, this depends on the levels and frequency of exposure. When exposed to cyanotoxins, food plants can accumulate these toxins. In turn, these will be transferred to human beings through the ingestion of these plants and hence pose human health risks (particularly in the long term). To foster policy formulation, a better understanding of the quality of irrigation water, impacts on the irrigated plants and the health risks posed by consuming contaminated plants, there is a need to understand the impact of joint effects of multiple cyanotoxins stressors and the ecotoxicological risk of cyanotoxins in combination with other environmental stressors.

An effective and reliable monitoring system for these toxins in the irrigation and source water is also of importance in the evaluation and understanding of the threats posed by irrigating food plants with cyanobacteria infested water and the health risks posed by consuming contaminated plants.

In this project, the research team monitored water intended for irrigation (canals and farm dams) from Roodeplaat and Hartbeespoort dams from the June, 2019, to February 2020. Parameters monitored included physico-chemical parameters (pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), turbidity, and temperature), nutrients (nitrates and phosphates), metal elements (in water and soils), cyanobacterial biomass (as chlorophyll-a), microcystins (MCs) and linear alkylbenzene sulfonate (LAS).

Results showed that the irrigation water from both dams was alkaline, with water from Roodeplaat Dam exceeding the DWAF (1996) and Ayers and Westcot (1985) guidelines. TDS and EC of Roodeplaat Dam water were also found to be non-compliant with the two regulations in the sampling of winter of 2019. Irrigation water from Hartbeespoort was found not to be

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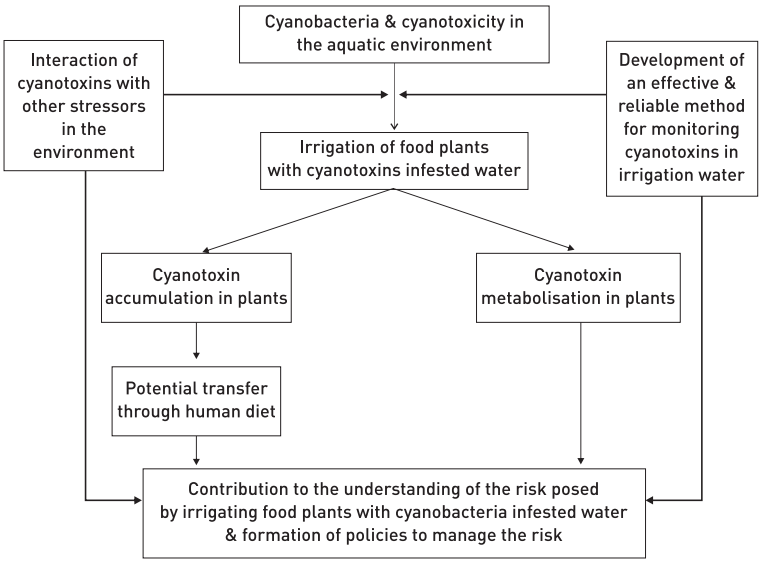

Figure 2: *Conceptual framework for the study and factors to be considered leading to policy formulation.*

compliant with the two regulations for TDS in the June 2019 and February 2020 sampling and EC was non-compliant in all the three sampling events. Water from Hartbeespoort was also non-compliant for nitrates in spring of 2019 and late summer (2020) sampling.

Chlorophyll-***a*** was used to estimate algal biomass. Algal biomass as chlorophyll-***a*** was relatively high in the two sites over the sampling period, ranging from 49.86±76.26 to 153.70±177.54 µg/L. Such high chlorophyll-a levels, places the two dams in the upper hypertrophic category (>56.00 µg/L).

In terms of metal elements, soils from the Roodeplaat site had nickel and copper exceeding the South African or the FAO (Food and Agriculture Organisation of the United Nations) guidelines for agricultural soils, whereas zinc was within the set thresholds for the sampled period. All the three essential elements (nickel, copper and zinc) exceeded the South African or the FAO guidelines for soils used for agricultural purposes at the Hartbeespoort site. The other elements reported to be high were hexavalent chromium (Cr (VI)), arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg), which are regarded to be non-essential and are toxic both to the plants and the consumers. Of these non-essential elements, only Hg was within the permissible limit for agricultural soils based on the South African and/or FAO guidelines.

