BRIEFING NOTE

BUILDING EXPERT CAPACITY IN SOUTH AFRICA: REFLECTIONS FROM A BEST PRACTICES COURSE IN STABLE ISOTOPE APPLICATIONS

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Prepared by: Nokubonga Mbandzi-Phorego, Lubabalo Mofu, Eleonora Puccinelli & Francesca Porri

Objective – A briefing note aims to provide a concise outcome based synopsis of recent research or expert opinion that may inform decision making and activities by authorities, NGOs and NPOs. The briefing note series complements the academic peer reviewed literature published by SAIAB.

Summary

Understanding aquatic ecosystems is critical for environmental sustainability and societal well-being, especially in developing economies like South Africa, where coastal and freshwater resources support livelihoods, food security, and biodiversity. Healthy aquatic ecosystems provide essential services such as fisheries, climate regulation, and coastal protection, making their conservation and sustainable management vital in the face of climate change, pollution, and habitat degradation. To effectively manage and conserve these ecosystems, robust research methodologies are essential. Stable isotopes and fatty acids play a crucial role in understanding energy flow, trophic interactions, contaminant transfer in food webs, and overall ecosystem health. The scope of this policy brief underscores the transformative potential of best practices courses in stable isotopes analysis (SIA) and fatty acid methodologies for developing economies. The **Best practices in aquatic food web investigations: stable isotope and fatty acid approaches course** serves as a critical platform for enhancing expertise, equipping participants with the necessary skills to apply these advanced methodologies effectively. The course, sponsored by the Scientific Committee on Ocean Research (SCOR) programme through mobility of international expert Dr Puccinelli from the Royal Netherlands Institute for Sea Research-NIOZ, and organised by the National Research Foundation-South African Institute for Aquatic Biodiversity (NRF-SAIAB), was held in August 2024 at the NRF-SAIAB, and aimed to address the pressing need for increasing African expertise in these approaches. Postgraduates and early-career researchers were trained by experts from NRF-SAIAB and NIOZ, building local capacity to address pressing environmental and socio-economic challenges (Figure 1). This initiative highlights how specialised training in stable isotope techniques, not only advances coastal research and derived knowledge production, but also empowers expertise in the continent to independently tackle issues like coastal pollution, food security, and ecosystem management, allowing to uncover early the environmental stressors to hence provide solutions and long-term societal benefits. Investing in specialised training programmes also ensures that developing regions carry the expertise to generate high-quality data, apply cutting-edge analytical techniques, and contribute to global scientific

advancements, fostering evidence-based policy and sustainable resource management.

Figure 1: Participating members at the training course “Best practices in aquatic food web investigations: stable isotope and fatty acid approaches” held at the NRF-SAIAB. Front row, from the left Zizonke Dlamini (Rhodes University postgraduate), Nokubonga Mbandzi-Phorego (co-facilitator, PDP-Postdoc, NRF-SAIAB), Nompumelelo Baso (NRF-SAIAB; PDP-Postdoc), Elelwane Nemanashi (Rhodes University postgraduate), Olwethu Maqalekana (Groen Sebenza Intern at NRF-SAIAB), second row from left, Eleonora Puccinelli (course facilitator, Principal Investigator, NIOZ), Amanda Gura (Biobank officer, NRF-SAIAB), Hlumelo Mantshi (Rhodes University postgraduate), Francesca Porri (course co-facilitator, Principal Investigator, NRF-SAIAB), Chaitanya Katharoyan (Stellenbosch University postgraduate), Seshnee Reddy (Biobank coordinator, NRF-SAIAB), Xiluva Mathebula (Groen Sebenza intern at NRF-SAIAB).

Background

Aquatic ecosystems play a pivotal role in supporting biodiversity, economies, and understanding the dynamics and sustainably managing these systems are particularly important efforts for regions where communities heavily depend on these ecosystems for food, livelihoods, and economic growth. Developing economies however often lack the expertise capacity and resources to address challenges such as aquatic pollution, habitat degradation, and food insecurity. Stable isotope analysis is a transformative tool[1] that enables researchers to explore complex ecological questions, such as tracking trophic dynamics, identifying pollution sources, and understanding the movement and interactions of species. Unlike traditional methods, stable isotope and fatty acids techniques provide integrated, time-resolved insights into food web structures, energy transfer[4, 5], and contaminant pathways[1, 2, 8], offering robust and reliable data to inform management and conservation practices. In chemical terms, the dietary history of organisms in aquatic systems can be reconstructed using stable isotope ratios like $\delta^{13}C$ and $\delta^{15}N$, which differentiate dietary sources and species trophic levels, making them invaluable for tracing nutrient flows. Since the consumer has an isotope ratio resembling that of the prey plus a known enrichment factor, the $\delta^{15}N$ is a useful indicator of the trophic level, while the $\delta^{13}C$ is a useful tool in tracing the dietary source assimilated, aiding differentiation in feeding habitats [1, 6] (Figure 2).

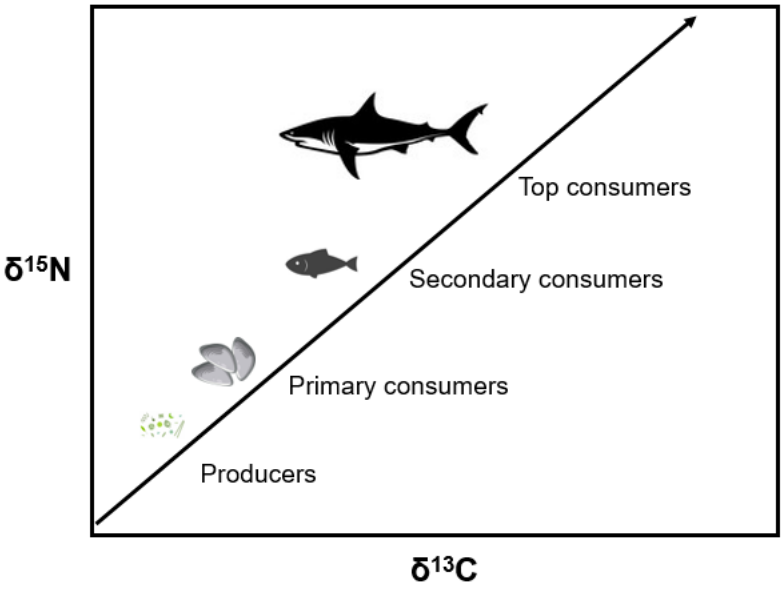

Figure 2: Schematic diagramme of the stable isotope aquatic food web.

Stable isotope analysis has become a significant and incorporated part of ecological research in the past decades. Further advancements are directed toward effective use of stable isotope analysis in measuring ecological interactions[6]. Globally, the application of stable isotopes has attracted the support of ecologists, evolutionary biologists and conservationists using this tool to study various aspects of ecology such as resource utilisation by species, species movement, competition and generally the interactions between organism populations and their environment [1, 6]. There has been an emergence of research interest in compound-specific stable isotope analysis which largely focuses on understanding the diet sources and how nutrients are distributed within organisms [6].

Status of stable isotope facilities in South Africa

Despite their potential applications, the use of isotopic techniques in many developing economies remains underutilised due to limited expertise, access to laboratories, and cost barriers. South Africa's case exemplifies this gap: while there are a few specialised facilities, these are sparse, and concentrated in large cities, leaving many postgraduate students and researchers (especially those based in the poorer provinces of the country) with limited access to resources and/or training.