Findings of the study also showed that levels of metal elements were higher in the spring sampling compared to the winter sampling for most of the elements. This could have been as result of the excessive irrigation during the winter months resulting in the accumulation of the metals which were detected in spring before the rains leach most of these elements from the soils. The levels of metal elements in the irrigation water from the two dams showed that all the elements (essential and non-essential) are in trace levels and none of them exceeds the DWAF (1996) and FAO (1985) (Ayers and Westcot, 1985) guidelines for these elements in irrigation water.

Levels of linear alkylbenzene sulfonate (LAS), an anionic surfactant found in detergents and discharged in wastewaters was recorded in the seven sampling points and ranged from 0.065±0.007 to 3.430±0.085 mg/L for Roodeplaat water and 0.010±0.000 and 0.215±0.021 for Hartbeespoort water. Microcystins (MCs) were detected in the irrigation water in farm dams and canals receiving water from both dams (Roodeplaat and Hartbeespoort). MCs levels ranged from 0.12 to 2.84 µg/L, with sampling points in Roodeplaat having higher levels of MCs compared to Hartbeespoort points and the winter season having higher levels compared to spring.

These findings imply a potential risk of contamination of crops irrigated with water from Roodeplaat Dam than from Hartbeespoort. These may impact both the health of the plants and also have potential health implications on the consumers of the plants. This is because cyanotoxins have been reported to affect the germination of seeds and general plant growth/health and thus impacting on the farmers' yields.

Cyanotoxins may also accumulate in the parts of the irrigated crops and thus indirectly affect human health. Future studies will thus need to investigate the effects of cyanotoxins on different crops grown in a particular region and farmers getting advice on the best crops to grow based on the available irrigation water quality. Research also need to look at the effects of LAS on cyanobacterial biomass and effects of LAS on the uptake of MCs by plants when irrigated with water from eutrophicated water bodies since previous studies have demonstrated a positive correlation of these factors (Wang ***et al.***, 2012; Wang ***et al.***, 2015).

Lani van Vuuren

Algae visible on the surface of the Loskop Dam.

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Lack of policy and regulation in South Africa

The bioaccumulation potential of cyanotoxins in food plants led to the World Health Organization (WHO) to propose a tolerable daily intake of microcystins-LR (MC-LR) for humans. According to the WHO the TDI of MC-LR in humans should not exceed 0.04 mg/kg body weight (bw) per day (Herschy, 2012). However, this guideline is for MC-LR only since there is still lack of data for other toxins (Mokoena, Mukhola and Okonkwo, 2016). This is regardless of the fact that total concentrations of MCs can range from 1 mg/L to 29,000 mg/L in surface waters and recent studies have shown that levels above the stipulated TDI can accumulate in food plants exposed to MCs under environmental relevant concentrations ((Bittencourt-Oliveira ***et al.***, 2016).

The research findings demonstrated an inherent risk of cyanotoxins and other pollutants accumulating in food crops if eutrophicated waters are to be used for irrigation. In a country like South Africa, water for irrigation of agricultural plants is essential yet it is becoming less available and its quality is deteriorating. Controlling harmful cyanobacterial blooms seems to be the best management practice to eliminate risks to agricultural productivity and human health. However forecasts predict an increase in proliferation of toxic cyanobacterial blooms (Machado ***et al***., 2017) and this presents challenges to regulatory authorities.

South Africa does not have water quality guidelines for cyanobacteria and cyanotoxins in recreational water bodies, in water intended for livestock consumption or for irrigation of food crops. The only regulation that guides and addresses irrigation water quality in SA is the South African Water Quality Guidelines Agricultural Use: Irrigation Volume 4 of 1996 (DWAF, 1996). However these guidelines only cover physicochemical aspects and coliforms bacteria and how these impact on crops and human health. Cyanobacteria and their toxins are not covered in these guidelines.

In the absence of legislation, farmers are encouraged to employ better practices such as reporting to the DWAS whenever they notice a blue-green bloom or blue-green colour in irrigation water, a layer of foul extraneous matter, a rotten plant-like odour in irrigation water. Blooms typically occur during late summer or early fall, when warm temperatures and low rainfall facilitate growth, but blooms can also occur anytime during the year. Blooms are also common in slow-moving waters or stagnant ponds and in waters with elevated nutrient levels.

Photo supplied

The research team monitored water intended for irrigation (canals and farm dams) from Roodeplaat and Hartbeespoort dams from the June, 2019, to February 2020.

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AQUACULTURE

The future of aquaculture is now

Lisl Robertson Lain and Marié E. Smith report on the ASTRAL project and the sustainable development of Atlantic aquaculture in South Africa.

Aquaculture in South Africa is really taking off, with around 230 farms countrywide, cultivating a wide variety of fish and shellfish species. Most of these are freshwater farms, and it is the freshwater sector that is indeed growing the fastest, with species like tilapia and trout in increasing demand. However, in terms of tons of produce, the marine sector is much larger and represents double the output of freshwater farms, despite coming from less than 10% of the total number of farms. In 2018, marine aquaculture represented over 86% of the value of the industry as a whole.

Given the size of these marine operations, it is increasingly important that the industry is developed in an ecologically safe and sustainable way. One of the ways to reduce environmental risks and maximise production is by employing an integrated multi-trophic (IMT) farming approach. This is the concept of cultivating animals and/or plants at different positions or levels in the food web, ideally those with a complementary function in the farm's overall ecosystem. For example, the waste of one species can be used as fertiliser or feed for another.

This is particularly relevant for aquaculture, where the target species are very sensitive to their environment, depending on nutrients in consistent supply while simultaneously requiring good water quality untainted by waste products and the growth of unwanted organisms. When managed well, integrated systems like this can reduce eutrophication from nutrient oversupply in farming systems, and can accelerate growth without detrimental side effects.

IMT farming can also provide valuable diversification of the business in terms of produce. An important potential benefit of investing in such systems is that advancing thinking towards recirculation of nutrients and energy in aquaculture (and in farming in general) can ultimately benefit under-resourced and small-scale farmers as well as large commercial operations.

The potential of aquaculture's contribution towards food security and economic benefit is increasingly recognised at an international level. Since 2014, the Horizon 2020 EU Research and Innovation programme has made available nearly €80 billion in funding with an emphasis on excellent science, industrial leadership and tackling societal challenges. One of the funding actions, the All Atlantic Ocean Research Alliance Flagship, aims to better understand and sustainably manage the Atlantic Ocean as a whole, with initiatives specifically focusing on aquaculture production; the four-year All Atlantic Ocean Sustainable, ProfiTable and Resilient AquacuLture(ASTRAL) project, which kicked off in September 2020, supports the development of this industry in a sustainable way, ensuring a strong climate-ocean-food value chain.

Sixteen partner organisations along and across the Atlantic ocean, three of which are from South Africa, are working together in acknowledgement of the need for this sector to be developed sensitively under good governance towards equitable and sustainable community benefit. With a targeted focus on IMT aquaculture (IMTA) farming, the project encompasses economic, social and environmental elements ranging from farming best practices to human capital development to business support to climatic and ecosystem risk assessment.

Above all, the project serves to provide a collaborative system for understanding Atlantic ecosystems and ensuring a sustainable harnessing of Atlantic Ocean resources. This effort is supported by the framework of the newly initiated Atlantic Aquaculture Alliance to enhance cooperation among all Atlantic countries and ensure the longevity of value created, after the project has ended.

The ASTRAL project oversees a wide range of tools and systems under development to facilitate the optimisation of such an approach: new sensors for environmental monitoring and hazard identification, new techniques for species combinations, as well as comprehensive investigations on regional climatic and environmental risks (including harmful algal blooms, which represent a major risk for systems open, or partially open, to the ocean).

ASTRAL partners encompass specialists in technology and IT development, marine science and biology, engineering and

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a variety of other fields from companies and organisations across three continents. South Africa's Council for Scientific and Industrial Research's Coastal Systems and Earth Observation Research Group will be contributing satellite-based monitoring capability and climate-related research, together with support for targeted technology development and the planning of sensor validation activities for the project. But the project's four aquaculture farms, termed the "IMTA labs", is where the magic happens.