In South Africa, there are few accredited stable isotope analytical facilities. These include the Stable Light Isotope Laboratory, at the University of Cape Town (under the Biogeochemistry Research Infrastructure Platform -BIOGRIP- research platform network funded by the Department of Science), which focuses on analysing stable light isotopes like carbon, nitrogen, and oxygen. This facility is equipped with instruments for research in areas such as biogeochemistry, ecology, and environmental science. The second facility is the Stable Isotope Laboratory of the Mammal Research Institute (MRI), at the University of Pretoria, also dedicated to applications of stable isotopes tackling food webs, including aquatic food webs. Thirdly, the NRF- South African Laboratory Facility (SAIF), at the national facility iThemba labs, targets radioisotopes such as radiopharmaceuticals and radiochemicals. To enhance expert capacity development, there are some training workshops offered to postgraduates and emerging researchers in some South African Institutions like the University of Cape Town (UCT). The UCT training, through the

course facilitated by BIOGRIP, targets for graduate students and emerging researchers planning to incorporate stable isotopes in their research. Though extremely useful, these courses and platforms are often oversubscribed, creating backlogs in training, with repercussions on laboratory processing, limited access to resources, expertise, and skill set needed to conduct cutting edge research using stable isotope techniques. This limited and localised access reflects on the ability to receive training and tackle urgent environmental challenges in South Africa and Africa at large.

The shortage of expertise in best practices for understanding complex aquatic food web structures and integrating stable isotope and fatty acid methodologies represents a critical infrastructural gap. This often leads to the reliance on external facilities for sample processing, significantly increasing costs and concentrating expertise in the hands of a limited few. The training course offered by this bilateral NRF-SAIAB and NIOZ partnership and facilitated by the Scientific Committee on Ocean Research (SCOR) programme, provided several South African participants with theoretical and practical training in trophic webs methodologies. The course covered both the theoretical background for SIA and fatty acid profiling, while the practical and analytical components of the course focused primarily on SIA (Figure 3).

Figure 3: Course participants introduced to fieldwork measures, when sampling on the shore (Kenton-on-Sea, South Africa) (Fig. 3A). Participants gained experience to handling, identifying and sorting of biological (Figs. 3B & 3C) and seawater samples (Figs. 3D & 3E) in preparation for stable isotope analysis.

The course provided participants with a comprehensive, step-by-step opportunity to explore every aspect of stable isotope research, from experimental design and field sampling to laboratory preparation, statistical analysis, and the interpretation of results. Marine and freshwater case studies from South Africa were used throughout the course to highlight the local importance of stable isotope applications in ecological research. For example, intertidal food web studies along the coastline utilised isotopic techniques to examine how urbanisation and wastewater inputs affect the diets of marine invertebrates and influence the trophic transfer of contaminants, revealing significant implications for both ecosystem and human health. Similarly, research conducted in freshwater systems, such as the Sundays River irrigation ponds, used stable isotope analysis to investigate interspecies competition, resource partitioning, and the impact of non-native fish species on native biodiversity. These studies offer valuable practical and theoretical insights for facilitating robust research that aims at managing pollution, conserving biodiversity, and ensuring the sustainability of aquatic ecosystem services.

CASE STUDY 1 (South Africa): Stable isotopes application in intertidal systems and trophic transfer of contaminants

The application of stable isotopes in the marine (intertidal) food web ecology allows us to understand the diet of organisms over time and this offers an integrated insight when compared to the traditional snapshot gut content analysis. The South African coastline's trophic food web is complex and largely influenced by the two contrasting currents, the cold Benguela and the warm Agulhas[2,3] which define the productivity and species composition, of the marine communities. Further, urbanisation can significantly alter the dietary regimes of intertidal marine invertebrates through increased nitrogen levels from the inputs of waste water[7].

Furthermore, global attempts have been made to investigate links between marine metal pollution and the trophic transfer of metals using stable isotopes. Little research has however focused on complementing metal and stable isotope approaches along coastal areas of South Africa[8], despite anthropogenic pollutants having worsened coastal water quality in South Africa in recent years. As the saying goes "You are what you eat", using the stable isotope technique, researchers have tracked the source of

pollutants, their trophic transfer, and human health risk assessment[8]. This is crucial knowledge needed considering that coastal environments provide multiple benefits of which seafood remains a fundamental one.

This background of local knowledge, coupled with identified gaps and needs, formed the foundation for a hands-on, locally relevant marine case study with both regional and global significance. Through this framework, participants were exposed to current, practical applications of stable isotopes and environmental data, specifically designed to understand the transfer of contaminants within coastal food webs[8]. This approach ensured that the course content was not only scientifically robust, but also directly applicable to real-world challenges in both local and broader contexts.