Viking Aquaculture

An aerial view of Buffeljags abalone farm

The ASTRAL IMTA labs represent the collaboration of commercial farms and research institutes in South Africa, Brazil, Ireland and the UK, and feature a variety of closed system, land-based flow-through, and open ocean systems in which new techniques and technologies can be tested. The South African IMTA lab is led by specialist marine animal and plant biologists from the University of Cape Town (UCT) and the Department of Forestry, Fisheries and Environment (DFFE), with a marine research lab at DFFE in Seapoint and practical implementation on site at Viking Aquaculture's Buffeljags abalone farm on the South Coast of the Western Cape.

At Buffeljags, commercial-scale multi-trophic farming is well underway. The abalone are grown on land in large 'raceway' tanks. Seawater flows constantly through the system, with half of it coming in fresh from the adjacent ocean, while half is recirculated within the system. Alongside the abalone raceways are large paddle raceways where ulva (a seaweed also called 'sea lettuce') is grown. The Ulva tanks receive abalone effluent containing high levels of nitrogen (excreted by abalone as ammonia). As the ulva grows, it takes up the nitrogen from this water, promoting healthy seaweed growth and enabling the water to be re-circulated back into the abalone tanks together with some fresh seawater intake. But the ulva serves another purpose too – it is feed for the abalone. In this way, an integrated multi-trophic interaction of nutrients, water, plants and animals has been established.

Above all, the project serves to provide a collaborative system for understanding Atlantic ecosystems and ensuring a sustainable harnessing of Atlantic Ocean resources.

There is a strong emphasis within ASTRAL on research and the creation of new production methods and value chains in aquaculture. The introduction of sea urchins to the Buffeljags farming ecosystem is a primary focus of the South African IMTA Lab research, and represents a new innovation towards an increasingly complex system. Sea urchins also eat ulva, and ulva may also benefit from urchin effluent. The economic advantage of incorporating urchins into the system is clear: abalone reach commercial maturity around 4 to 5 years, while urchins grow rapidly and are ready for consumption at 9-10 months. This research speaks directly to ASTRAL's objectives of increasing

Viking Aquaculture

The Buffeljags abalone IMTA system, with ulva (seaweed) raceways in the center and the abalone tanks on the sides

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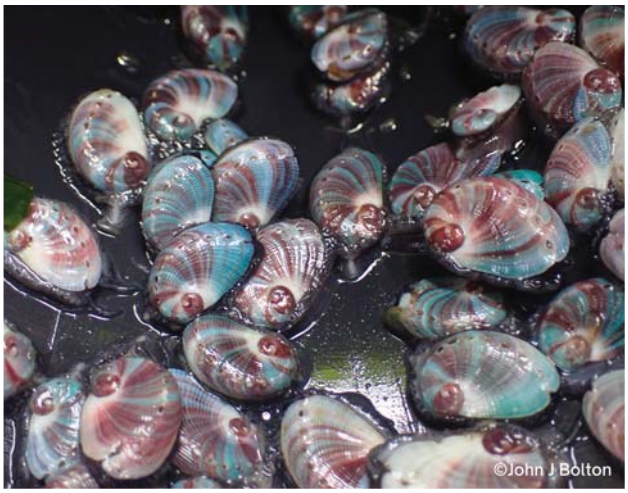
Lisl Robertson Lain

The white-spined sea urchin, Tripneustes gratilla, cultured at the Buffeljags aquaculture facility as part of the ASTRAL project

John Bolton



The abalone species grown at the Buffeljags aquaculture facility, Haliotis midae

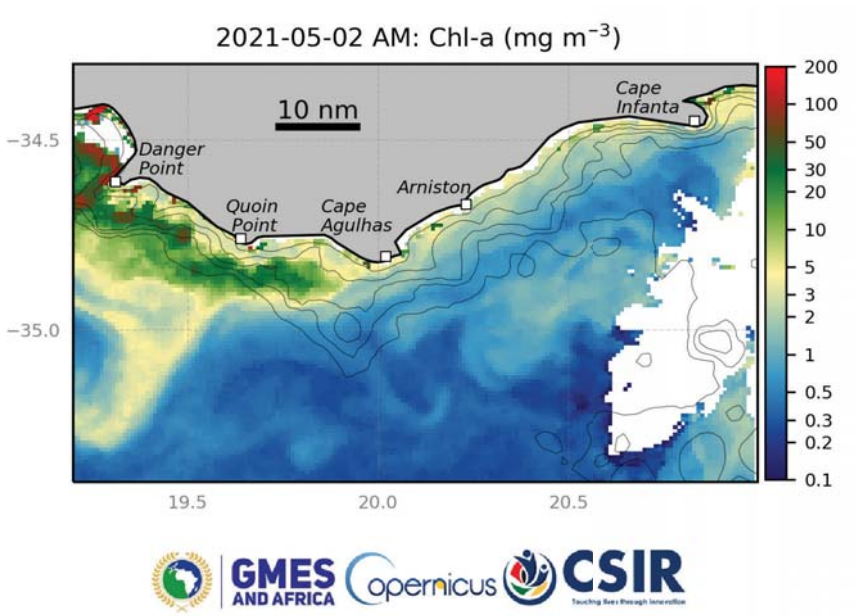
resilience and profitability in aquaculture, concentrating the focus on multi-trophic farming as a means to reducing waste, increasing the sustainability of farming ecosystems, and increasing business stability by diversifying farm revenue. One of ASTRAL's tabled outputs is a ***Species for the Future*** catalogue, which will provide comprehensive descriptions of the best species to be cultivated regionally within the partner countries, assessed in terms of their nutritious value, profitability and sustainability. The catalogue will also include details on business models and production estimations.

There is a strong emphasis within ASTRAL on research and the creation of new production methods and value chains in aquaculture.

It is a central tenet of ASTRAL that the public availability of such documents will inform and encourage the sustainable development of the aquaculture industry, and there is a long list of public documents and reports that will be made available as the work of the project progresses. These include practical manuals for animal husbandry, health and welfare, guides to environmental monitoring technology, as well as reports on climate trends and change informing risk profiles.

ASTRAL is mindful to contextualise the development of the industry with the understanding that climate variability and a changing environment present great risks to aquaculture farming. The project addresses three main environmental risks: the presence of microplastics as an increasingly ubiquitous pollutant, and the frequency of occurrence of pathogens and harmful algal blooms (HABs) – particularly in terms of climate change.

CSIR



A satellite image from the Sentinel 3 OLCI sensor of the Western Cape's south coast, showing the surface ocean chlorophyll a concentration (as a proxy for phytoplankton biomass). A phytoplankton bloom is visible in the western part of the image.

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HABs can take on many forms, ranging from low concentrations of toxin producing algal species, to extreme cases of high biomass blooms that risk collapse, decay and hypoxia. Although toxin producing phytoplankton are found endemically along the entire southern African coastal region, they generally occur in very small numbers of no real concern. Below a certain concentration, most phytoplankton present no threat to animal or human health and form an important part of the marine food web.

However, particular atmospheric and oceanographic circumstances can result in environmental conditions that favour specific algal species, providing the ideal growing conditions that allow them to 'bloom'. These blooms, often referred to as "red tides", typically discolour the surface of the water depending on the type of species present and the type and concentration of photosynthetic pigments they contain. When they cover a large enough area of the ocean's surface they can even be detected by satellite imagery.

Aquaculture farms keep a close eye on what is happening in the water in order to mitigate HAB-related risk: frequent water samples are taken at the intake pipes in order to identify and count the phytoplankton species, while satellite imagery are used to monitor the regional near-shore coastal zone for blooms and potentially exacerbating environmental conditions (e.g. warmer sea surface temperatures).

Abalone are particularly vulnerable to the presence of yessotoxins, produced by certain algal species found in the region. Yessotoxins cause inflammation of the external soft fleshy surfaces and gills of abalone, potentially causing secondary infections and deterioration of animal health. A variety of contingencies exist that can be implemented if a potentially harmful bloom is detected, ranging from slowing the pumps, decreasing the animals feed, and temporarily increasing the proportion of recirculated water on the farm.