CASE STUDY 2 (South Africa): Stable isotopes application in the freshwater ecosystems

Much like its application in marine environments, stable isotope analysis is an invaluable tool in understanding food web structure and trophic interactions within freshwater ecosystems. One of the key uses of stable isotopes in freshwater systems is to study the movement, impact, and management of invasive species. The course hence explored case studies on the interactions between indigenous and non-native species in South African freshwater systems[9].

A particular focus of the course was on irrigation ponds Swart irrigation pond from the Sundays River Valley irrigation ponds (Figure 4A). While these ponds are mainly used for agriculture, they also serve as habitats for diverse aquatic communities. This case provided a unique opportunity for participants to gain insights into trophic relationships in freshwater ecosystems, especially in agricultural settings. Participants were trained in sampling protocols for both biotic and abiotic components of freshwater food webs (Figures 4B, C).

The case study underscored that stable isotope analysis is crucial for identifying key energy sources and understanding trophic relationships within freshwater systems, an essential knowledge for informing conservation and management strategies. Additionally, participants learned how implementing these sampling protocols can significantly enhance the management and sustainability of freshwater ecosystems.

Figure 4: Course participants introduced to plankton sampling at the ML Swart irrigation pond from the Sundays River Valley, Eastern Cape, South Africa, (Fig.4A) and invertebrate collection (Fig. 4B), for further laboratory analysis (Fig. 4C).

Recommendations

Expanding training programmes in stable isotopes is a strategic investment for developing economies, with far-reaching benefits for science, society, and sustainability. By building capacity in cutting-edge methodologies, such initiatives foster innovation, enhance local research capabilities, and address urgent environmental issues that disproportionately affect vulnerable communities. Stable isotope training promotes equitable participation in global research, empowers early-career scientists, and enables local policymakers to make informed and timeous decisions based on robust ecological evidence. Furthermore, by integrating isotopic techniques into routine monitoring and resource management, developing economies can ensure the long-term resilience and productivity of their aquatic ecosystems, safeguarding these critical resources for future generations.

In light of the insights gained from the course, and to support these empowering goals, we propose the following recommendations:

1) **Develop local expertise and infrastructure**: invest in building capacity and infrastructure to support stable isotope analysis, ensuring that local laboratories and research institutions are equipped with the tools necessary for cutting-edge research.

2) **Strengthen institutional support, mentorship, and collaboration**: foster a strong network of mentorship and collaboration among academic institutions, industry experts, and government agencies to equip postgraduate students and emerging researchers with best practices in stable isotope and fatty acid techniques.

3) **Integrate stable isotope analysis into monitoring**: incorporate stable isotope analysis as a routine tool in both freshwater and marine ecosystem monitoring, enabling evidence-based decision-making for sustainable resource use and environmental protection.

4) **Magnify research funding for stable isotope applications**: increase research funding dedicated to stable isotope applications in both

freshwater and marine ecosystems, promoting innovative solutions for ecosystem conservation and resource management.

Further reading

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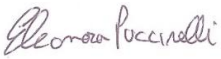
Authors:

Nokubonga Mbandzi-Phorego: 

Lubabalo Mofu: 

Eleonora Puccinelli: 

Francesca Porri: 

Approved by:

Albert Chakona (NRF-SAIAB Managing Director): 

Agencies that should be contacted:

- Scientific Committee on Oceanic Research (SCOR)
- Royal Netherlands Institute for Sea Research (NIOZ)
- NRF-SAIAB
- TNPA
- Keiskamma Trust
- Mbulelo Dopolo (DEA) (MDopolo@environment.gov.za)
- Lumko Ncapai (TNPA) (Lumko.Ncapai@transnet.net)
- Cebile Nzuza (TNPA HQ) (Cebile.Nzuza@transnet.net)