ASTRAL seeks to provide integrated information systems to support this kind of decision-making, together with recommendations on optimal monitoring strategies to minimise risk and maximise mitigation opportunities. Sensors aimed specifically at the identification and quantification of pathogens, microplastics, and phytoplankton particles will be integrated into a farm-wide Internet of Things network together with other valuable physico-chemical environmental monitoring information (water pH, temperature, salinity, and so on) – all accessible via a data analytics platform enabling real-time data visualisation as well as record-keeping.

Given identified thresholds for microplastics or pathogen detection, and for physico-chemical parameters such as pH or salinity, alerts can be programmed to facilitate the identification of problems but also to mitigate them. The system will go further, though, with Artificial Intelligence (AI) processing information brought to the platform from multiple sources – looking at parameters inputted from sensors at the farm in the context of the biogeochemistry and weather/climate of the wider region, in order to make a comprehensive assessment of current anomalies or impending threat.

On-site testing of the new monitoring systems will inform a comprehensive feedback report with recommendations for optimising environmental monitoring strategies at the different types of IMTA farms across the Atlantic. Close monitoring is essential not only for external risks washing in with seawater, but also to ensure the healthy functioning of recirculation systems. The circularity approach, as it is called, is encouraged as a path towards zero waste in the IMTA labs – a goal requiring intensive research and sensitive implementation in order to achieve balance in the very delicate IMTA ecosystems. Business models as developed and recommended by ASTRAL will all be created with climate change mitigation, nutrient recycling, waste profiles and environmental sustainability at the forefront.

The potential for South African aquaculture to benefit from ASTRAL's outputs and develop farming businesses in innovative, environmentally secure ways, with the support and guidance of international partners, is a valuable opportunity. A number of training courses and educational materials will be made available, and the interested public is encouraged to take part in the conversation.

Further information is available at https://www.astral-project.eu/.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863034.

Cultivation of abalone in South Africa

Abalone has been cultivated in South Africa since the late 1980's and is the most successful and valuable commercial aquaculture product in the country. The value of the abalone industry was estimated to be R837 221 000 in 2018, with a contribution of R114 123 543.00 to the export market. South African abalone is well regarded, with the current industry producing between 1270 and 1700 tons a year between 2013 and 2018.

MAGUGA DAM – GIANT OF SWAZILAND

Group 5

Maguga Dam spilling in 2006.

While most people are familiar with the giant dams of Lesotho, less people know of the dams of South Africa's neighbour Swaziland. One of these is Maguga Dam, located on the Komati River.

Situated 12 km south of Piggs Peak, Maguga Dam was constructed following agreements between Swaziland and South Africa over the use of the Komati River, and mainly serves irrigation farmers. The dam was built between 1998 and 2002. At the time, it was the biggest government construction project that Swaziland had ever undertaken. With a dam wall rising up 115 m, Maguga Dam is the fifth highest dam in southern Africa, and the highest dam of its kind in the region.

Maguga is an earth-core rockfill dam. The main wall comprises a rockfill embankment with a clay core, flanked both upstream and downstream by graded filters of crushed rock. The upstream face is protected against wave action by a layer of selected riprap. Some 760 000 m^3 of clay, 2.7 million m^3 of rock, and 420 000 m^3 of crushed rock filter material was placed and compacted to form the embankment. An important road runs over its crest.

Source: SANCOLD

A notable feature of Maguga Sam is its spillway, An additional notable feature of the dam is the spillway, which is of a 'labyrinth' design. This effectively compresses the length from 460 m to only 181 m to accommodate a flood of 15 000 m^3/s.

The dam, one of the biggest in southern Africa, has a reservoir capacity at full supply level of 332 million m^3.

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DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

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The Water Research Commission not only endeavours to ensure that its commissioned research remains real and relevant to the country's water scene, but that the knowledge generated from this research contributes positively to uplifting South African communities, reducing inequality and growing our economy while safeguarding our natural resources. The WRC supports sustainable development through research funding, knowledge creation and dissemination.

The knowledge generated by the WRC generates new products and services for economic development, it informs policy and decision making, it provides sustainable development solutions, it contributes to transformation and redress, it empowers communities and it leads various dialogues in the water and science sectors.

The WRC Vision is to have highly informed water decision-making through science and technology at all levels, in all stakeholder groups, in innovative water solutions through research and development for South Africa, Africa and the world.

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