- Zuko Gabela (KT) (zuko@keiskamma.org)
- Cebo Mvubu (KT) (ceramics@keiskamma.org)
- Veronica Betani (KT) (veronica@keiskamma.org)
- Michaela Howse (KT) (michaela@keiskamma.org)
- Emily Twigg (SCOR) (emily.twigg@scor-int.org)
- Vusi Mthombeni (DEDEA) (vusi.mthombeni@dedea.gov.za)
- Piliso Neliswa (DEADEAT) (neliswa.piliso@deaet.ecape.gov.za)
- Kyle Smith (SANParks) (kyle.smith@sanparks.org)
- Bonani Madikizela (bonanim@wrc.org.za)
- Mawila Kaluke (Kaluke.Mawila@mandela.ac.za)
- Kerry Sink (SANBI) (K.Sink@sanbi.org.za)
- Ashley Naidoo (ashley.naidoo@capenature.co.za)
- Cliff Jones (RU) (c.jones@ru.ac.za)
- Harrison Pienaar (CSIR) (HPienaar@csir.co.za)
- Stanley Liphadzi (WRC) (stanleyl@wrc.org.za)
- Julie Coetzee (NRF-SAIAB/RU) (j.coetzee@saiab.nrf.ac.za)
- Larry Oellermann (loellermann@ori.org.za)
- Jean Harris (Wildtrust) (jeanh@wildtrust.co.za)
- Judy Mann (judy@aquariumfoundation.org.za)
- Ramashwar Bharuthram (rbharuthram@uwc.ac.za)
- Janine Adams (NMU) (Janine.Adams@mandela.ac.za)
- Nasreen Peer (npeer@sun.ac.za)
- Martin Hill (RU) (m.hill@ru.ac.za)
- Taryn Riddin (NMU) (Taryn.Riddin@mandela.ac.za)
- Lara Van Niekerk (lvnieker@csir.co.za)
- Gonasageran Naidoo (UKZN) (NAIDOOGN@ukzn.ac.za)
- Trishan Naidoo (RU) (trishan.naidoo@ru.ac.za)
- Gavin Rishworth (NMU) (Gavin.Rishworth@mandela.ac.za)
- Ntuthuko F. Masikane (masikanen@unizulu.ac.za)
- Daniel Shaddai (DWS) (DanielS@dws.gov.za)
- Lyle Vorsatz (UCT) (lyle.vorsatz@uct.ac.za)
- Ursula Scharler (UKZN) (Scharler@ukzn.ac.za)
- Thembinkosi Dlaza (WSU) (tdlaza@wsu.ac.za)
- Lucienne Human (SAEON) (lr.human@saeon.nrf.ac.za)
- Tommy Bornmann (SAEON) (tg.bornman@saeon.nrf.ac.za)
- Phumlile Cotyane Pondo (SAEON) (pl.cotiyanepondo@saeon.nrf.ac.za)
- Shaun Deyzel (SAEON) (hp.deyzel@saeon.nrf.ac.za)
- Vincent Motebang Nakin (WSU) (mnakin@wsu.ac.za)
- Niall Vine(UFH) (nvine@ufh.ac.za)
- Tammy Robinson (SU) (trobins@sun.ac.za)
- Phumza Ntshotsho (CSIR) (pntshotsho@csir.co.za)
- Sven Kerwath (DFFE) (SvenK@daff.gov.za)
- Toufiek Samaai (DFFE) (tsamaai@dffe.gov.za)
- Sarah Fawcett (UCT) (sarah.fawcett@uct.ac.za)
- Julie Lyut (UCT) (julie.luyt@uct.ac.za)
- David Glassom (UKZN) (glassom@ukzn.ac.za)
- Nicola Carrasco (UKZN) (Carrasco@ukzn.ac.za)
- Carl van der Lingen (DFFE) (CarlVDL@nda.agric.za)

- Eric Okuku (KMFRI) (ochiengokuku2003@yahoo.com)
- James kairo (KMFRI)(gkairo@yahoo.com)
- Kennedy OSUKA (CORDIO) (kosuka@cordioea.net)
- Ogega Matundura (CORDIO)(obed.matundura@gmail.com)
- David Obura (CORDIO) (dobura@cordioea.net)